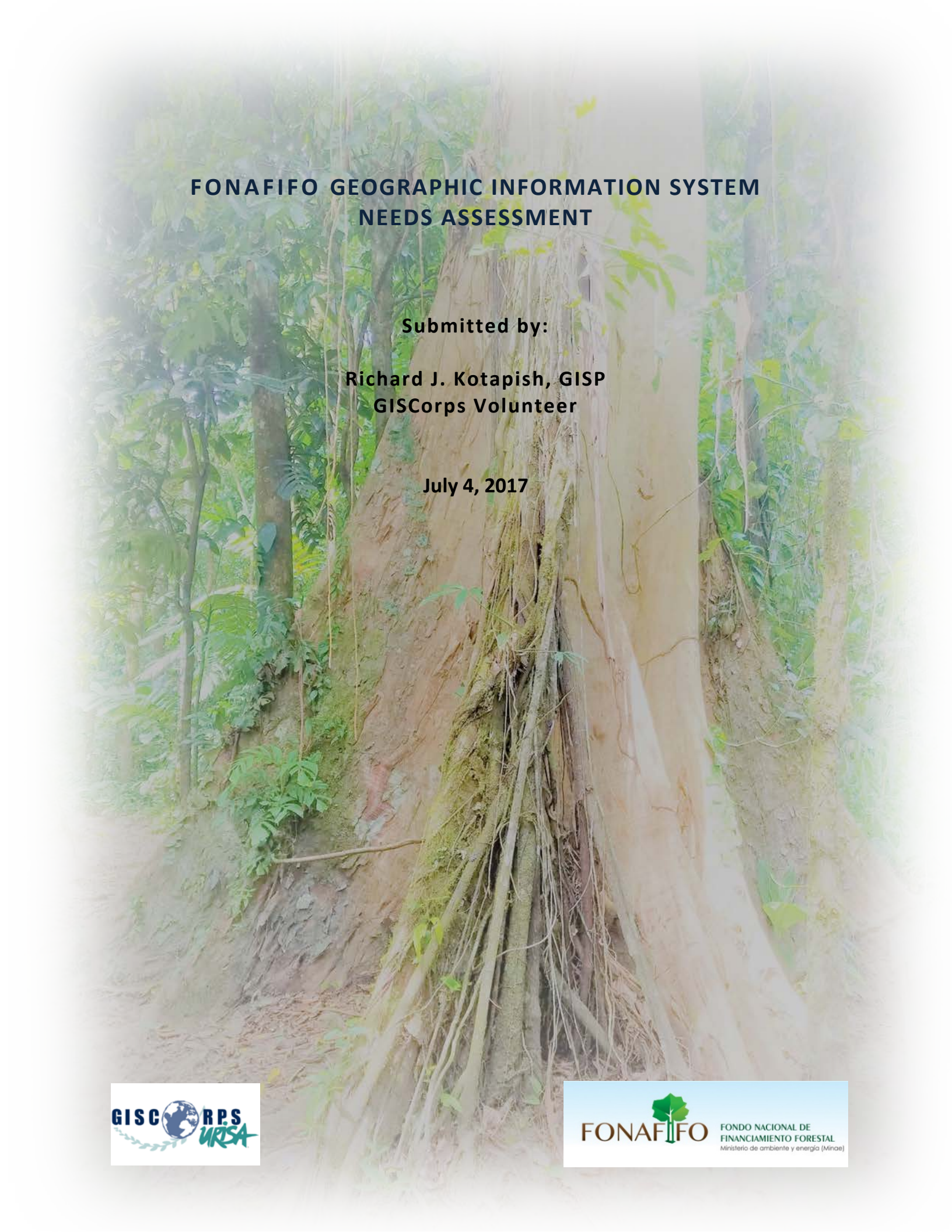

FONAFIFO GEOGRAPHIC INFORMATION SYSTEM NEEDS ASSESSMENT

Submitted by:

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July 4, 2017

GISCORPS URISA

FONAFIFO
FONDO NACIONAL DE FINANCIAMIENTO FORESTAL
Ministerio de ambiente y energía (Minae)

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SECTION 1
INTRODUCTION

1.1 INTRODUCTION

This GIS Needs Assessment Report is respectfully offered to the National Government of Costa Rica. This report provides various recommendations regarding the current and future use of Geographic Information System (GIS) technologies within the National Forestry Financing Fund (FONAFIFO). This GIS Needs Assessment Report is intended for your use in exploring new strategic directions for your GIS program. This plan puts forth recommendations regarding GIS related hardware, software solutions, specifications, costs, risks and benefits, as well as implementation strategies and options.

This report is the result of the efforts of many people and organizations, including FONAFIFO, the U.S. Forest Service and GISCorps. Thanks and appreciation are directed to the FONAFIO Board of Directors and the U.S. Forest Service. The U.S. Forest Service funded all traveling and on-site expenses for Mr. Kotapish's trip to San Jose, Costa Rica. The engagement was held March 20 to 24, 2017. Special thanks to Mr. Gilmar Navarrete for his leadership, knowledge, organization and drive; as well as the FONAFIFO team members that participated in this engagement who all are clearly talented, professional and focused on results. And kudos to Mr. Randy Hamilton who is contracted by the U.S. Forest Service. Mr. Hamilton provided key context and communication of the existing institutional environment during the workshops and vital input into these GISCorps reports.

1.2 Project Development Information

<u>FONAFIFO Operations Discovery</u>

In the months prior to the on-site project, Mr. Kotapish and FONAFIFO staff exchanged information, held Skype sessions and prepared for the engagement. Sample FONAFIFO GIS data were provided, along with the Payments for Environmental Services Program (PSA) Procedures Manual; and the 2009 revision, which Mr. Kotapish translated using Google to learn about operational procedures.

- Questionnaires

A series of questionnaires were developed to inventory information on FONAFIFO's geospatial infrastructure, existing software, hardware, networking, land records, potential applications, potential data layers, sources and formats and data sharing. These allowed us to hit the ground running and not spend valuable on-site time collecting and learning this information.

- Workshops

Five days of workshop style interactive presentations and meetings were held on site in San Jose, Costa Rica. These sessions allowed for the exchange of detailed information about existing conditions and geospatial options for the future.

FONAFIFO staff spent the first two days covering topics such as the history of FONAFIFO, existing systems, software usage, applications engineering and technical environments, workflows, legalities and other operational specifics. There was much interactive discussion through the interpreter who did a fantastic job of translation. His ability to listen to two or even three people talking and interpret conversations into both languages real-time provided a critical resource for our task.
The third day included a visit to the FONAFIFO Sarapiquí Field Office. On-site, we discussed their existing environment – PC hardware/software, connectivity, devices, business operations workflows and wish

lists. We viewed land records such as the Planos - the PSA farm owner's official parcel ownership map from the Costa Rica National Registry, the Forest Regent's GIS map of the effective areas, contractual documents, certifications of taxes or fees not owed, etc.

After our discussions in the field office itself, we adjourned to the field to go through the field processes. We worked through a "validation visit" at a participant's "farm" as they are called. The validation visit primarily checks property boundaries and looks for evidence of violations.

We discussed the other field process, a "first-time applicant" where the objectives are to identify and confirm the effective areas for the contract, and collect baseline site information including both GPS/GIS data and hand written field notes.

After the Sarapiquí Field Office visit on Wednesday, Mr. Kotapish delivered two days of interactive presentations to FONAFIFO staff covering:

- Esri and Open Source Solutions
- GIS and Information Technology: Options and Considerations and Data Models and Architectures
- UAVs (drones)
- AGOL website development demo
- Data Gap analysis exercise
- Discussions on GIS and the planning of business goals and objectives.

See the Agenda for the week on the following page.

AGENDA FONAFIFO / GISCORPS MISSION

March 20 – 24, 2017

1st day	2nd day	3rd day	4th day	5th day
08:30-12:00	08:30-12:00	08:30-4:00	08:30-12:00	8:30-12:00
Introductions FONAFIFO overview Staff presentations: FONAFIFO history, overview Existing environment	Staff presentations: Existing environment and systems, legal, administrative issues	Staff interviews: Field office Existing environment documentation, business operations workflow documentation	Workshop presentation: Esri and Open Source Solutions	Workshop: - Strategic planning – Potential Solutions - Human resources - Potential applications approaches - Esri sales representative call - Action items (next steps) development
Attendees				
Applicable staff	Applicable staff	Sarapiquí Field Office staff	Applicable staff	Applicable staff
01:00-4:00	01:00-4:00		01:00-4:00	01:00-4:00
Software applications, Current systems, Usage, Software engineering SIPSA	Staff presentations: Existing environment documentation, business operations workflow documentation.	Property visit – Sample validation visit to an existing PPSA participant	Workshop presentation: GIS and Information Technology: Options and Considerations and Data Models and Architectures Discussion on GAP Anaysis and business goals and objectives	- Support and tailored GIS advisory (Leave open-ended, we can use this time for the best purpose determined.) Mr. Kotapish will be available to answer questions, perform demos, etc.
Attendees				
Applicable staff	Applicable staff	Sarapiquí Field Office staff	Applicable staff	Applicable staff

SECTION 2
EXISTING CONDITIONS

2.1 Introduction and history

This section is meant to document the configuration of the existing GIS infrastructure to identify any areas needing improvement, enhancements, etc. and to identify any potential conflicts or incompatibility between existing resources and proposed additional software and hardware resources or changes to geospatial technologies.

The Payment for Environmental Services Program (PSA) is a property parcel based program, a national payment program for carbon storage, hydrological services, and the protection of biodiversity and landscapes. This scheme has been credited with reducing the rate of deforestation in Costa Rica from one of the worlds highest to net negative deforestation currently. Forest cover has now returned to over 50 percent of the country's land area, from an estimated low of approximately 20 percent in the 1980s.[1] The PSA scheme recognizes four main services that ecosystems provide to people:

1. Carbon sequestration: the capture and long-term storage of atmospheric carbon dioxide, a greenhouse gas
2. Hydrological services: protecting watersheds or 'recharge' areas,
3. Biodiversity conservation: protecting a wide variety of coexisting plant and animal species
4. Preservation of scenic beauty.

The PSA program results include the inclusion of over 1,150,000 hectares within the Program, from 1997 to 2016. Eighty-seven percent of this area is under Forest Protection and the remaining thirteen percent is distributed between Reforestation, Forest Management, Regeneration and Agroforestry Systems. Annual investment is between 25 and 30 million dollars with a cumulative investment of more than $420 million USD. Fourteen thousand families are involved in the program. More than 120,000 hectares of PSA have been placed in Indigenous Territories (10% of PSA properties), and 6.5 million trees have been planted in the Agroforestry Systems sector.[2]

In 1997, FONAFIFO was created and GIS data collection was begun under this new organization. In 2003, a transition was begun to move away from hard copy records and towards the digital world. Differing projections in the north and south of the Country were causing spatial transformation concerns, so in 2009 a new consolidated custom projection was developed by the Instituto Geografico Nacional, the "Proyección CRTM05". This custom projection is another example of the local institutions and FONAFIFO improving the quality of their data and information. I note that FONAFIFO has a culture of seeking improvements in information quality, process efficiencies, elimination of redundant processes and improved constituent service.

Costa Rica now uses national level priority-setting criteria to select contracts in line with PSA conservation policy goals. The priority matrix awards higher points to forest protection applications located in pre-selected areas such as forests in conservation gaps, biological corridors, indigenous territories, those located around important water sources, areas with low social development scores, and from properties under 50 hectares. See Section 3.2.1 – Key Documents and Processes for more information on priority setting criteria.

Costa Rica's PSA program was based on a reform of an existing forest subsidy program. In the 1970s

[1] Learning from 20 years of Payments for Ecosystem Services in Costa Rica David N. Barton Norwegian Institute for Nature Research
[2] Ing. Gilmar Navarrete Ch. FONAFIFO workshop PowerPoint, March 2017

Costa Rica had begun to provide incentives for timber plantations through tax rebates, due to concerns over shrinking timber supplies. The Forest Credit Certificate expanded the program which continued to evolve to support forest conservation as well as timber production. When introduced, the PSA program built on the base of this payment scheme, with two major changes:

- payments were to be based on the provision of environmental services instead of timber, and

- financing would change from the government budget to an earmarked tax and payments for beneficiaries[3]

Permitted land uses include: forest protection, reforestation, forest management and agroforestry.

FONAFIFO Financing

- Fuel Tax: 3.5%

- Canon of Water: 25% of total income is derived from the water usage tax.

- Borrowings with the World Bank: Ecomercados I (2000-2005); Ecomercados II (2008-2013)

- Huetar Norte Forest Program (2003-2010)

Agreements with the Private sector and Public sector

The history of FONAFIFO shows a resilient organization, dedicated to a critical mission that a large majority of Costa Ricans support. There are many examples of innovations in the Payments for Environmental Services program over the years. It is the hope of this author that this report will assist in the implementation of tools that will increase the productivity of staff, accountability and transparency.

2.2 Software

FONAFIFO uses a software stack that includes both Open Source and Esri solutions. I have organized the software solutions into Desktop, Browser-based and Handheld mobile device GIS software groupings. Below is a list of the various software used by FONAFIFO.

ArcGIS	Office 365 – Correo, OneDrive, Skype for business
Qgis	Pixlr
GIMP	SQLServer 2012
PowerDesigner	Visual Studio

2.2.1 Non - GIS software

Many of these are useful in combination with GIS derived products and data. **GIMP** is an Open Source image editing program and **Pixlr** is a robust browser-based photo editor. **PowerDesigner** is a collaborative enterprise modeling tool produced by Sybase, currently owned by SAP. PowerDesigner runs under Microsoft Windows as a native application and supports model-driven architecture software design. PowerDesigner stores models using a variety of file extensions, such as .bpm, .cdm and .pdm. The internal file structure can be either XML or a compressed binary file format. PowerDesigner can also

[3] Pagiola (2008); TEEB (2009)

store models in a database repository. **Office 365** is the brand name Microsoft uses for a group of software and services subscriptions. OneDrive provides Cloud back-up services for FONAFIFO.

2.2.2 Desktop GIS software

2.2.2.1 Open Source GIS software

OpenGeo Suite provides several open source software tools for geospatial infrastructure development. These span web app development, server and web map client based tools, desktop and database solutions. Many robust integrated applications are deployed using these Open Source tools.

QGIS is a user friendly Open Source Geographic Information System that supports most geospatial vector and raster file types and database formats. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, UNIX, Mac OSX, Windows and Android and supports many vector, raster, and database formats and functionalities. This component provides tools, plug-ins and modifiable code allowing users to create, edit, visualize and publish GIS information.

PostGIS - PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing location queries to be run in SQL. FONAFIFO uses this for spatial routing applications.

QGIS Browser - The QGIS Browser is a panel in QGIS that allows for navigation within your file system and provides tools to manage geospatial data. You can access common vector files (e.g., ESRI shapefiles or MapInfo files), databases (e.g., PostGIS, Oracle, SpatiaLite or MS SQL Spatial) and WMS/WFS connections.

2.2.2 Esri Desktop GIS software

ArcGIS for Desktop is the industry standard for fully functional desktop GIS software. FONAFIFO licenses approximately 14 copies of ArcGIS for Desktop Basic 10.0, 10.1, or 10.2 that are used in all nine FONAFIFO Offices. These support data development, provide for the standard GIS data format (shapefile), produce thematic maps, field maps, visualize GPS control points, perform geospatial analyses and support other tasks. One license of ArcGIS for Desktop Advanced is located at the Central Office providing a more robust set of GIS analysis tools.

The current version of ArcGIS for Desktop licensing options is 10.5.x. Unfortunately, FONAFIFO historically has been unable to make budgetary resources available to fund on-going Esri software maintenance and support. *This is of concern because software updates contain security flaw patches* as well as *new tool enhancements*. For example, a potential second GISCorps mission was identified after it was discovered during the workshop that the new “conflate tools” (in the editing toolbox) were introduced with the ArcGIS Desktop Advanced 10.2.1 update. The most recent version available within FONAFIFO in March was 10.2.0. Hence, this tool was unavailable. I will discuss software maintenance further in Section 5 - Costs, Benefits and Recommendations.

2.2.3 Open Source Browser-based GIS software

OpenGeo Suite browser-based tools for the web ecosystem are discussed below. This is used by FONAFIFO for the support of many mission critical workflows through GIS modules in the Integrated System for the Payment of Environmental Services (SIPSA). See Section 3 – Department of Monitoring and Control Workflows for more on SIPSA.

Open GeoSuite – GeoServer

GeoServer is a map and geospatial data server. It is an Open Source software server written in Java that allows users to share and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards.

Being a community-driven project, GeoServer is developed, tested, and supported by a diverse group of individuals and organizations from around the world.

GeoServer is the reference implementation, or the standard from which all other implementations and customizations are derived. Associated Open Geospatial Consortium (OGC) Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as a high performance certified compliant Web Map Service (WMS) are critical standards used by most users today.

GeoServer is available on GitHub. (https://www.github.com/geoserver/)

QGIS Server - QGIS Server is an Open Source WMS 1.3 and WFS 1.0.0 implementation which, in addition, implements advanced cartographic features for thematic mapping. The QGIS Server is a FastCGI/CGI (Common Gateway Interface) application written in C++ that works together with a web server (e.g. Apache, Lighttpd).

QGIS Server uses QGIS as the backend for the GIS logic and for map rendering. Furthermore the Qt library is used for graphics and for platform independent C++ programming. In contrast to other WMS software, the QGIS Server uses cartographic rules as a configuration language, both for the server configuration and for the user-defined cartographic rules.

The QGIS Server project also provides the 'Publish to Web' plug-in, a plug-in for QGIS desktop which exports the current layers and symbology as a web project for QGIS Server (containing cartographic visualization rules expressed in SLD).

Because QGIS desktop and QGIS Server use the same visualization libraries, the maps that are published on the web look the same as in desktop GIS. The 'Publish to Web' plug-in currently supports basic symbolization, with more complex cartographic visualization rules introduced manually. As the configuration is performed with the Styled Layer Descriptor (SLD) standard and its documented extensions, there is only one standardized language to learn, which greatly simplifies the complexity of creating maps for the Web.[4]

FONAFIFO has been a productive user of geospatial technology for many years. This has enabled the development of an integrated, enterprise-wide information system using a common platform, which is the Integrated System for the Payment of Environmental Services (SIPSA).

The FONAFIFO application implementations using QGIS are **very impressive**. This includes tracking and managing much of the PSA processes. SIPSA manages the dual processes of the both the administrative processes and the GIS-related processes. SIPSA includes modules for setting up the initial appointment, online forms to enter the applicant's data, requirement verification, legal evaluation, affectation and notarization of the contract a financial module, and reporting and inquiries. While the administrative process works its way through, the GIS-related processes regarding approving the Planos, reviewing the

[4] Creative Commons Attribution-ShareAlike 3.0 license (CC BY-SA) http://creativecommons.org/licenses/by-sa/3.0/

Regent's property map and other geospatial workflows are simultaneously tracked and managed by certain SIPSA modules.

However, there are risks accompanying the benefits of using Open Source solutions such as QGIS. The primary risk is that QGIS is a volunteer driven project lacking formal technical support.

Primary Report Recommendation: ***The custom coding required for development will necessitate cross training so more than one staffer can maintain the solution should the primary programmer leave.***

FONAFIFO extensively uses GIS in many aspects of mission critical tasks including the successful integration of formerly disparate workflows and elimination of some tasks through the custom C# ("C Sharp") SIPSA PSA modules.

SIPSA's suite of modules is providing enormous operational advantages to FONAFIFO staff, the PSA participants and applicants, the Regents, and others. I did not list the general public and interested external stakeholders as realized GIS recipients. This is because there is a need for a public access GIS website. See Section 5 - Costs, Benefits & Recommendations.

2.2.3.1 Browser-based Esri software

There is no Esri browser-based software currently in use in FONAFIFO.

2.2.4 Handheld mobile device Open Source GIS software

There is no handheld mobile device Open Source GIS software currently in use in FONAFIFO. The Garmin GPS units use OruxMaps mobile data collection software.

2.3 Hardware

FONAFIFO's existing hardware includes:

Personal computers - Windows-based PC's are the standard in FONAFIFO and all are capable of running any of the options for GIS software. These PCs are on an upgrade schedule that follows budgetary constraints that all government agencies must abide by.

Smart Phones

Smart phones are used in many governmental agencies in the U.S. for GIS in-the-field applications. Although many apps are available through both Esri and Open Source solutions for this purpose, utilizing staff phones for in-the-field data entry, geo-referencing, disconnected editing (no Internet) and other applications is not recommended for use in FONAFIFO, *at this time*. Cell phones are becoming increasingly more popular for field data collection in other countries and technologies are being developed to work around the limitations.

Using a personal phone also introduces problems of personal liability, cost allocation, and platform standardization – iOS, Android or Windows OS. Using phones owned by FONAFIFO introduces issues of cost (plans) and personal liability. However, the inability of a cell phone to get a signal in remote areas or capture GPS points accurately enough for FONOFIFO's requirements when collecting under a tree canopy limits cell phone utilization at this time.

Mobile handheld personal devices

The recently purchased, Cedar Tree Technologies CT4 GPS handheld mobile devices that use the Android operating system may meet your accuracy and durability needs, however, continued testing is planned and necessary. Using the Android operating system is preferable due to the well documented lack of the Apple iOS in the GIS space.

Cedar Tree specifications include Android 6.0, 3 GB RAM, 32 GB internal storage, 2-4m unobstructed GPS, 5 MP front/13 MP rear camera, IP68 waterproof rating (see Section 4.5 for description), Bluetooth, and Wi-Fi & 4G LTE communications.

Field testing has shown a horizontal accuracy specification that is within an acceptable 6 - 8 meters horizontal displacement error under full tree canopy and 2 - 4 meters horizontal displacement error under partial or very limited tree canopy.

However, there were some locations where the Cedar could not collect a point; but the older Garmin 60CSX units could. *The ongoing, further testing of environmental durability and point collection is recommended.* Hopefully these initial operational specifications will remain good and the Cedar device's inability to collect GPS points is limited.

Geometric DOP

It is recommended that FONAFIFO develop a protocol for pre-planning a window of time when the most GPS satellites are available; with a more optimum configuration to maximize the spatial accuracy of the GPS points. This is related to the Geometric Dilution of Precision, or GDOP.

The idea of Geometric DOP is to state how errors in the GPS constellation of satellites' measurement will affect the final coordinate point. GPS point collection pre-planning can maximize your signal strength by allowing you to schedule when to capture better satellite availability and positioning geometry. A low DOP value represents better positional precision due to the wider angular separation between the satellites used to calculate a unit's position. Most GPS data management software provide these pre-processing tasks as well as post-processing (differential correction) to enhance accuracy for survey-grade data.

Bar Code Technology

FONAFIFO described plans to implement barcode technology. Barcode systems provide an extremely effective method to inventory and track just about anything. *The plan to barcode all PSA documentation is a fantastic idea* given the dynamic, multi-office nature of the PSA documents processes. This is yet another indicator of the constant drive to expand the use of technology to increase productivity and improve service, data quality and transparency. *I strongly endorse this endeavor.*

A barcode is a machine-readable code in the form of numbers and a pattern of parallel lines of varying widths that can be printed on an item for identification. Barcode readers or scanners are electronic devices that scan a barcode by shining a laser beam on it.

Barcode systems provide an extremely effective method to inventory and track just about anything. The plan to barcode all PSA documentation is a fantastic idea given the dynamic, multi-office nature of the PSA documents processes. Barcodes will provide an indispensable tool for tracking PSA documentation. This is yet another indicator of the constant drive to expand the use of technology to increase productivity and improve service, data quality and transparency. *I strongly endorse this endeavor.* Below are six benefits to using this technology.

1. Barcodes eliminate the possibility of human error. The occurrence of errors for manually entered data is significantly higher than that of barcodes. A barcode scan is fast and reliable, and takes considerably less time than entering information manually.

2. Barcodes are inexpensive to design and print. Commonly they cost mere pennies, regardless of their purpose, or where they will be affixed or printed onto. They can be customized economically, in a variety of finishes and materials.

3. Barcodes are extremely versatile. They can be used for any kind of necessary data collection. This could include Agency ID, time stamping or inventory information. Additionally, because barcodes can be attached to just about any surface, they can be used to track not only the PSA documents but also equipment.

4. Barcodes provide more accurate data and barcodes can be customized to contain other relevant information as needed. They provide fast, reliable data for a wide variety of applications.

5. Data obtained through barcodes is available rapidly. Since the information is scanned directly into the central computer, it is ready nearly real-time. This quick turnaround ensures that time will not be wasted on data entry or retrieval.

6. Barcodes promote better decision making. Because data is obtained rapidly and accurately, it is possible to make more informed decisions. Better decision making ultimately saves both time and money.[5]

Servers

A server virtualization program is underway at FONAFIFO with plans to include more servers that have systems that allow for virtualization. Virtualization benefits include significant cost savings by reducing hardware acquisition costs, reducing power, cooling, deployment time, providing for greater availability, improved disaster recovery and more efficient management of resources. FONAFIFO has a plan to migrate the remaining PSA GIS data from 2003 to 2016. FONAFIFO provided an estimate that these data total one TB of disc storage. This amount will be required when these data are moved into the virtualized server environment. *I strongly endorse this server virtualization program and further consolidation of physical servers.*

FONAFIFO Servers:

- Website server
- SQL Server Database server
- Domain Controller server
- Data Server (information shared by users)
- Print server
- GeoServer (see maps on the Web)
- DNS Server

[5] Serialio https://serialio.com/

FONAFIFO Server Configuration

2 Servers - DELL PowerEdge R720
RAM 80 GB
OS: Windows Server 2012 Standard
Processor: Intel Xeon ES-2637 CPU @ 3.00 HHZ (2 processors)
Hard disks 1: 200GB
Hard disks 2: 1000 GB
Hard Disks 3: 3000 GB
Hard disks 4: 3000 GB
Hard disks 5: 3000 GB
Hard disks 6: 150GB
Note: The first server has 3 virtual machines
The second server has 2 virtual machines

2 Servers - Dell PowerEdge R910
RAM 16 GB
OS: Windows Server 2008 R2 Standard
Processor or Intel (R) Xeon CPU E7520 @ 1.87GHZ (2 processors)
Hard disks 1: 150 GB
Hard disks 2: 500 GB
Note: Both servers have 1 virtual machine

1 Server - Dell PowerEdge 2970
RAM: 8 GB
OS: Windows Server 2008 R2
Processor: Quad Core AMD Opteron 2378 Processor 2.39GHZ (2 processors)
Hard disks or 1: 160 GB
Hard disks or 2: 500 GB
Hard Disks or 3: 500 GB
Hard disks or 4: 500 GB

There are also 5 servers defined as "low - end".

Cameras

Cameras and trap cameras are used to collect imagery in support of farm documentation and illegal activities.

2.4 Network

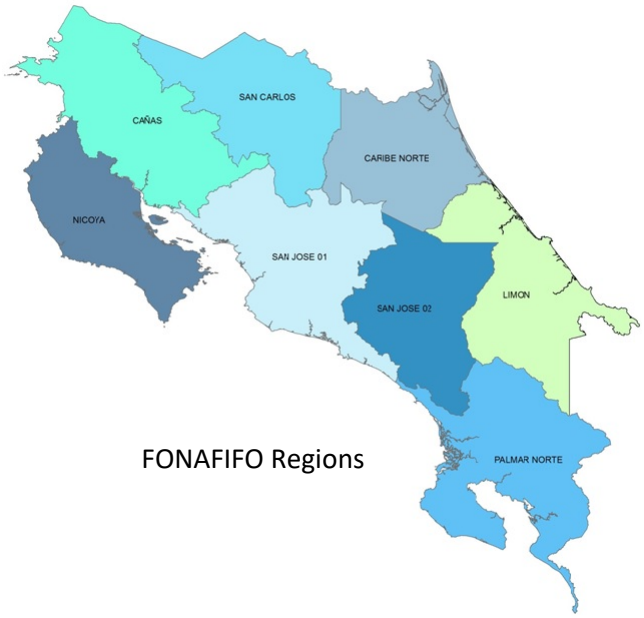
There are two networks in use by FONAFIFO staff. One is located in the Central Office in San Jose. For the eight Regional Offices, the Internet is the means of digital communications with the Central Office. The SMS network (cell) plays an important role in supporting communications.

Central Office

The Central Office employs a high-speed network which supports all offices sufficiently. Browser based solutions are also being used to leverage the benefits of using the Internet to share information.

Regional Offices

It is prohibitively expensive to install long distance high-speed communications and probably impossible to accomplish given the mountainous geography. So the Internet and cell networks are the only option for data transfer, connecting and syncing with the Central Office Data Warehouse and for enterprise-wide oriented GIS application access. The eight Regions are pictured here. The ninth office is the Central Office.



FONAFIFO Regions

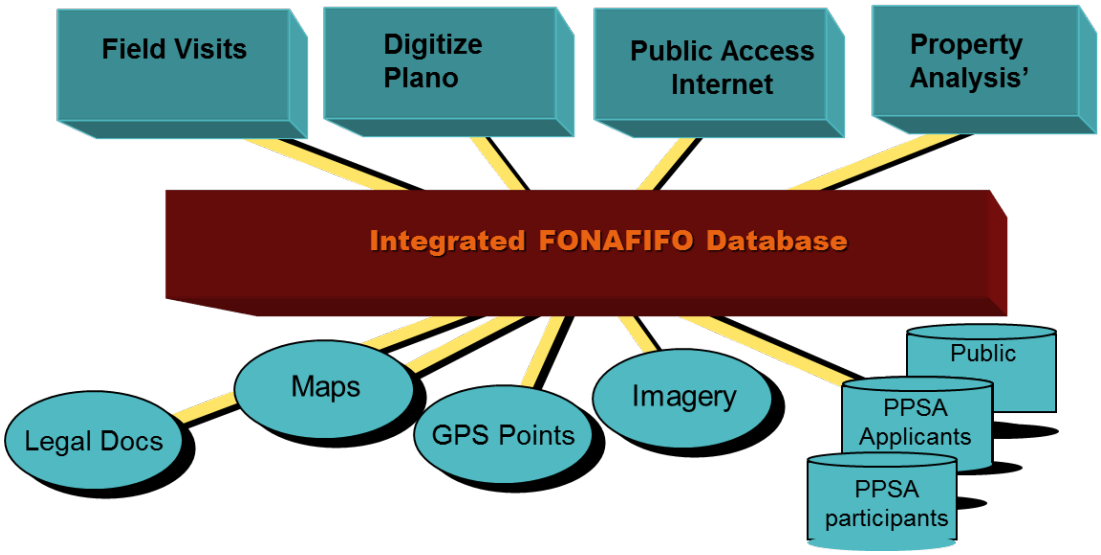


Figure 1 - Existing FONAFIFO Networked Operational Environment

2.5 GIS Data and GAP Analysis

FOFAFIFO has amassed geospatial data for many years. These include vector GIS layers such as GPS control points, protected areas, PSA parcel polygons and more. Imagery has been acquired as well as remotely sensed data from Landsat and other space-based assets.

Below is a table of the major GIS datasets within FONAFIFO.

Major GIS Datasets

GIS Data Set	Year
Biological Corridors	
National Parks	
PRIO2016	
Important Conservation Areas	
Important Watersheds	
Indigenous Territories	
Forest Coverage Inventory	2010, 2013
Landsat imagery	1997, 2000, 2005, 2010, 2015
Rapid Eye imagery	2013
SPOT	2010

Below is a table of the amount of data generated by the system to date.

Geospatial Data File Size Totals

Shapefiles, backup server and databases			
Year	System	Files	Size
2017	geoPSA	BD WKB-	14 MB
2016	geoPSA	BD WKB-	20 MB
2017	geoPSA	.ZIP- Server	133MB
2016	geoPSA	.ZIP- Server	170 MB
2015	Adax	BD WKB-	70MB
2015	Adax	.ZIP- Server	848MB
2003-2016 PSA layers	Dept. of Monitoring and Control	Shape files	1 GB

GIS Data Backup - Microsoft OneDrive is used to sync/backup data with unlimited storage capacity. Every three days a physical hard drive is used to backup data. **It is strongly recommended to take this drive to a secure off-site location, if it is not already.**

A brief GAP Analysis exercise was conducted during the workshops, led by the list of prioritized GIS layers in Appendix "A" of this report. Some highlights of this discussion include:

There is a need for a standardized land cover classification system. This issue is very common in my experience with different agencies using different classification names for the same or similar land cover. There is a committee of all national Stakeholder Agencies working to construct a national system for monitoring land cover, entitled SIMOCUTE. This is related to the REDD+ program which is a United Nations sponsored program focused on reducing emissions from deforestation and forest degradation in developing countries. This process should result in a standardized land cover classification system.

There is a need for more resolute imagery. Current satellite-based panchromatic and color imagery have resolutions ranging from 30cm (Digital Globe) to 1.5 m (SPOT 6 & 7). Landsat 8 includes six 30 m resolution multispectral bands, a 60 m thermal infrared band plus a 15 m resolution panchromatic band. While these all provide useful data, higher resolution imagery will provide for more accurate assessments of ground conditions. More resolute satellite imagery will become available in the future as the many countries and private companies continue to evolve in this space.

There is a need for more current imagery. Ideally, an annual acquisition of higher resolution imagery will provide for better change detection and analysis. Satellite imagery costs should lessen as time goes on and more players launch satellites; free-market competition should lower prices.

SECTION 3
DEPARTMENT OF MONITORING AND CONTROL WORKFLOWS

3.1 Introduction

A workflow can be defined as a repeated pattern of business activity facilitated by the methodical organization of functions and resources. This can be depicted as a series of operations in a workflow chart. It shows relationships and activities between entities within your organization.

Physically diagramming all of the extensive workflows is beyond the scope of this report. The information on FONAFIFO workflows is presented below to illuminate any processes that can be modified for greater efficiency, redundancies that can be eliminated, or to illustrate that efficient workflows are in place.

3.2 FONAFIFO PSA Workflows

There are very many workflows involving scores of staff in nine offices spread across the country. In this report I will focus on those major work processes that are related to the use of GIS and related technologies for the Payments for Environmental Services Program.

The Forest Regent, a professional forest engineer (called a Professional Surveyor in the U.S.) who creates the authoritative source PSA mapping, typically accompanies FONAFIFO staff when performing an annual compliance review of a random 20% of the PSA properties. The FONAFIFO central office checks 10% and the FONAFIFO Regional Offices check another 10%. Field Inspectors are looking for any violations or contractual requirements violations, e.g., illegal logging, parcel split or changes, monitor agriculture uses, etc.

There are approximately one-thousand (1,000) PSA Applicants annually. There are approximately five-thousand (5,000) PSA participants in total. 130,000 ha of land is applied for with a capacity to fund 40,000 to 50,000 ha.

For new applicant properties, all the Regent's mapping information is confirmed in the field, and much information is captured/inventoried. Simultaneously, the many legal and procedural application requirements are being verified through a parallel administrative process. If anything is amiss, the application is on hold until the problems are resolved. Applicants must have taxes or fines current and are advised to use a reputable licensed forest engineer who won’t compromise the integrity of the survey. The requirement that PSA participants have no outstanding debts with the national social security system is a good example of cross-compliance designed to guarantee that farm employees have access to social security financed health services.

For existing PSA properties, all site conditions must match the pictures, notes and information gathered on the initial and any other previous visits. Tree theft does occur, underscoring the value of these exotic trees.

Below is a depiction of the nodes of geospatial data involved within the PSA program.

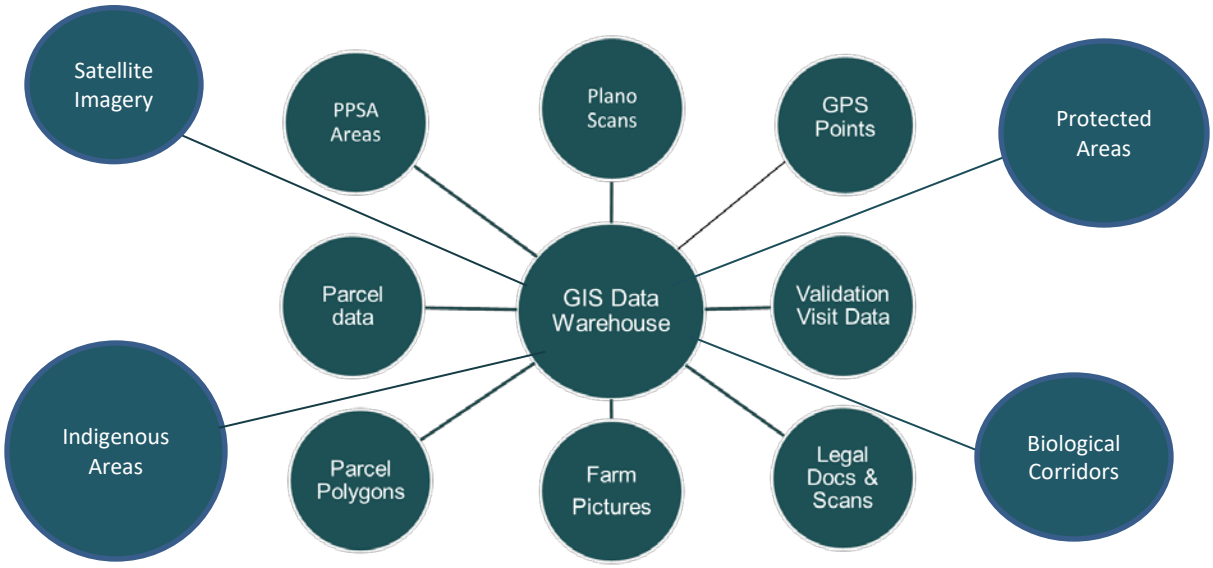


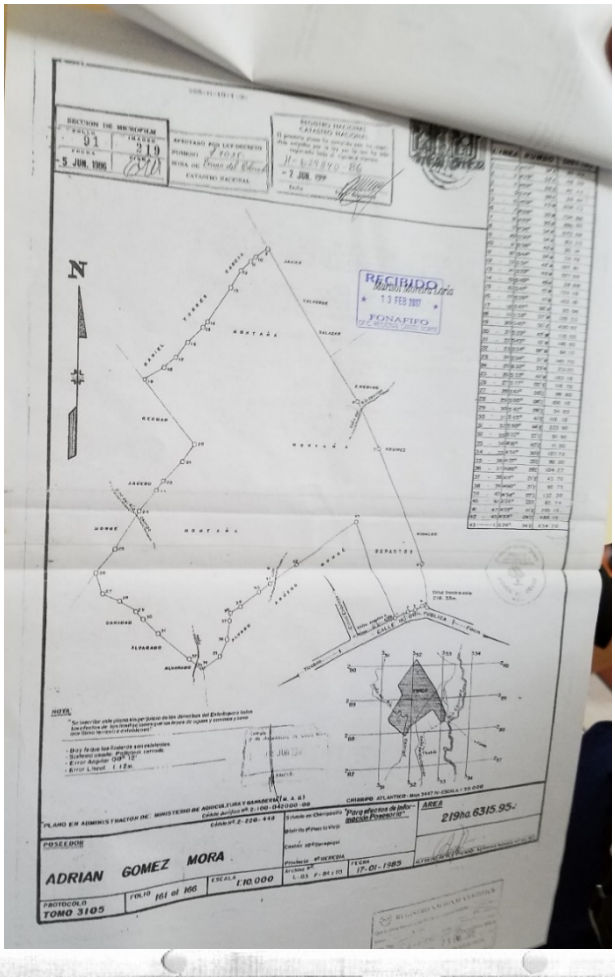
Figure 2 - Simplified Geospatial Data Diagram

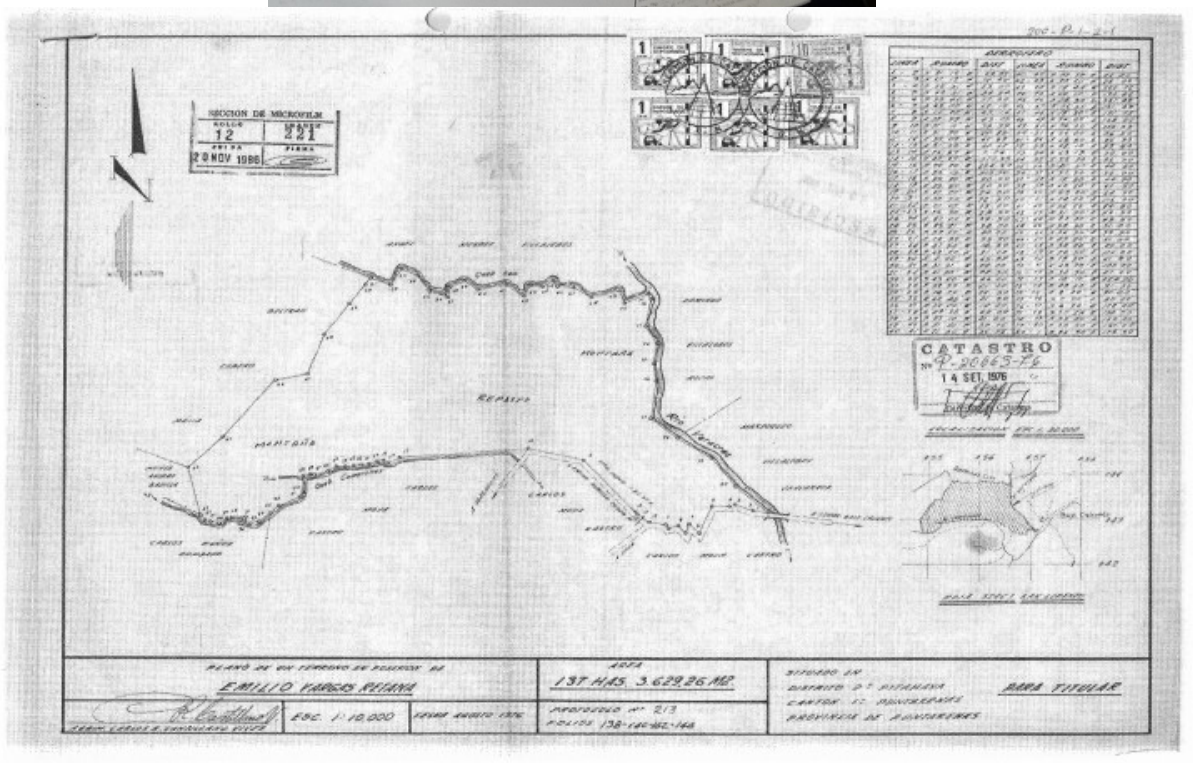
3.2.1 Key documents and processes

3.2.2 The Planos – The Planos is the official parcel ownership card or map from the National Registry. It is a primary land record required for the PSA Program applicants and participants. The U.S. equivalent would be a County Mylar tax map. The Planos originated in the 1960s and these land records are the primary authoritative-source, official government document which is critical to the validation of property ownership. The Planos include essentials of land ownership Cadastre such as mapped & scaled parcel boundaries, an index map, survey-control-point x, y coordinates, recordation stamps (official certification) with dates and initials, area in hectares, etc.

It was said that the total of all of Costa Rican Plano's parcel polygons is estimated to be over 25% larger (or more) than the true land mass of Costa Rica. It is not unusual or unexpected to have adjacent owners' parcel boundaries overlap, for example, between an applicant's parcel and an existing PSA parcel. Approximately twelve to fifteen percent of applicants' parcels overlap. The parcel boundaries based upon the surveyed information contained on the Planos conflict due to deficiencies in the methods originally used to create the parcel surveys. These overlaps require the affected PSA applicants and participants to resolve their neighborly dispute through the legal administrative process, employing a certified forest engineer for new mapping. At least one of the affected parties must make a new property map and formally register the new information before re-admission to the PSA program.

Below are two sample *Planos*.





3.2.3 Workflows

The graphic below shows the process of submitting a PSA Application.

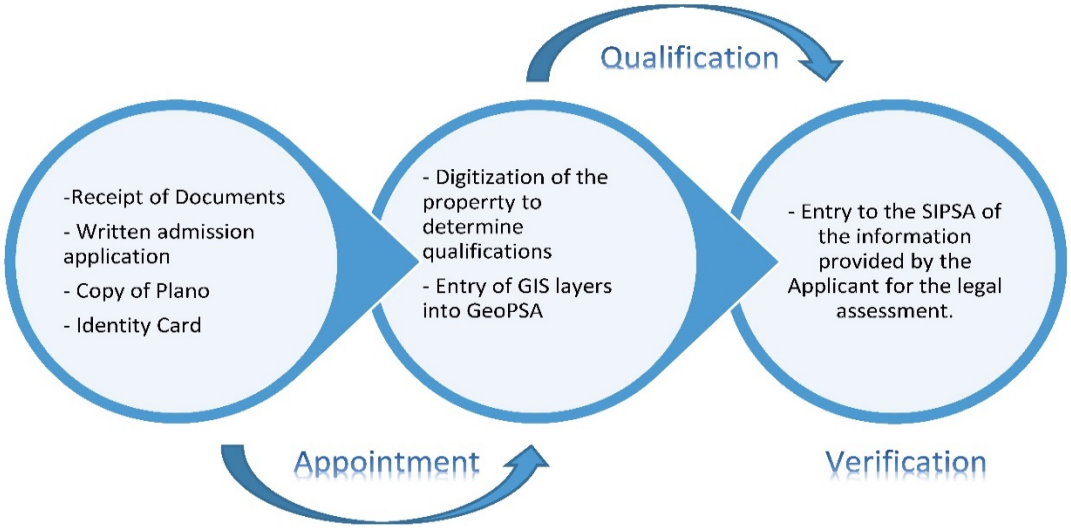


Figure 3 – PSA Application Workflow

In search of the modernization of its management system during the last years, and particularly in 2016, FONAFIFO has been dedicated to the development and testing of a series of custom modules, according to the requirements of the PSA. The graphic below illustrates the workflow of the Integrated System for the Payment of Environmental Services, or SIPSA, modules:

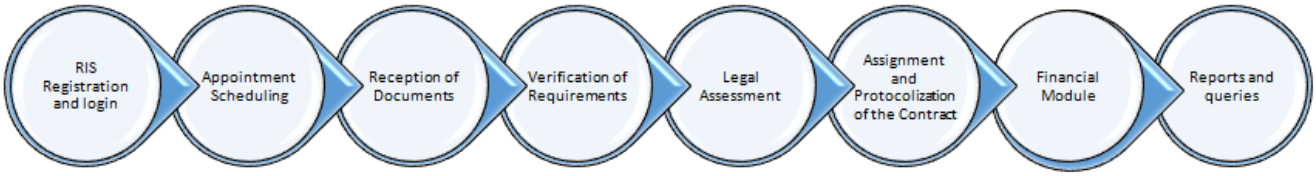


Figure 4 – PSA Approval Process Workflow

SIPSA manages the dual processes of both the administrative and GIS-related processes. SIPSA includes modules for setting up the initial appointment, online forms to enter the applicant's data, requirement verification, legal evaluation, affectation and notarization of the contract, a financial module, and reporting and inquiries. While the administrative process works its way through, the GIS-related processes regarding approving the Planos, reviewing the Regent's property map and other geospatial workflows are simultaneously tracked and managed by certain SIPSA modules.

There are very detailed and established procedures and protocols that are applied in the PSA processes. There are explicit rules defining landowner eligibility, contract selection, administration area, priority areas/locations, application fees, contract renewal criteria, contract cancellation criteria and min/max PSA contract areas.

Application procedures are available online and by telephone. Grace periods for obtaining the necessary documentation for application process are provided. The Operations Manual provides detailed information on grace periods for obtaining necessary documentation to resume the application process (information rules). Applicants may also qualify if they can document possession rights, but the process

of documentation and obtaining witnesses is laborious. Smallholder applicants may choose to pay surveyor and legal services to obtain a formal title[6]

The requestor submits a certified copy of the Planos and the Forester's (or NGO's) GIS representation of the Planos and property characteristics. The GIS data and associated applicant information are entered into SIPSA which documents all requirements and issues.

Quality Control is assisted through various filters and sequenced tasks. There is a need to validate ALL edits.

3.2.4 Multi-agency Coordination

A hallmark of the PSA program is the cross-compliance techniques used and the innovative blend of regulatory and economic mechanisms supporting program compliance and information requirements. This is achieved through an unusually coordinated fashion across a national government.

3.2.5 Inter-agency agreements

- VPN with the Supreme Electoral Tribunal TSE provides access to name, citizenship and Identification card.

- INTERDATA with Migration and Aliens
  Through the DIMEX of resident clients. This provides citizenship validation and name/ID confirmation.

- Web Services for Water Utility reports of fines.

- CCSS (Costa Rica Department of Social Security)
  Queried to see if an applicant is delinquent.

- FODESAF (The Fund for Social Development and Family Allowances)
  Queried to see if an applicant is delinquent.

- National Registry
  Free certifications of real estate and legal entity information.

3.2.6 Forest Engineers and NGOs

Forest engineers, or Regents, are registered/certified Professional Surveyors. These individuals are critical linchpins of authoritative source PSA GIS spatial data. They provide all PSA GIS data of relevance to individual property owners. FONAFIFO emphasizes the importance of the 'regentes forestales' (forest engineers or Forest Regents) role as a facilitator for small property holders in particular. The introduction of agroforestry contracts has been a successful way to engage with smaller properties, whose participation has significantly increased.

The Regents are authorized to use apparent lines of occupation (fence lines, tree lines, paths) and waypoint tracks to resolve overlapping PSA parcel polygons – when the overlap is deemed marginal. Otherwise the affected participants are denied program participation until the overlap is resolved and certified by the parties.

[6] Porras, I., Barton, D.N, Miranda, M. and Chacón-Cascante, A. (2013). Learning from 20 years of Payments for Ecosystem Services in Costa Rica.

Pre-2015, all changes in contracts and documents were processed manually. Now everything is scanned, with bar coding planned to further streamline document management.

Apart from FONAFIFO, there are a number of intermediaries who provide services to participating actors for a commission or fee (usually between 12 and 18 percent of the payment). For example, NGOs FUNDECOR and CODEFORSA and small farmer cooperatives that promote the use of PSA. These services include managing applications and preparing forest management plans.

An updated national property register also makes it easier for the municipalities and Ministry of Finance to collect taxes. Property titles are required to be correctly registered in the National Register.

3.2.7 Priority Setting Criteria

The award process includes a scoring process that uses a weighted system of priority criteria. The priority setting criteria favor applications from a variety of circumstances. Weighting variables include areas within biological corridors; indigenous territories; conservation gaps; protected areas; areas with low social development scores; properties under 50 hectares, and others. See the specific criteria below.

For example, an application from a forested area in an area defined as a 'conservation gap' receives 85 points. If it is a small property (less than 50 hectares) it will receive 25 additional points, making a total of 110 points. A similar sized property with forest located in a non-priority area will receive 55 initial points and an additional 25 points for its size, making a total of 80 points. There is an official requirement for FONAFIFO to support small and medium-sized forestry producers.

Below is a list of the Conservation Area Specific Criteria. These are the weighting variables used to develop the final point totals used in the ranking of applicant's properties for inclusion in the PSA program.

<u>Conservation area (CA) Specific Criteria</u>

- Non-priority Forest
- Indigenous territories
- Conservation gaps (GRUAS II)
- Protected areas (PA)
- Forest protecting water resources
- Biological corridor (GRUAS, CBM)
- Ecomercados#, KfWproject areas
- Non-expropriated properties
- Expiring forest management PSA
- Expiring contract this year
- Expired PSA contract
- Expired CAFMA >10yrs
- Low SDI (<40%)
- Contracts, properties <50 hectares (123.5 acres)

FONAFIFO is tasked with a complex mission and has a culture of continuous improvement to operations, data quality and integrity, leveraging the latest technology solutions, providing transparency and security. The leadership and technical capacity of FONAFIFO staff to manage and improve upon their complex workflows and organizational dynamics is assured and robust.

3.28 Functional Environment Overview

FONAFIFO and the PSA program is well known for its unique blend of regulatory processes that cross between and leverage data from various sectors. The below diagram attempts to summarize the various agencies and groups involved and describe the functional areas that are support the FOFAFIFO mission.

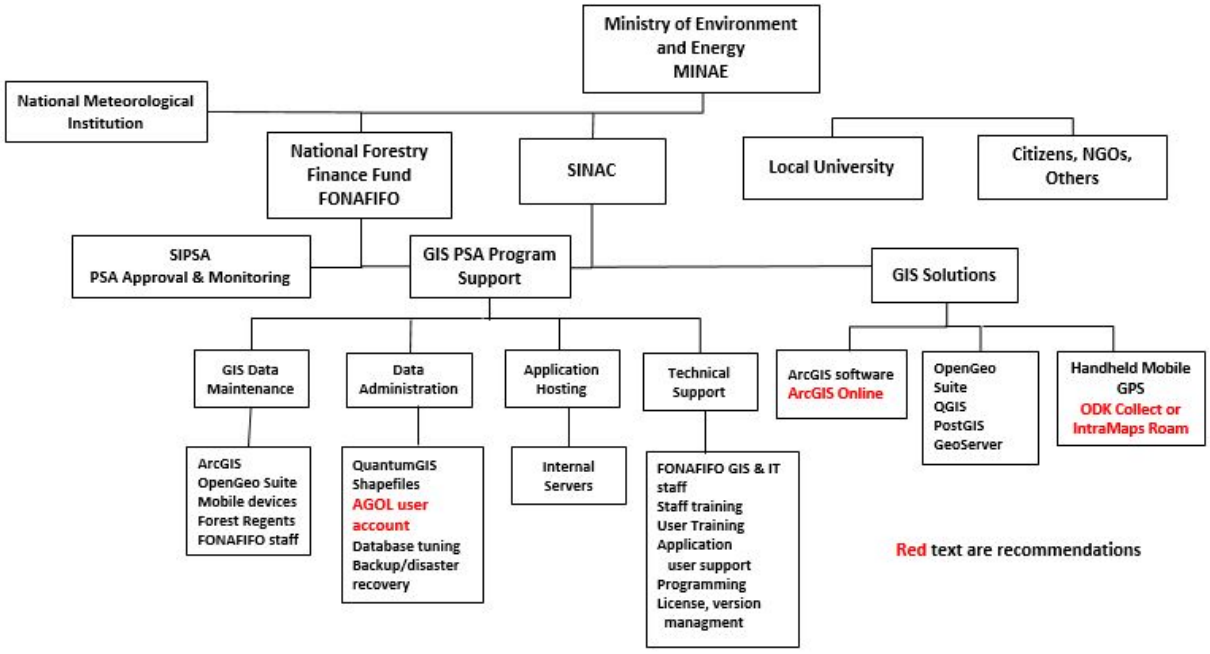


Figure 5 - FONAFIFO Functional Environment

SECTION 4
SYSTEM ARCHITECTURE / TECHNOLOGY OPTIONS

4.1 Introduction

This section delves into the marketplace solutions for enhancements to FONAFIFO's suite of GIS tools. This includes information related to the overall GIS system architecture, including options for Esri and Open Source GIS software, with a discussion of Cloud-based options using a hybrid software stack such as Esri and QGIS. GIS software capabilities and geospatial analysis tool options will be followed by discussion of platform types and hardware alternatives. This is followed by a discussion of UAS and remote sensing options. A short discussion of metadata concludes this section.

Given the huge number of Esri software offerings, third party add-ons and varied deployment configurations, I will focus on Esri products and solutions that are most applicable to the mission and work flows of FONAFIFO.

4.2 GIS Software Infrastructure: Open Source, Esri and Cloud-based Considerations

The decision on whether or not to deploy Commercial off the Shelf (COTS) GIS software or Open Source GIS software is a complex series of tradeoffs between the many positives and negatives of both software platforms as well as the benefits and risks of both options.

The matrixes below describe advantages and disadvantages of QGIS and Esri geospatial software. The considerations below are provided enable readers to make their own decisions based upon their individual circumstances and the importance of each factor to them.

Advantages and disadvantages of using QGIS products

Advantages	Disadvantages
Software licensing is free, less total cost of ownership	No technical support when you need it, no obligation by the community to help
Very good cartography, attractive labeling	Loss of key programmers can doom implementations
Large numbers of GIS analysis tools	Viewed as risky due to no brick & mortar company behind the products
Large user base, good documentation	Compared to popular COTS offerings, features and functionality are lacking in FOSS
Plugins (over 500)	Lack of 3-D integration, no automated topology correction
Highly reliable	Indirect costs involved, such as unanticipated support or development costs
Cost free mobile collection apps & form editors	Vulnerability to malicious users who can potentially view it and exploit vulnerabilities, infect hardware, steal personal ID info, etc.
Faster release cycles, providing improvements and fixes.	FOSS can require more technical know-how than commercial proprietary systems, especially when developing more complex customizations. (Unlike Esri with many Esri users available to maintain a standardized product).
Reliably deploy map/feature services - Open Geospatial Consortium (OGC), WMS, WFS, RESTful, etc.	

Advantages and disadvantages of using Esri products

Advantages	Disadvantages
Enormous user base	Software licensing is costly
Top of the line cartography	Required maintenance contracts are costly
Large numbers of GIS analysis tools	Loss of financial investments in software and technologies that are deprecated, no longer supported and replaced with new platforms
Un-rivaled functionality and scalability through multiple platforms	
Plugins (widgets)	
Automated topology correction	
Huge R & D budget ensures timely transitions to fundamental changes in technology	
Robust technical support, training, tutorials and help documentation	

4.2.1 Map Service vs. Feature Service

The publishing of Open Geospatial Consortium (OGC) compliant geospatial services to the web for consumption by users is a well-established best practice, and this is already being implemented at FONAFIFO. These include the ability to deploy notable Map and Feature services such as RESTful and WMS. These capabilities provide standardized conduits of connectivity to GIS data and applications for Internet users.

A Map Service is a standard protocol for serving (over the Internet) georeferenced map images which a map server generates using data from a GIS database. Internet or intranet users can then use the map service in web applications, QGIS, ArcGIS for Desktop, ArcGIS Server, and other client applications. Typically a "RESTful endpoint", a Map Service (or server) is a host that provides map services. A map service is the technique that allows a user to make maps available to the web. For example, in the Esri world, you can create a map in ArcMap, then publish the map as a service to your ArcGIS Online site (or ArcGIS Enterprise, FKA ArcGIS for Server). Internet or intranet users can use your map services in web applications, ArcGIS Desktop, ArcGIS Online, and other client applications.

A Feature Server is a host that provides Feature Services for your users. Feature Services allow you to serve features over the Internet and provide the symbology to use when displaying the features. Clients can execute queries to get features and *perform edits* that can be applied to the server. Feature Services provide templates that can be used for an enhanced editing experience for the client. Data from relationship classes and non-spatial tables can also be queried and edited using feature services.

4.2.2 Cloud Computing

The advent of the "Cloud" has ushered in a new era of handling your mission critical software, applications and data. Traditionally, a server was purchased, and then decisions and purchases were done for the operating system, firewall software/security appliances, database systems, application software and other components. All of these components need maintenance, upgrades, tuning, threat protection, electricity, space, disaster recovery, etc., and staff to run it all. With a Cloud solution, the Cloud vendor handles the majority of these tasks.

The overall advantages of using the Cloud in various configurations is clearly recognized, with cost efficiency and IT standardization topping the list of key benefits. Expensive investments in equipment, software, personnel, and data center facilities can be mitigated.

What is a Public Cloud versus Private Cloud? Public Clouds are based on shared physical hardware which is owned and operated by a third-party provider, i.e., Microsoft OneDrive, Google Drive, and Amazon EC2. A Private Cloud is infrastructure dedicated entirely to your organization which is hosted either on-site or in a service provider's data center. *Given the size and budgetary constraints, I do not recommend the implementation of a Private Cloud*.

Pricing for cloud services typically includes initial upfront costs, maintenance fees, renewal costs, and volume commitments, i.e., ArcGIS Online (AGOL) "Credits" (more on these below).

I recommend FONAFIFO continue the use of Microsoft OneDrive Cloud solution for backing up critical data using the unlimited storage solution – OneDrive Plan 2 for $10.00 per month, per user, or Office 365 Business Premium for $12.50 per month per user, as currently set up. I also recommend the implementation of AGOL as described below.

GIS Platform Types

Below is key information on GIS Platform options and recommendations regarding GIS Platforms for FONAFIFO.

Types:

1. Software as a Service (SaaS)
2. On-Site Data Center
3. Infrastructure as a Service (IaaS)
4. Platform as a Service (PaaS)

1. Software as s Service (SaaS)

- Service or application is delivered over the web through a browser and/or an Application Program Interface (API)
- Typically licensed by a third party on a subscription basis
- This term can refer to accessing software (e.g., Office 365)

SaaS is my recommended Cloud Platform option for FONAFIFO. FONAFIFO currently is taking advantage of the Office365 SaaS. ArcGIS Online (AGOL) is another SaaS solution set. ***I strongly recommend the use of the AGOL Cloud solution.***

Benefits of SaaS include:

- No initial set up costs, robust apps and functionality with no programming
- No hardware costs, processing is supplied by the Cloud provider
- Automatic software upgrades, patches
- Any Internet connected device can access applications
- Cross-compatibility on any device
- Outsource security, a huge concern now that will only will get worse
- Scalable up to any load. For example, a natural disaster strikes and a disaster response website is quickly set up showing impact area, closed roads and detours. This very important website could be scaled up in the Cloud to handle enormous volumes of website traffic that would occur from everyone accessing it on their smart phones, PCs, etc.

2. On-site data center

- Organization manages the server hardware, security, Operating Systems, in-house network and databases
- Responsible for all administration, maintenance and upgrading of all system infrastructure
- All software installations and operations are managed by the organization
- Provides full control of the entire application stack

Like virtually all large organizations, FONAFIFO has a robust data center which services FONAFIFO needs, as well as those of staff and external stakeholders. *I recommend that the data center have a permanent, long-term role supporting the Information Technology operations of the central office and FONAFIFO overall, despite other choices for outsourcing and Cloud computing. Maintaining local control trumps potential short term financial benefits.*

3. Infrastructure as a Service (IaaS)

- Core infrastructure and data center capabilities are in the cloud
- No need to maintain an on-site data center
- Outsource security and disaster recovery
- Nearly unlimited scalability

4. Platform as a Service (PaaS)

- A cloud service that provides a computing resource, the operating system, database, application server, and programming language. These are all managed in the cloud
- Using PaaS the users can develop, run and manage their software and no longer have to worry about installing, managing this infrastructure

IaaS and PaaS are not practical platform options for FONAFIFO until such time these resources become more affordable*. This is an effective technology to be aware of in the long term if costs come down.*

4.3 GIS Software and Analysis Tools

4.3.1 Desktop GIS software

ArcGIS for Desktop

The decision to further embrace the Esri solution set, or not, is an important decision related to this report. As a reminder, one ArcGIS for Desktop license must be purchased for every PC/laptop it is on.

ArcGIS for Desktop functions well, meeting your needs and provides the ability to leverage your existing investment by using the tremendous resources of AGOL. *I recommend the continued use of ArcGIS in the current configuration, with maintenance for one license of ArcGIS for Desktop Basic paid annually.*

Operations Dashboard

The Operations Dashboard provides a common interface for monitoring, tracking, and reporting an event or series of events to a group of people within your organization. Create and share operation assessments that include interactive maps, charts, gauges, and other performance indicators.

This will allow for Funders and managers to monitor a near real-time window into staff and operations.

Inflated Esri Pricing

Esri product pricing is significantly elevated in Costa Rica. For example, one five-5-user AGOL licensing plan that costs $500 in the U.S. costs $2,750 in Costa Rica. Factors driving Esri product prices in the USA (in this author's opinion) include funding research & development, extensive technical support resources, marketing and administrative costs for a company with 3,500 staff and over 1,000,000 desktop licenses. Esri software is located in over 350,000 organizations worldwide including all 200 largest cities in the U.S., more than two-thirds of Fortune 500 companies, most national governments and more than 7,000 colleges and universities. [7]

There is an absence of free market competition in Costa Rica as there is only one Esri software distributor. I think the higher software and maintenance costs are a major reason for the on-going migration away from Esri software and towards Open Source products in FONAFIFO as well as at The National System of Conservation Areas SINAC. I empathize with this economic migration.

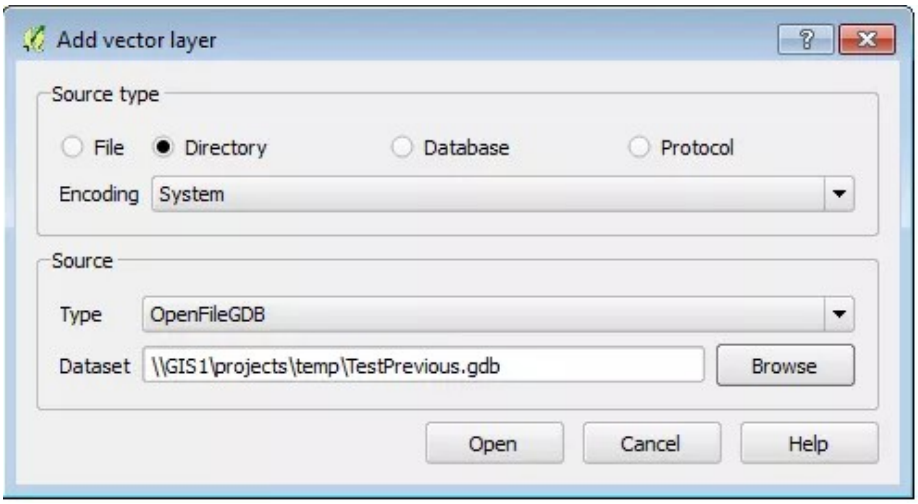
QGIS Desktop recommendations

QGIS Desktop should continue to be a key, primary software solution for FONAFIFO.

Below is the information FONAFIFO requested regarding using an Esri geodatabase in QGIS.

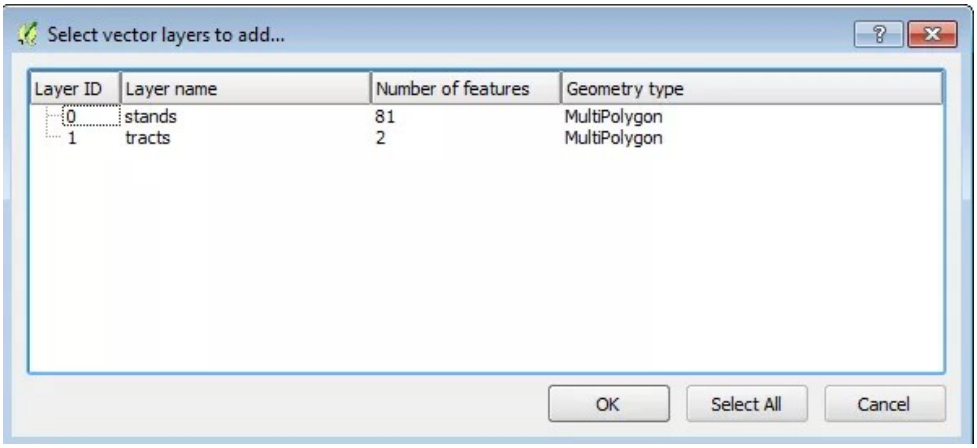
To use an Esri File geodatabase in QGIS (QGIS V 2.6, 2.8. Platform Windows 7, Linux)

1. Open QGIS. Add Vector Data. Check the radio Button for Directory and Select type to be the OpenFileGDB. Select the File Based Geodatabase by clicking browse:

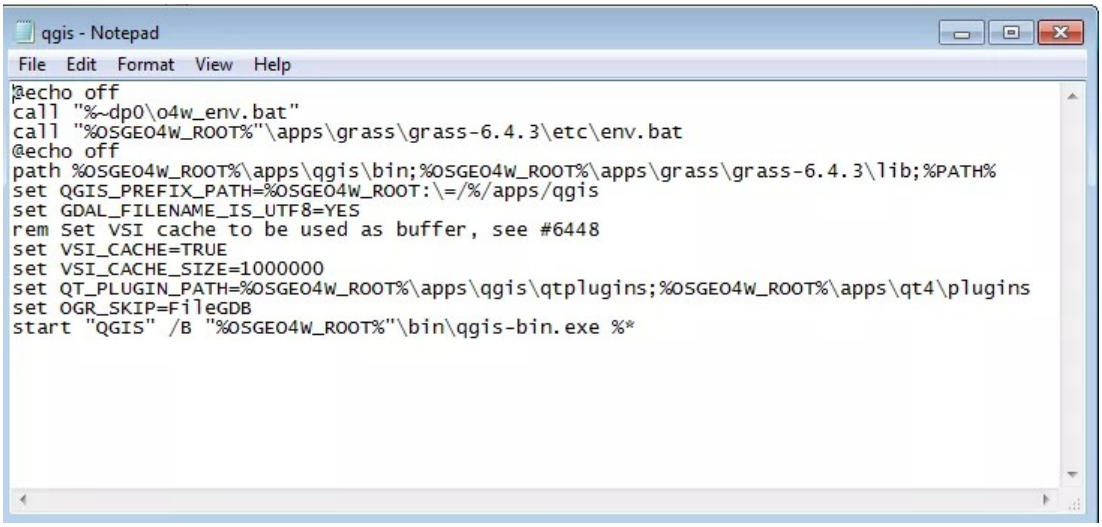


[7] Copyright © 2016 Esri

2. Once you click open you will be presented with a screen to select the feature classes:



Note: In 2.6 (On windows) with the OSGEO Installer and the standalone it is reported that there can be a slight hiccup between the ESRI Driver and the OpenFileGDB. In case of problems opening a geodatabase, open the qgis.bat file located under the install of QGIS under the bin directory. Add set OGR_SKIP=FileGDB to the 2nd to last line:



After saving and restarting QGIS you should be able to open Esri File or Personal Geodatabases.

4.3.2 Handheld mobile device GIS software

Mobile device use is presented as a Best Practice for field staff. Of course, FONAFIFO was a pioneer in this space, continuing to self-assess and improve their hardware/software as time has progressed. FONAFIFO is again looking to maintain its global leadership position in the use of cutting edge GIS and associated technologies for natural resource conservation and stewardship.

The recently purchased, Cedar Tree GPS mobile devices which have Android operating system may meet your accuracy and durability needs; however, continued testing is planned. Continue testing until your failure rate metric is exceeded and you need to look for new GPS units. Using the Android Operating System for handheld mobile devices is recommended due to the well documented lack of Apple iOS in the GIS space. Mobile handheld personal devices can provide the GPS signal accuracies, provide more ruggedized options and larger screens.

4.4 Hardware Options

4.4.1 Desktop

The Dell XPS 8700 is a good example of a PC specification that will provide ample capacity for a 3-4 year desk life. Model - Dell XPS 8700 - Core i7 4770 3.4 GHz - 16 GB RAM - 2 TB Hard drive

More information on the Dell XPS can be found by clicking here. Detailed specifications are included in Appendix "B" - PC Hardware Specifications.

ArcMap software requirements are listed below to enable FOFNAFIFO to properly configure new PC's purchased for ArcMap usage. These are minimum requirements and must be adhered to use ArcMap.

ArcMap Software Requirements

	Description
Python requirement for geoprocessing	ArcMap geoprocessing tools require Python 2.7.12 and Numerical Python 1.9.3 to be installed. If the ArcMap setup does not find either Python 2.7.12 or Numerical Python (NumPy) 1.9.3 installed on the target computer, Python 2.7.12 and Numerical Python 1.9.3 will be installed during a complete installation of ArcMap. You can choose a Custom installation to unselect the Python feature and avoid installing it. Additionally, if the Python setup is executed during the ArcMap installation, you will be provided with the opportunity to choose its installation location. The Python installation location should not include spaces.
Microsoft .NET Framework requirement	Microsoft .NET Framework 4.5 or higher must be installed prior to installing ArcMap.
Browser requirement	Microsoft Internet Explorer (minimum IE 9) must be installed prior to installing ArcMap. Internet Explorer 9, 10, and 11 are supported.

The hardware requirements for QGIS are not a robust as those for ArcGIS Desktop so the following specifications will handle all GIS and other software.

ArcGIS Minimum Hardware Specifications

	Supported and Recommended
CPU speed	2.2 GHz minimum; Hyper-threading (HHT) or Multi-core recommended
Platform	x86 or x64 with SSE2 extensions
Memory/RAM	Minimum: 4 GB Recommended: 8 GB
Display properties	24-bit color depth Also see Video/Graphics adapter requirements below.*
Screen resolution	1024x768 recommended minimum at normal size (96 dpi)
Disk space	Minimum: 4 GB Recommended: 6 GB or higher ArcGlobe creates cache files when used. If using ArcGlobe, additional disk space may be required.
* Video/Graphics adapter	64 MB RAM minimum; 256 MB RAM or higher recommended. NVIDIA, ATI, and Intel chipsets supported. 24-bit capable graphics accelerator OpenGL version 2.0 runtime minimum is required, and Shader Model 3.0 or higher is recommended. Be sure to use the latest available drivers.

ArcMap virtualized 10.5 environments

ArcMap is supported as a hosted application running on the following virtualized environments. This is included given FONAFIFO's goal of increasing its virtual footprint.

Virtual Desktop Infrastructure (VDI)
Citrix XenDesktop 7.6
Citrix XenDesktop 7.11
Windows Server 2012 R2 Hyper-V
Windows Server 2016 Hyper-V
VMWare vSphere 6.0 Horizon View

ArcMap Cloud Environments

ArcGIS Desktop will provide adequate performance and usability in many of the cloud environments. The cloud virtual machine (VM) must support Windows Server 2012 or 2016 and have adequate number of virtual cores (2 minimum), memory (64GB minimum) and storage (based on data profile).

Note: When running in a 64 bit environment, ArcGIS Desktop runs as a 32-bit application.

4.4.2 Tablets

There is no need for bulky, more expensive hardened tablets because FONAFIFO's data collection needs are relatively limited to allow for the use of a more convenient, smaller form and screen like the Cedar Tree handheld device under testing currently. Less to carry, smaller backup batteries and less total cost of ownership are notable benefits of using a handheld device instead of a tablet.

4.4.3 Smart phones

Phones are not currently considered a viable option due to limitations in their ability to collect accurate GPS points under tree canopy.

4.5 Unmanned Aerial Systems (UAS, UAV, Drones)

UAS provide a means of capturing images of natural and man-made land-based features and areas that may be difficult to access or fully cover because of size or terrain. And **by introducing enormous productivity gains through a substantial reduction of time spent per farm**, UAS can provide a return on investment (ROI) worthy of investigating. A FONAFIFO UAS could also be used for occasional ad-hoc inspections of physical facilities such as roofs, communications infrastructure, etc.

UAS vs. UAV – These are different terms for the same device:

- UAS - Unmanned Aerial System
- Drone - Military oriented term
- sUAV - Small Unmanned Aerial Vehicle
- UAV - Unmanned Aerial Vehicle
- RPAS - Remotely Piloted Aircraft System. The International Civil Aviation Organization (ICAO) endorses the acronym RPAS

I recommend working with a local UAS vendor to explore the feasibility of using this technology in such extreme environmental conditions. Even limited use of Drones can save many, many hours of staff time.

Costa Rica's meteorological conditions present very unforgiving environment for such precision equipment. *Ruggedized water-resistant, or preferably nearly water-proof models are recommended. Strict usage protocols to mitigate usage during the harshest conditions should be implemented. Obtaining advice of experienced UAS users in Costa Rica is strongly recommended. I fully support and strongly recommend the testing for implementation of UAS technology. The potential for ROI is great because so much time is spent traversing difficult terrain. Ruggedized units are a must. A top IP rating of IP67 or more is recommended.*

The IP Code (or International Protection Rating, sometimes also interpreted as Ingress Protection Rating) consists of the letters IP followed by two digits. It classifies the degrees of protection provided against the intrusion of solid objects, dust, accidental contact, and water in electrical enclosures.

Below is a description of the Ingress (or International) Protection waterproof rating system. The first digit indicates the level of protection that the enclosure provides against access to hazardous parts (e.g., electrical conductors, moving parts) and the ingress of solid foreign objects. The second digit indicates the level of protection of the equipment inside the enclosure against harmful ingress of water. The degrees of protection for **IP67** are highlighted.

First # Solid Foreign Object	Second # Water Ingress Protection
0 no protection	**0** no protection
1 protected against solid objects up to 50mm	**1** protected against vertically falling drops of water
2 protected against solid objects up to 12mm	**2** protected against direct sprays of water up to 15° from the vertical
3 protected against solid objects over 2.5mm	**3** protected against sprays of wwater up to 60° from the vertical
4 protected against solid objects over 1mm	**4** protected against water splashed from all directions
5 protected against dust	**5** protected against low pressure jets of water from all directions
6 totally protected against dust	**6** protected against strong jets of water
	7 protected against immersion
	8 protected against complete continuous submersion in water

Quad-copter and fixed wing UAS systems provide high resolution geo-referenced imagery and *immediate access to difficult terrain.* This cannot be emphasized enough with the mountainous terrain encountered on a regular basis. Fixed wing drones are ideal for longer missions, generally when the area to be mapped exceeds 100 acres or 40Ha. Given the mountainous terrain in Costa Rica, a multi-rotor or quad-copter would be best.

Multi-rotor UAV

UAS provides the ability to generate highly accurate 3D models and point clouds for coal and other materials stockpile volume calculations. These 3D models, point clouds, sensors, etc. are not applicable to FONAFIFO's mission or requirements. High resolution geo-referenced imagery, both still and video, will meet FONAFIFO's requirements.

Most drones are operated with radio controllers, but many can also be programmed and controlled via tablet or smart phone.

UAS workflows

I strongly recommend that FONAFIFO follow the UAS workflow below:

1. Develop a flight mission plan - site analysis, route and waypoints, weather check.
2. Flight and data capture - fly the farm, download images, video and telemetry file (telemetry is a digital two-way data stream, which can both send data about the flight down to a ground station and send command up to the autopilot).
3. Data processing - Imagery download and/or map or measurement creation. Vendors offer cloud based solutions to outsource the huge processing requirements that can be associated with sensor collected data.
4. Data delivery - Very large files. Transfer using two terabyte hard drives to manage imagery transfer and backup.

UAS software

There are many options regarding software solutions. At UAS conferences I have noted many new startups, adding even more options to the many leading solution providers such as Pix4D, DroneDeploy, PrecisionHawk, Agisoft, etc.

However, *FONAFIFO's business needs are met through simple photography; so, an expensive solution like Pix4d to create point clouds is unnecessary.* The software that is bundled with a UAS will be able to handle the processing of photo imagery from the field. Confirm this capability with your UAS vendor or Subject Matter Expert.

It was interesting to learn from Randy Hamilton that digital terrain models cannot be reliably created using UAS derived point clouds or raster datasets. This is due to the lack of bare earth returns in the rain forest due to an inability to penetrate thick vegetation.

OpenDroneMap – OpenDroneMap (ODM) is an Open Source toolkit for aerial drone imagery. *I recommend this free, Open Source option.*

There are many ways to install ODM:

- Natively using Ubuntu 14.04 or later (or with Virtual Machine via vagrant)
- Linux, MacOS or Windows, by installing Docker
- Via the above methods but with a Web-based GUI called WebODM

Learn more at: OpenDroneMap.org. I can facilitate the implementation of ODM by connecting FONAFIFO staff with Stephen Mather, the creator of ODM, whom is an associate. A translator would be needed for approximately eight hours over several days for initial configuration and training.

Training - *Practice piloting skills with an inexpensive UAS.* Once the operator is more expert, then work with the expensive production model. UAS safety concerns and operational training is a must.

Safe Operating Protocols – *I recommend strict safety protocols.* The Uaviators are an international organization that promotes the safe and responsible use of UAVs, in the humanitarian space. See the Code of conduct here. (Versión en Español Aquí**.)** Their UAV Best Practices guide contains everything you need to be safe, responsible and ready for flight. Pre and post-flight check lists can be found in this guide here.

Batteries - UAS batteries have a limited amount of flight time per charge and life span*. I recommend that FOFAFIFO budget to have an adequate supply of charged batteries and budget for replacements.*

Maintenance - Schedule regular maintenance. This is *especially important* given your extreme environmental conditions, heat, humidity, difficult to predict precipitation and strong winds in mountainous areas.

4.6 Remote Sensing

FONAFIFO has been an early adopter of remote sensing products to monitor and classify land use. The no-cost, long-term availability and national coverage of LandSat has provided baseline land classification data and trends. These data, while not as resolute as desired nonetheless provide a consistent authoritative data source for monitoring the ecologically important land cover. SPOT data has provided another source to quantify the state of land cover. Digital Globe satellite imagery products have also provided critical imagery data at a high resolution.

Higher resolution imagery from small Satellites, CubeSats and other space-based imagery providers will multiply and provide less expensive remote sensing products in the future.

4.7 Metadata

Metadata, or "data about data", is important to any GIS program in order to provide information to users about the spatial data of your organization. This information provides users with critical information regarding content, projection, quality, source and lineage and more, including what is available and is the data appropriate for an intended use.

ERSI has provided the capability of creating your metadata within ArcGIS software - no additional software to purchase. Within Arc Catalog the tools are provided to create metadata, both automatically and manually. Automatic creation does not fill in many of the fields but is the best way to start because basic information is filled out for you.

The International Standards Organization (ISO) geographic metadata standard 19115 would typically be my recommendation for a metadata standard outside of the USA. This ISO standard is based on the consensus of the international community. However, *given that Instituto Geografico Nacional is currently developing standards, I defer to the Instituto Geografico Nacional's final protocols, information fields and metadata tool selection.*

At a minimum, metadata should include the following information:

- Title
- Description of Data Layer
- Purpose of Data Layer
- Time Period of Content

- Maintenance and Update Frequency
- Source of Information/Data Collection Method
- Scale of Original Source/Data Collection
- Map Projection
- Positional Accuracy
- Attribute Accuracy
- Attribute Definitions
- Known Limitations
- Custodian/Point of Contact

SECTION 5
COSTS/BENEFITS & RECOMMENDATIONS

5.1 Introduction

These recommendations are respectfully submitted for your review and analysis. While this study may not be a rigorous cost-benefits analysis, the conclusions do present recommendations that take into account the overall cost of ownership for each software stack, COTS or Open Source, while being mindful of the risks and tangible and intangible benefits.

5.2 Esri based solutions

Recommendation: The decision to further embrace the Esri solution set, or not, is an important decision related to this report.

I recommend the continued use of ArcGIS in the current configuration. It is functioning well, meeting your needs and providing the ability to leverage your existing investment through ArcGIS Online. I endorse the payment of annual maintenance for the next 3 years for one copy of ArcGIS for Desktop Basic. Beyond 3 years Esri will have moved desktop solution focus into the ArcGIS Pro space I believe. Paid maintenance will provide access to the ArcGIS Online (AGOL) platform. Leveraging the AGOL platform is a primary recommendation of this report. This will enable you to:

- Quickly and nimbly serve up public access GIS web map apps
- Use the Operations Dashboard
- Outsource security
- Outsource software administration
- Provide for disaster recovery

Being current on one license of ArcGIS will also give access to technical support, and provide at least one copy that has some of the more recent functionality upgrades like the conflate tool for “shifted” PSA parcel polygons.

Having some of your infrastructure invested in the Esri product line ensures a stable solution suite with technical support and immense resources behind it that drive innovation in this industry. Using a standardized, ubiquitous software tool such as AGOL ensures a pool of available GIS specialists. There is no complicated custom code to decipher with this COTS solution as opposed to an Open Source based solution

5.2.1 Desktop software

Recommendation: *I recommend the payment of maintenance for one copy of ArcGIS for Desktop – Basic.* This will provide access to AGOL, a key recommendation of this report.

5.2.2 Esri Software Cost Matrix

A suite of options for Esri GIS software products is shown below in order to provide a picture of the range of options and costs associated, as of June, 2017.

Item	Initial Cost	Primary Maintenance	Secondary Maintenance
ArcGIS Desktop Basic Single Use	$2,500	$700	$450
ArcGIS Desktop Standard Single Use	$7,900	$1,725	$1,200
ArcGIS Desktop Advanced Single Use	$15,800	$3,000	$1,400
ArcGIS (for Server) Enterprise - Basic 4-Core	$11,000	$3,300	$3,300
ArcGIS (for Server) Enterprise Standard - 4 Core	$22,000	$5,500	$5,500
ArcGIS (for Server) Enterprise Advanced - 4 Core	$44,000	$11,000	$11,000
5 pack of level 2 AGOL licenses (annual)	$2,750	$0	$0

5.2.3 Browser-based Esri GIS software

There are multiple web-based solutions from Esri in this space. I have included only those that match FONAFIFOs needs and resources.

FONAFIFO recognizes the need for a public access GIS viewer to provide mapping and information for the general public, NGOs, educational institutions, environmental advocacy organizations and anyone interested in the preservation of the Costa Rica rain forests, commonly referred to as the jewels of the earth. I would venture to say that there is a large demand for information about the world-renowned conservation efforts continuing in Costa Rica and particularly at FONAFIFO.

5.2.4 Operations Dashboard - The Operations Dashboard provides a common interface for monitoring, tracking, and reporting an event or series of events to a group of people within your organization. Create and share operation assessments that include interactive maps, charts, gauges, and other performance indicators.

Recommendation: *I recommend the implementation the Operations Dashboard solution from Esri. Funders and managers can monitor a near real-time window into staff and operations productivity and monitor data work flows.*

5.2.5 ArcGIS Online (AGOL)

Of all the Esri solutions, I recommend the adoption of ArcGIS Online (AGOL) by FONAFIFO to meet the need for a public access web-based GIS viewer to provide mapping and information for the general public, NGOs, educational institutions, environmental advocacy organizations, etc. Other information and benefits of AGOL are listed below.

Recommendation: *I recommend the use of AGOL for web-based collaboration.* ArcGIS Online is an online, collaborative web-based GIS that allows you to create data, access your data and apps, manage your data, including automated syncing to a central server, and share this information through collaborative web apps. *Specifically, I recommend AGOL for public GIS website development and data analysis through the AGOL Map Viewer.* Through the sharing of maps, apps, layers, analytics, and data, FONAFIFO can keep everyone involved in your data workflows updated with the most current, authoritative-source data.

Out of the box templates and the Web AppBuilder for ArcGIS provide a code-free development environment that is easy to learn. It includes powerful tools to configure fully featured HTML apps.

More advanced custom solutions are available through the Developer Edition of Web Appbuilder. Web AppBuilder Developer Edition includes an extensible framework for developers to create custom widgets and themes. See a video on custom widget creation here. (https://www.youtube.com/watch?v=RWvWolv8Wy0&feature=youtu.be)

- Build HTML/JavaScript apps that run on desktop, tablets and smart phones.
- Create apps using ready-to-use widgets, such as query, measure, geo-processing, printing, etc.
- Customize the appearance of your apps with configurable themes.
- Host map apps online or utilize your own server.
- Create custom app templates.

The Analysis widget provides a simple method to use the ArcGIS Online spatial analysis tools, from the Map Viewer, in your web map application. One can configure one, or more, tools per widget. Using these tools in a web app (publicly available for example) will use Service Credits. Using these tools in AGOL Map Viewer (internal users) does not. *A key distinction, as your staff can be productive for free.*

I recommend the use of the ArcGIS API for JavaScript version 3.20 for a more robust and functional website deployment capability once staff are familiar with WebAppBuilder and AGOL. JavaScript Version 4.3 is focused on expanding 3-D modeling and associated capabilities and should not be used.

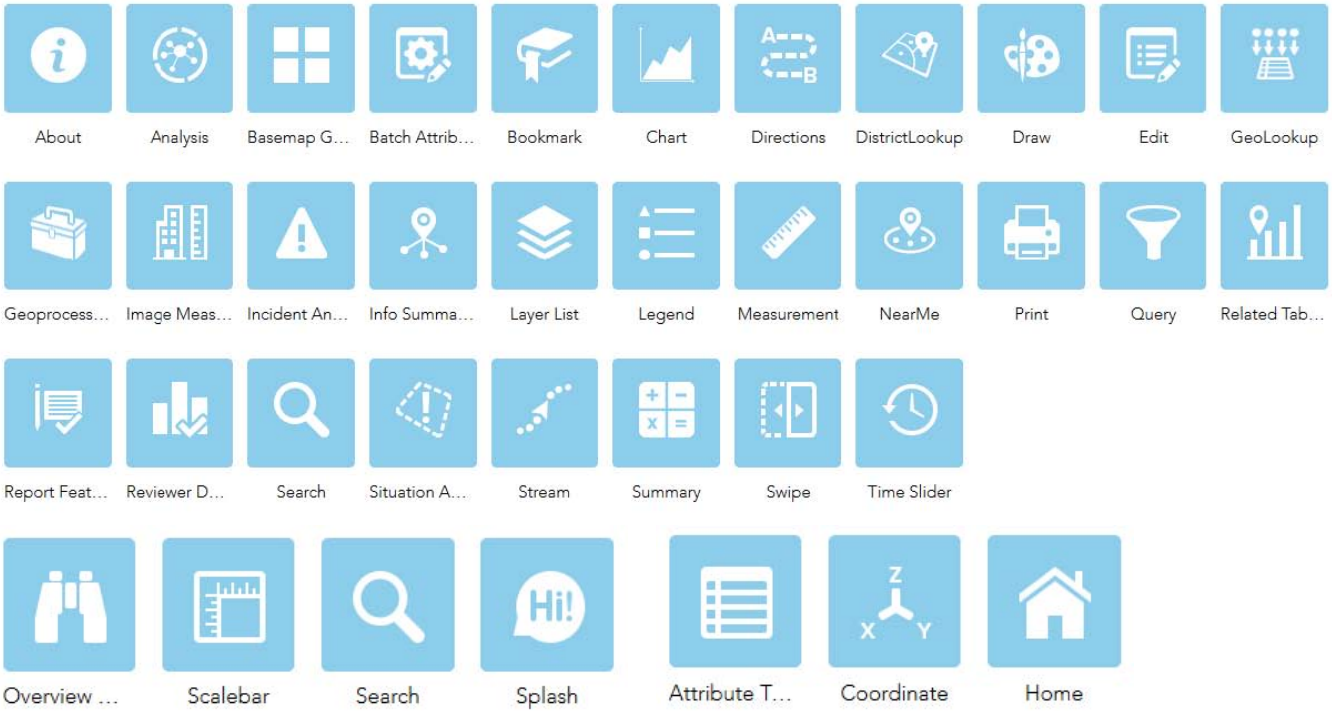
AGOL for public GIS website development

As I demonstrated for FONAFIFO, a user can create simple, focused websites using AGOL web app/map templates - quickly (“low hanging fruit”) - and serve them out to either credentialed AGOL account users, or groups of users, or for the public. There are many different configurable apps available to provide a default driven web app map. To add different options, use the "Web AppBuilder" to provide users with various types of functionality, such as various editing tools, identify, search for features, apply different layouts and color schemes, social media feeds, side-by-side map viewers, etc.

The AGOL GIS web site workflow is quite simple:

1. Create a new app
2. Pick a style
3. Select a map
4. Add widgets
5. Configure attributes

Below is a listing of many of the widgets available out of the box.



Graphics courtesy of Tim Hensley, Esri. PowerPoint, "Web AppBuilder for ArcGIS: JavaScript Apps Made Easy".

As was also demonstrated, the functionality that comes with an ArcGIS Online account within the AGOL Map Viewer is impressive. ***Using these tools could eliminate months, if not years of custom development in QGIS to match the 25 included tools.***

<u>AGOL Service Credits</u>

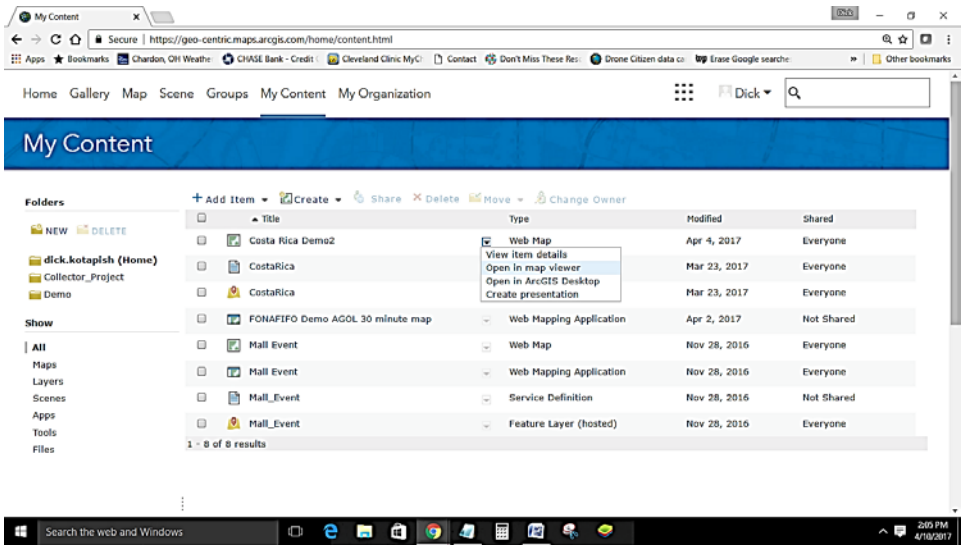
- Your annual ArcGIS Online subscription comes with a set amount of service credits. Typically 2,500 credits for each ArcGIS Desktop license with its maintenance fees paid. Pay for what your use – set up properly, the Credits charges should be cost free, using existing credits. Of course annual maintenance is always there.

Service credits are required in exchange for storage, analytics, demographics and lifestyle maps. If one account for a Public Access website is set up properly, I can estimate that FONAFIFO would have to purchase little, if any, additional credits. What doesn't involve Service Credits? Most of what you do with AGOL does not require service credits:

- Accessing the data you store in ArcGIS Online in apps
- Using ArcGIS Online foundation maps and data (basemaps, Landsat imagery, landscape layers, live traffic, and other live feeds)
- Exporting data stored in ArcGIS Online
- Performing single address or place search

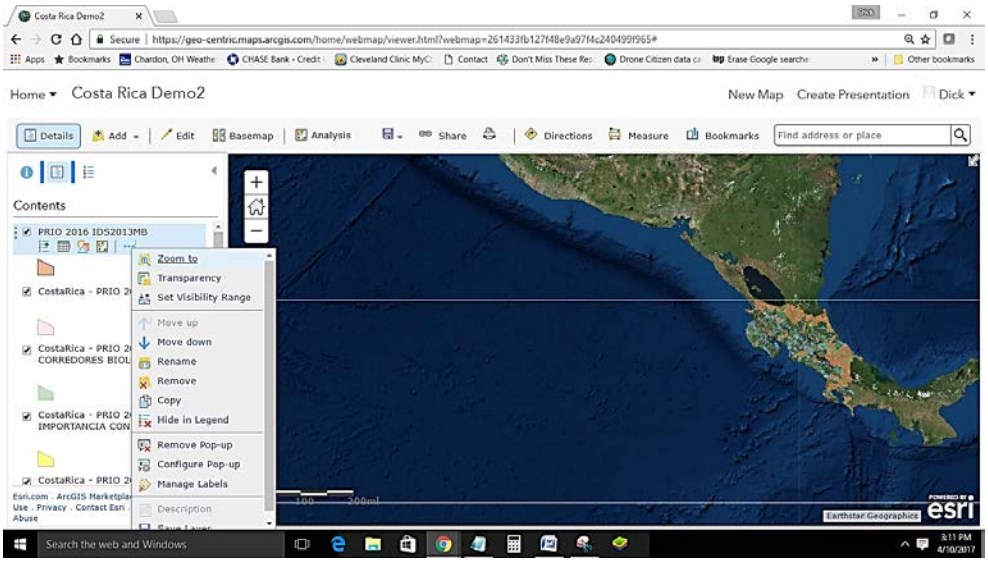
The Analysis widget provides a simple method to use the ArcGIS Online spatial analysis tools, from the Map Viewer, in your web map application. One can configure one, or more, tools per widget. Using these tools in a web app will use Service Credits. Using these tools in AGOL Map Viewer does not.

Below are some screen shots of a few of the more important components of an AGOL account.



Above is the My Content window in an AGOL account. The interface shown above provides tools and options to you to manage your services, modify feature layers and Web Map Apps.

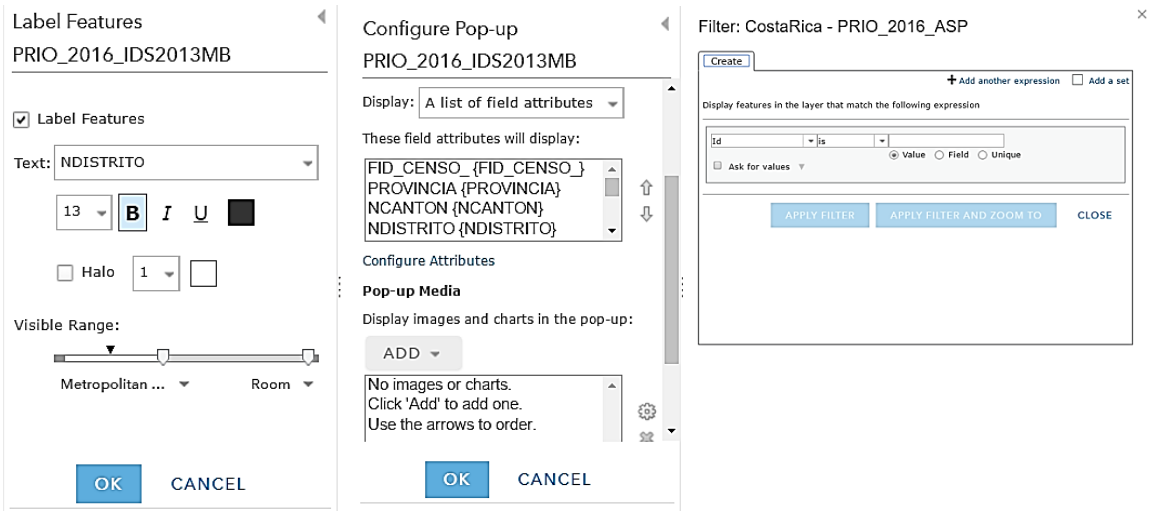
A demo Web Map App that was developed during the workshop for FONAFIFO is shown below.



The above GIS Portal can be embedded within the FONAFIFO website.

<u>The AGOL Map Viewer</u>

The Map Viewer gives users the ability to configure many aspects of your map such as labeling, pop-ups, transparency, access spatial analysis tools, run filters on your data, etc. (see diagram below).



AGOL Spatial Analysis Tools include 25 tools in this viewer. ***These resources are available for the cost of maintenance for one license of ArcGIS for Desktop.***

AGOL CAN SAVE FONAFIFO A SUBSTANTIAL AMOUNT OF DEVELOPMENT TIME AND EXPENSE, PROVIDE A SUPPORTED SOLUTION THAT CAN BE MORE EASILY DEVELOPED & MAINTAINED PLUS THE ABILITY TO START USING THESE TOOLS QUICKLY.

5.3 Open Source GIS software

Recommendation: *I recommend the continued use of the Open GeoSuite* – GeoServer, QGIS and related software components in the current configuration. With SIPSA, FONAFIFO has developed a series of modules that has achieved an exceptional custom coded solution. I have trouble finding anything to criticize or suggest improvements to, in all the software modules, existing workflows and related administrative processes.

The SIPSA series of modules reduce redundant activities, establish effective methods and protocols for ensuring data integrity and ensures the automated syncing of temporal data by cross checking of related tables or databases to manage and track the PSA program processes.

5.3.1 Open Source handheld mobile device software

Recommendation: *I recommend the use of either Open Data Kit's ODK Collect or IntraMaps Roam to develop forms for use on your mobile handheld devices.* ODK is more robust (including barcode prompts) but a simpler solution like Roam is most likely adequate to support FONAFIFO in-the-field form data entry and export.

Open Data Kit (ODK) is an open-source suite of tools that helps organizations author, field, and manage mobile data collection solutions. Currently, ODK Collect uses the Android platform, supports a wide variety of prompts (text, number, location, multimedia, barcodes), and works well without network connectivity.

IntraMaps Roam is a simple data collection application built using QGIS. Roam is built as a standalone Python application. QGIS is not required to be installed on the user's hardware.

5.4 Mobile hardware solutions

5.4.1 Smart phones

Recommendation: Phones for support of data collection applications is not recommended for use in FONAFIFO, *at this time*. However, cell phones are becoming increasingly more popular for field data collection in other countries and technologies are being developed to work around the limitations. However, the inability of a cell phone to get a signal in remote areas or capture GPS points accurately enough for FONOFIFO's requirements when collecting under a tree canopy limits cell phone utilization at this time. *I would recommend researching new technologies annually in this space to leverage this space when your requirements can be met*.

Handheld mobile GPS devices provide the GPS point accuracies, provide more ruggedized options and offer larger screens.

5.4.2 Handheld mobile GPS devices

The recently purchased Cedar Tree Technologies CT4 GPS handheld mobile devices use the Android operating system and seem to meet your accuracy and durability needs. However, continued testing is planned and necessary, see below. Using the Android operating system is preferable due to the well documented lack of Apple iOS in the GIS space.

CT4

Recommendation: *Continue testing until your failure rate metric is exceeded.* New GPS units may be needed as there were some locations where the Cedar could not collect an accurate point but the older Garmin 60CSX units could. Hopefully these initial operational specifications will remain good and the Cedar device's inability to collect GPS points is limited.

A performance metric should be established regarding the GPS points that are only able to be collected using the Garmin. In other words, a decision point regarding the percentage of GPS points that cannot be collected per farm (perhaps over fifteen percent) that will trigger the decision to abandon the current Cedar Tree CT4 device.

If the Cedar Tree CT4 performs acceptably, then the next step would be to develop a replacement schedule to replace the Garmin users with this device. This will facilitate the standard use of field forms for data collection into a standardized database contained on the Cedar Tree CT4.

The adoption of Android OS for the handhelds is a solid decision. It will support the leading Open Source GIS solutions such as QGIS as well as Esri solutions. The Android ecosystem of apps is extensive and the resources of Google will continue to drive innovative marketplace solutions.

5.4.3 Tablets

Recommendations: There is no need for bulky, more expensive ruggedized tablets in my opinion because FONAFIFO's data collection needs are limited. These include the relatively small number of attributes needing population, and the on-going data maintenance needs are limited enough to allow for the use of a more convenient, smaller screen like the Cedar Tree CT4. Also, there is less to carry, smaller backup batteries and less total cost of ownership.

5.5 Servers

Recommendations: The Dell PowerEdge Servers in use are all very reliable models with adequate dual processors. The RAM seems low at 16GB on the PowerEdge 910 and only 8GB on the PowerEdge 2970.

If you are experiencing sluggishness or locking up on either of these server's apps, I would recommend increasing the RAM to 32GB on the 910 and 16GB on the 2970.

FONAFIFO has their data center IT infrastructure adequately resourced, including the server configuration. My somewhat limited interviews into these IT operations drew no red flags, such as connectivity issues or slowly responding applications. The Internet connectivity instability we experienced is being mitigated with installation of additional hardware. Much of the connectivity or bandwidth issues are external to FONAFIFO's network and originate in the local Internet Service Provider's infrastructure.

5.6 UAS Solutions

Recommendations: *I fully support and strongly recommend the testing for implementation of UAS technology*. The potential for ROI is great because so much time is spent traversing difficult terrain. Ruggedized units are a must. *A top IP rating of IP67 or more is recommended.*

Data management - Hard drives are needed for transfer of imagery data to the central office. The very large size of both still and motion photo imagery prohibits the use of the Internet for transferring these data and eliminates the use of Cloud based storage and processing services. This is due to the roughly 0.7 MB per second upload rate we tested for and observed at the Sarapiquí FONAFIFO Field Office.

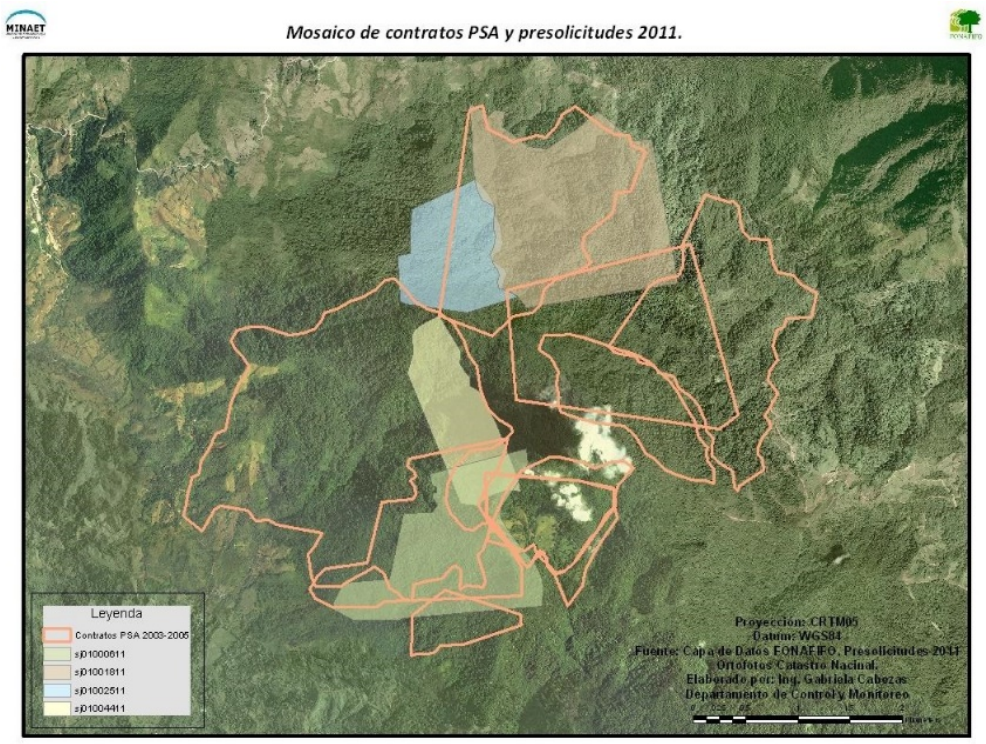
5.7 Shifted PSA parcel polygons

There is a second GISCorps pilot project planned to assess the feasibility of volunteers performing these conflation tasks for all years of data. The PSA Procedures Manual specifies a horizontal absolute accuracy standard of within 500 meters. Many of the PSA parcel polygons that were created before 2016 are in some degree of absolute spatial inaccuracy. This is due to the Forest Engineers use of different methods and techniques to create the GeoPSA shapefiles over many years, without a strict protocol of procedure. So there are occasions when parcels overlap and same-owner, identical parcels are shifted from year to year.

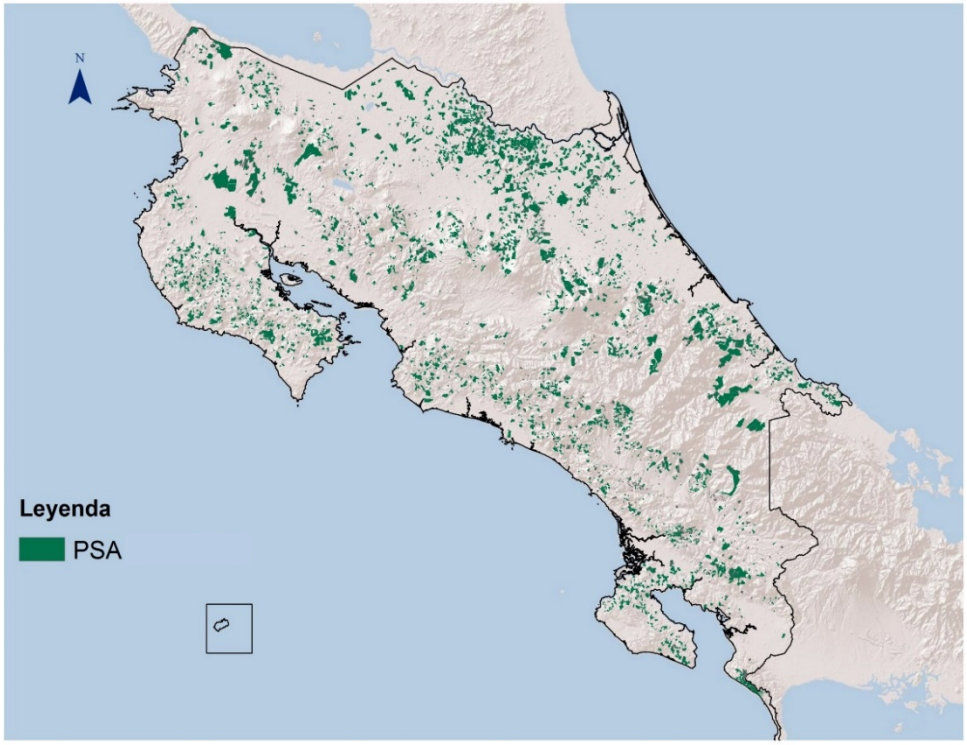
Conflation tools help to reconcile and move spatial data from differing sources. The ArcGIS Desktop Advanced version 10.2.2 contains the Editing Toolbox which holds the Conflation Toolset. Unfortunately, FONAFIFO has 10.2.1. The Conflation Toolset provides the functionality FONAFIFO needs to resolve the spatial discrepancies of the "shifted" PSA parcel polygons. This tool will allow for the movement of the displaced graphics so they are coincident with the correct "accurate" most recent parcel polygons. The original, official parcels are not being affected. This project would work with a copy of these data that would become a "PSA Parcel Analytics" layer that will allow for multi-year spatial analysis of PSA parcel polygons as they would be coincident spatially.

<u>Conflation Toolset Tools</u>

- Align Features
- Calculate Transformation Errors
- Edgematch Features
- Generate Edgematch Links
- Generate Rubbersheet Links
- Rubbersheet Features
- Transfer Attributes
- Transform Features



Overlapping PSA parcels



PSA parcels

5.8 General observations

GIS Data Backup - Microsoft OneDrive is used to sync/backup data with unlimited storage capacity. However, every three days a physical hard drive is also used to backup all data. ***It is strongly recommended to take this drive to a secure off-site location, if it is not already.***

There is a need for a standardized land cover classification system. This issue is very common in my experience with different agencies using different classification names for the same or similar land cover. There is a committee of all national Stakeholder Agencies working to construct a national system for monitoring land cover, entitled SIMOCUTE. This is related to the REDD+ program which is a United Nations sponsored program focused on reducing emissions from deforestation and forest degradation in developing countries. This process should result in a standardized land cover classification system for Costa Rica.

There is a need for more resolute imagery. Current satellite-based panchromatic and color imagery have resolutions ranging from 30cm (Digital Globe) to 1.5 m (SPOT 6 & 7). Landsat 8 includes six 30 m resolution multispectral bands, a 60 m thermal infrared band plus a 15 m resolution panchromatic band. While these all provide useful data, higher resolution imagery will provide for more accurate assessments of ground conditions. More resolute satellite imagery will become available in the future as the many countries and private companies continue to evolve in this space.

There is a need for more current imagery. Ideally, an annual acquisition of higher resolution imagery will provide for better change detection and analysis. Satellite imagery costs should decrease as time goes on and more players launch satellites. The advent of small satellites or smallsats will provide near constant coverage as well.

I recommend FOFAFIFO develop the capacity to store and access certified PSA contracts on the web. These could be attached to the PSA parcels as an attribute link and provide access through AGOL although integrating into SIPSA would also need to be done to provide users access through this main interface.

I was astonished at the higher cost for Esri products in Costa Rica. I will be strongly advocating to Jack Dangermond to introduce additional distributors, and thus free market competition, to hopefully reduce prices and gain and retain customers.

SECTION 6
NEXT STEPS

6.1 Introduction

The suggestions below are respectfully offered and relate specifically to this report's recommendations that I sincerely hope FONAFIFO acts on.

6.2. Task Series

6.2.1 ArcGIS Online (AGOL) Implementation

1. Re-instate ArcGIS for Desktop Basic maintenance.
2. Establish and configure the associated AGOL account.
3. Develop a plan for managing this resource
   - establish a group(s)
   - assign the account roles: Administrator, Publisher, User or Viewer

6.2.2 Implement ArcGIS Online Map Viewer

Determine other websites to be created; for example, a Regent GIS website with frequently needed documents and pictures attached to the PSA parcels and a comments form for in-the-field details.

Begin by developing a database design, or schema, to *enhance the content of the attribute tables and institute hyper-links* to scanned authoritative source records through population of SIPSA or other currently hard copy records. Make decisions regarding exactly what data, which widgets, configurations for attributes, pop-ups, labeling, scale thresholds, transparency, etc.

These scanned documents and GIS data can be easily served up on the web to stakeholders, governmental offices, NGOs and the public. This will reduce phone calls and foot traffic and provide universal, transparent access to these critical data 24/7. Sensitive data are only available to credentialed users.

Then create your web map. In a nutshell, begin by developing a pilot using Web AppBuilder for ArcGIS.

1. Create a new app
2. Pick a style
3. Select a map
4. Add widgets
5. Configure attributes
6. Publish!

After using the out of the box templates and the Web AppBuilder for ArcGIS, then develop more advanced custom solutions through the Developer Edition of Web Appbuilder.

6.2.3 Open Source GIS software

Continue the development focus using Open GeoSuite – GeoServer, QGIS and related software components, further enhancing functionality of SIPSA. Move forward on plans to scan documents that are currently not being captured for inclusion in SIPSA through new modules or modifications to existing ones. An entire report could be dedicated to this, SIPSA is quite complex.

6.2.4 Open Source handheld mobile device software

Implement the development of forms for use on mobile handheld devices. Determine which Open Source form creation software to use (Open Data Kit's ODK Collect or IntraMaps Roam). Then develop a database schema for data collection in the field for uploading into SIPSA and AGOL.

6.2.5 Handheld Mobile GIS devices

Finalize Cedar CT7 testing. The performance metric (10% failure rate?) testing should be completed regarding the GPS points that are only able to be collected using the Garmin. If acceptable, schedule and budget for additional CT7 units. I truly hope these work out because my research did not turn up any similarly priced models with an IP68 water and dust intrusion rating. See full report for IP68 information.

6.2.6 Servers

Install additional RAM as recommended if response time or performance is unacceptable.

6.2.7 UAS Solutions

Investigate UAS experience from local UAS users to ascertain viability in the harsh environmental conditions of Costa Rica. If viable, acquire local professional assistance to specify the entry-level model (for piloting practice) and the production model. Acquire the UAS units, conduct training, and define a pilot program to develop piloting skills, protocols for collection; plus all the other aforementioned recommendations on UAS operation. Then develop criteria for selection of PSA parcel eligibility for UAS support. Criteria should include terrain and ease of access. The more difficult properties are more suitable. Documentation of storm damage, theft or FONAFIFO capital infrastructure inspections pose special circumstances that are good use cases; *these ad-hoc situations are a good starting point for targeting of UAS resources.*

6.2.8 Shifted PSA parcel polygons

I recommend moving forward with the below GISCorps project to allow GISCorps to save FOFAFIFO many months of work for a useful but labor intensive exercise.

There is a second GISCorps pilot project planned to assess the feasibility of volunteers performing these conflation tasks for all years of data. The PSA Procedures Manual specifies a horizontal absolute accuracy standard of within 500 meters. Many of the PSA parcel polygons that were created before 2016 are in some degree of absolute spatial inaccuracy. This is due to the Forest Engineers use of different methods and techniques to create the GeoPSA shapefiles over many years, without a strict protocol of procedure. So there are occasions when parcels overlap and same-owner, identical parcels are shifted from year to year.

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Conflation Toolset Tools

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- Calculate Transformation Errors
- Edgematch Features
- Generate Edgematch Links
- Generate Rubbersheet Links
- Rubbersheet Features
- Transfer Attributes
- Transform Features

6.2.9 Five year strategic plan

This would be another exceptional project that Mr. Kotapish would be more than happy to work on. He stands at the ready to develop a detailed report in conjunction with another site visit to FONAFIFIO to lead a Strategic Planning Workshop! Preferably with Mr. Hamilton's assistance, which has been invaluable throughout this project.

Appendix "A"

Prioritized GIS Layers

Mr. Gilmar Navarrete, Manager of the Department of Control and Monitoring created these rankings as part of the workshop preparations.

1 = Critical importance 2 = Important

[1] GPS PROPERTY PHOTO ID CONTROL POINTS - Key base map layer

[1] IMAGERY: SATELLITE - Key base map layer

[1] IMAGERY: HIGH-RES ORTHOPHOTO - Key base map layer

[1] IMAGERY: HIGH-RES OBLIQUE ANGLED - Bing Maps Bird's Eye View

[1] IMAGERY: UAS, UAV - Site specific surveys

[1] LANDSAT - Remote Sensing Data

[1] LAND COVER - Deciduous forest, broadleaf forest, farmland, etc.

[1] LAND USE - Farming, residential, commercial, etc.

[1] LIDAR - Tree canopy visualization - change detection for logging

[1] MULTI-SPECTRAL SENSOR DATA - Tree canopy visualization - change detection for logging

[1] PROTECTED LAND: OTHER - Conservation easements, parks, etc. Corridor, bio-region analysis

[1] PROXIMITY ANALYSIS LAYERS - Corridor and priority conservation analysis

[2] BIODIVERSITY HOTSPOTS, REGIONS, CLASSIFICATIONS - Triage applications

[2] BUILDING FOOTPRINTS - Change detection for program parcels

[2] EASEMENTS: POWER, ACCESS - Indicators for disturbances, neighbor boundary disputes

[2] ELEVATION (TOPOGRAPHY) - 1 meter contours, at-risk flood areas, landslide risk mapping.

[2] HAZARDOUS MATERIALS SITES (Large) - Good to know locations after natural disasters.

[2] HYDROGRAPHY (Rivers, streams, lakes) - Key base map layer.

[2] HYDROGRAPHY WATER QUALITY DATA - External metrics related to reduction of ecosystem stresses.

[2] PARCEL DIMENSIONS - Assist in tracking boundary disputes/ discrepancies.

[2] PARCELS: PROGRAM PARTICIPANTS - Key base map layer.

[2] PARCELS: HISTORICAL CHANGES - Should be a key base map layer.

[2] WILDLIFE CORRIDORS - Base map layer.

Appendix “B” – PC Hardware Specifications

Dell XPS 8700 - Core i7 4770 3.4 GHz - 16 GB

Specifications

Part Number: X8700-3129BLK

GENERAL /

Product Form Factor	Mini tower
Packaged Quantity	1
Manufacturer	Dell, Inc.

PROCESSOR / CHIPSET /

CPU	Intel Core i7 (4th Gen) 4770 / 3.4 GHz
Max Turbo Speed	3.9 GHz
Number of Cores	Quad-Core
Chipset Type	Intel Z87 Express
Processor Main Features	Intel Turbo Boost Technology 2, Intel Virtualization Technology
Processor Socket	LGA1150 Socket

CACHE MEMORY /

Installed Size	L3 cache - 8 MB
Cache Per Processor	8 MB
Type	L3 cache
Per Processor Size	8 MB
Installed Size	8 MB

RAM /

Installed Size	16 GB / 32 GB (max)
Technology	DDR3 SDRAM - non-ECC
Memory Speed	1600 MHz

Memory Specification Compliance	PC3-12800
Features	unbuffered
Technology	DDR3 SDRAM
Installed Size	16 GB
Data Integrity Check	non-ECC
Rated Memory Speed	1600 MHz

STORAGE /

Interface Type	Serial ATA-600

MEMORY /

Max Supported Size	32 GB
Form Factor	DIMM 240-pin
Slots Qty	4

DISPLAY /

Type	none.

HARD DRIVE /

Interface Type	SATA 6Gb/s
Spindle Speed	7200 rpm
Type	HDD
Interface Class	Serial ATA
Installed Qty	1
Capacity	2 TB

STORAGE CONTROLLER /

Interface Type	Serial ATA-600
Type	Serial ATA
Installed Qty	1

COMMUNICATIONS /

Wireless Protocol	802.11b/g/n, Bluetooth 4.0

HARD DRIVE (3RD) /

Type	none

OPTICAL STORAGE /

Drive Type	DVD-Writer
Type	DVD±RW

PROCESSOR /

Installed Qty	1
Max Supported Qty	1
Type	Core i7
Processor Number	i7-4770
Generation	4

Manufacturer	Intel
Clock Speed	3.4 GHz

CARD READER /

Type	19 in 1 card reader
Supported Flash Memory Cards	CompactFlash Card type I, CompactFlash Card type II, MultiMediaCardplus, RS-MMC, SD Memory Card, SDHC Memory Card, SmartMedia Card, miniSD, xD-Picture Card, Memory Stick, Memory Stick Duo, Memory Stick PRO, Memory Stick PRO Duo, Memory Stick PRO-HG Duo, Microdrive, MultiMediaCard, MultiMediaCardmobile

STORAGE REMOVABLE /

Type	none

HEADER /

Brand	Dell
Product Line	Dell XPS
Model	8700
Packaged Quantity	1
Compatibility	PC

MONITOR /

Monitor Type	None.

NETWORKING /

Data Link Protocol	Bluetooth 4.0, Ethernet, Fast Ethernet, Gigabit Ethernet, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n
Form Factor	integrated
Compliant Standards	Bluetooth 4.0, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n
Wireless LAN Supported	Yes
Wireless NIC	Dell Wireless 1703

SYSTEM /

Type	personal computer
Hard Drive Capacity	2 TB

GRAPHICS CONTROLLER /

Form Factor	plug-in card
Interface Type	PCI Express x16
Graphics Processor	NVIDIA GeForce GTX 645
Video Memory	1 GB GDDR5 SDRAM
Video Interfaces	DVI, DisplayPort, HDMI
HDCP compatible	yes

CHASSIS /

Form Factor	mini tower
Manufacturer Form Factor	mini tower

DIMENSIONS & WEIGHT /

Width	7.3 in
Depth	17.5 in
Height	16 in

MAINBOARD /

Processor Socket	LGA1150 Socket
Chipset Type	Intel Z87 Express

AUDIO OUTPUT /

Form Factor	integrated
Sound Output Mode	7.1 channel surround
Compliant Standards	High Definition Audio

PRINTER /

Type	none

ENVIRONMENTAL STANDARDS /

ENERGY STAR Qualified	Yes

PHYSICAL CHARACTERISTICS /

Form Factor	mini tower
Weight	30.42 lbs

POWER /

Type	power supply

OPERATING SYSTEM / SOFTWARE /

OS Provided: Type	Windows 8.1 64-bit Edition
OS Provided	Windows 8.1 64-bit Edition

VIDEO OUTPUT /

Interface Type	PCI Express x16
Graphics Processor	NVIDIA GeForce GTX 645
Graphics Processor Series	NVIDIA Geforce GTX
Video Interfaces	DVI, DisplayPort, HDMI
HDCP compatible	yes

VIDEO MEMORY /

Technology	GDDR5 SDRAM
Installed Size	1 GB

GENERAL /

Manufacturer	Dell, Inc.