GIS Web and Mobile Development with Interfaces in QGIS for Variable Rate Fertilization

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Abstract.

In this paper we described the implementation of a GIS for Precision Agriculture for sugarcane crop in Colombia. An spatial equation for Variable Rate Fertilization Model was defined using as inputs estimated harvest data, nutrients in soil and fertilizer efficiently. Models for soil and harvest variability are also defined. A personalized plugin for precision agriculture was developed into QGIS software, there is the option of upload maps to a Web and mobile app using the Desktop software and data import and export is also implemented to used with tractor and soil data. Processing time and costs was reduced in comparison with the initial project state.

Keywords.
Precision Agriculture, Geographic Information Systems, Variable Rate Fertilization, Sugarcane Crop, QGIS.

Introduction

The precision agriculture processes had been implemented in the sugarcane crop into Riopaila Castilla company in Colombia since 2007 using separated files and software increasing processing time and costs. In this case of study we want to understand and improve the current precision agriculture workflow that had been used and improve it using Geographic Information System (GIS) which could be useful to produce the prescription maps based on a variable rate fertilization (VRF) model (GRDC, 2010) and associated maps implemented in QGIS with other capabilities as Web and Mobile publishing.

Precision Agriculture Division in Riopaila Castilla is also looking for a system that can reduce the production costs associated to processing, reduce the time spent collecting and ordering the information, can add or edit other cartographic data and easily share each result to internal and external customers.

According with the initial workflow and the requirements, the objectives in this case of study are listed below:
- Create a geographic database for precision agriculture including the normalization process of existing data (Beeri et al, 1978).
- Define a spatial VRF model based on the sugarcane nutritional requirements, soil nutrients and fertilizer efficiency.
- Define spatial models for spatial soil and harvest variability.
- Develop a desktop GIS plugin in QGIS to produce the maps.
- Develop a Web and Mobile GIS tool with offline capabilities to navigate in the maps.
- Develop interfaces to easily import and export data to different tractor onboard computers and soil data.

Methodology

The first step is understanding the current workflow for precision agriculture in Riopaila Castilla and the improve it using a complete GIS solution.

Initial Precision Farming Workflow in Riopaila Castilla company

We had three cartographic farming products that are the end of this workflow:
1. Soil Data Collection and Analysis.
2. Variable Rate Fertilization map.
3. Harvest Data Variability.
4. Spatial Variability of Soil.

Soil Data Collection and Analysis

The initial soil data structure was a spreadsheet file used and populated by different people without data quality protocols. The soil data are the results of the laboratory tests property of Riopaila Castilla related to basic physical and chemical analytics from some predefined test points when every four years are recollected including the GPS coordinates when the soil samples were collected. In the same table there was historic information since 2007, so it was a long process to extract the specific data to be used in the other processes because only is used the most recent information in each crop management units called "suertes".

In the initial condition, the laboratory data was independent of geographic data validation and was

not possible to fix commonly problems like duplicate values and soil sample taken in a wrong position, so there was a propagation of errors up to the final products.

Variable Rate Fertilization Map

After a data extraction process from the historic soil spreadsheet file for an specific crop management unit then this data was uploaded to a online service software called SST Summit to process it using an equation based on a linear regression.

In this step of the workflow was difficult to group data and the process was only one by one, so it was not a efficient way to do that and the other problem was that in the equation was not spatial according with soil offer, crop nutrients demands and crop variety.

Harvest Data Variability

Riopaila Castilla has two kinds of Harvest techniques according with manual and mechanical machines and both equipments have a measurement system called ENVICAÑA which create a harvest log file as text plain format with gps coordinates that was used to be processed in the software QGIS, when it was charged to create the maps, but there was not control about the relationship between collected data and crop management units, data was stored as shapefile in local computers to produce maps to print and pdf format.

Harvest maps are also produced using SST Summit but requires another step to organize the information as a compatible input in that system that needs to separate spatial data and delete atypical measures, all it was using operational tools into QGIS software and Spreadsheets.

Spatial Variability of Soil

Collected soil data had an associated geographic coordinate which were used to produce a map that describe a continuous surface showing a soil analysis variable like potassium (K), sodium (Na), phosphorus (P), PH and organic material, the result is called Spatial Variability of Soil.

In this case was used soil data from a entire farm that had a prerequisite which requires a previous process of the historical Spreadsheet, the spatial field to be mapped is filtered using alphanumeric filters with the farm code inside the data that is associated to spatial data.

The map could be produced in the SST Summit or QGIS software using ordered soil data with the respective GPS coordinate for each point.

Improved Workflow

Taking the initial state as a reference, we are proposing a improved workflow that take the advantages of GIS applied to agriculture (Pierce and Clay, 2007).

Spatial Database

As is shown in the Fig 1, there are three initial datasets: Soil Data Spreadsheet, Farm Polygon and Crop Management Unit Polygon, we started the process making an extraction of Sample Point features and the making a spatial process to determine the real Point codification validated with Farms and Crop Management Units and in the other part of the process we use database normalization procedures to create a Entity-Relationship Model with it validators an triggers to automatic make laboratory operations like calculate soil texture or phosphorus using instruments data as inputs. Finally we linked both data and validate it before upload to Database.
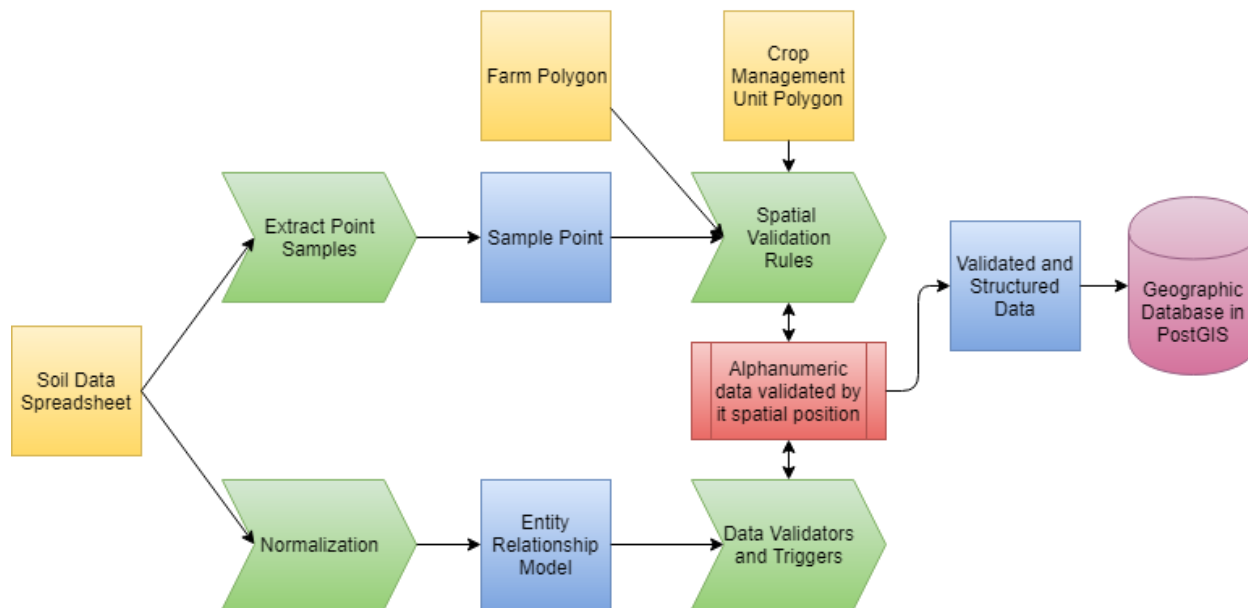
Fig 1. Spatial Database creation process

Variable Rate Fertilization VRF model

Variable rate fertilization is a process which involves the use and interpretation of soil data, its variability and harvest data variability (Giles, 2010). As the basics along all this process, in the Figure 2 is shown the Integrated Nutrition Plan that is described by Sherchan and Kakri (2006) that will be used into the VRF model .
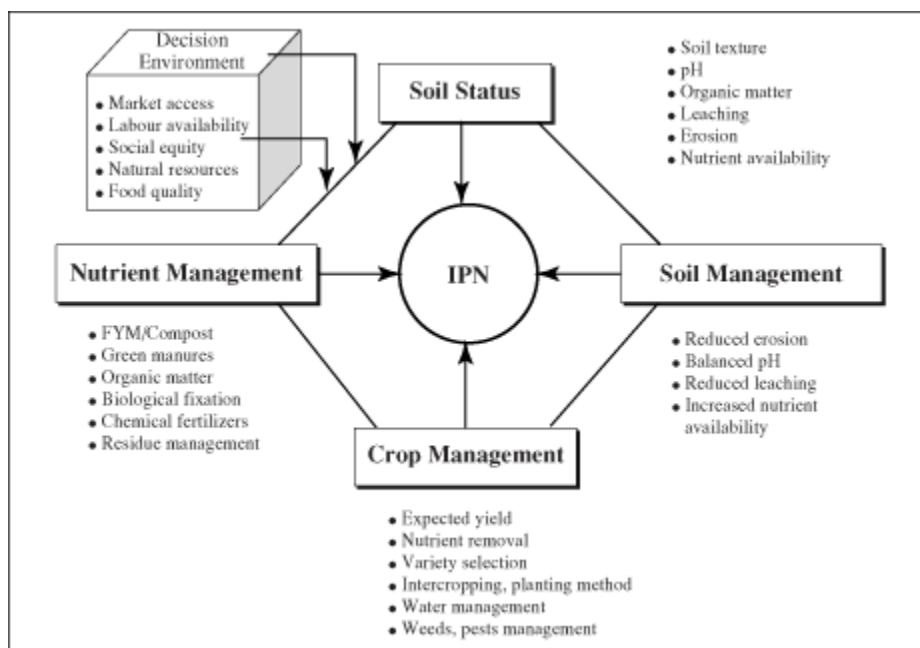

Fig 2. Integrated Plant Nutrition Sherchan and Karki (2006)

In order to obtain an appropriate balance between the crop and the soil, the engineer Castro (1998) designed an equation that is used to calculate the needs of nutrients to apply:

$$N = \frac{Nr - S}{Fe} \times 100$$

Where,

N as the nutrients needs to apply

Nr as Nutritional Requirement of the crop in order to satisfy the potential production that is estimated using the historic harvest data, now stored in the database.

S as Concentration of nutrients in the soil expressed in kilograms per hectare.

Fe as Fertilizer efficiency that is estimated as a soil texture function.

The Fertilizer efficiency (Gómez, 2006) is calculated from the soil texture and the values are shown in the Table 1.

Element	Soil Classes				
	Sandy	Francs	Clayey	Allophanics	Organic
N	0.55-1.0	0.77-1.0	0.77-1.0	0.67-1.0	0.67-1.0
P	0.29-0.30	0.25-0.33	0.25-0.33	0.10-0.20	0.20-0.33
K	0.50-0.56	0.59-0.67	0.56-0.67	0.56-0.67	0.67-0.71
Ca	0.10-0.20	0.13-0.20	0.10-0.20	0.10-0.20	0.13-0.20
Mg	0.20-0.33	0.25-0.50	0.20-0.33	0.20-0.33	0.25-0.50
S	0.67-0.71	0.67-0.71	0.67-0.71	0.45-0.55	0.50-0.55
B	0.10-0.13	0.13-0.20	0.10-0.13	0.13-0.20	0.13-0.20
Cu	0.10-0.20	0.10-0.20	0.10-0.20	0.08-0.10	0.07-0.08
Fe	0.05-0.08	0.05-0.08	0.05-0.08	0.05-0.08	0.05-0.08
Mn	0.04-0.07	0.04-0.07	0.04-0.07	0.04-0.07	0.04-0.07
Mo	0.02-0.04	0.02-0.04	0.02-0.04	0.02-0.04	0.02-0.04
Zn	0.10-0.20	0.10-0.20	0.10-0.20	0.07-0.10	0.07-0.10

Table 1. Fertilizer Efficiency (Gómez, 2006)

Each of this inputs is expressed as spatial bands that will be implemented as a personalized algorithm using the Processing, SAGA GIS, Grass GIS and natives libraries into QGIS software development environment.

Spatial Variability of Soil and Harvest Data Variability.

The sample soil data and the harvest points stored in the database is used as input to create spatial variability of soil using GIS as kriging interpolation (Jahanshiri et al (2015), Denton et al (2017) and Mohamed et al (2011) combined with other GIS algorithms to generate maps wich will be stored in the database for sharing and analysis purposes.

Software Development

The project envisioned software for desktop data collection and processing, as well as software for web and mobile publication and dissemination of results. Software engineering process was iterative and incremental, following agile development principles.

On the one hand, the process was iterative in order to handle change, after all, the goal was to develop tailor-made software and the workflow was under review and improvement. An initial set of requirements was identified with direct interaction with people involved in the workflow. An interdisciplinary group of engineers collaborated in feature and user interface design.

On the other hand, the process was incremental because small groups of features were added

each time, making it possible to frequently release versions that could be used and involved early in production. A QGIS plugin repository was implemented to make it easier for users to access and install new software versions.

The development was driven by user feedback and satisfaction. Usability of the user interface was fundamental. As soon as RIOPAILA-CASTILLA engineers observed ways to enhance efficiency or to customize the software to better fit their language or workflow, those adjustments were made, tested and incorporated into a new release.

Export / Import Data.

Soil data is collected and processed in the laboratory and then is charged in real time directly to the database using some web interfaces developed for us.

Recommendation files are generated and then in the export module is possible to obtain a shapefile which can be used in the Fertilizers tractors.

Harvest Data is loaded and processed from the generated files that are generated with the collector Software Envicaña.

Results and Discussion

Spatial Model for Variable Rate Fertilization

The spatial model was created using GIS techniques and is materialized as a Python Script that use as inputs sample points, management units, harvest variability and fertilizer efficiency.

Spatial Models of Variability of Soil and Harvest Variability

Models of Soil and Harvest Variability were defined into the improved workflow, the algorithms takes as inputs the data directly from the database.

SIGAP Software

The software developed is called SIGAP (Geographic Information System in Spanish for Precision Agriculture).

SIGAP Desktop

SIGAP Desktop is a QGIS v2,14.x plugin written in Python that allows users to collect, analyze, process and store (upload) agriculture data. In the Figure 3 is shown a preview of the plugin with a result obtained with it.
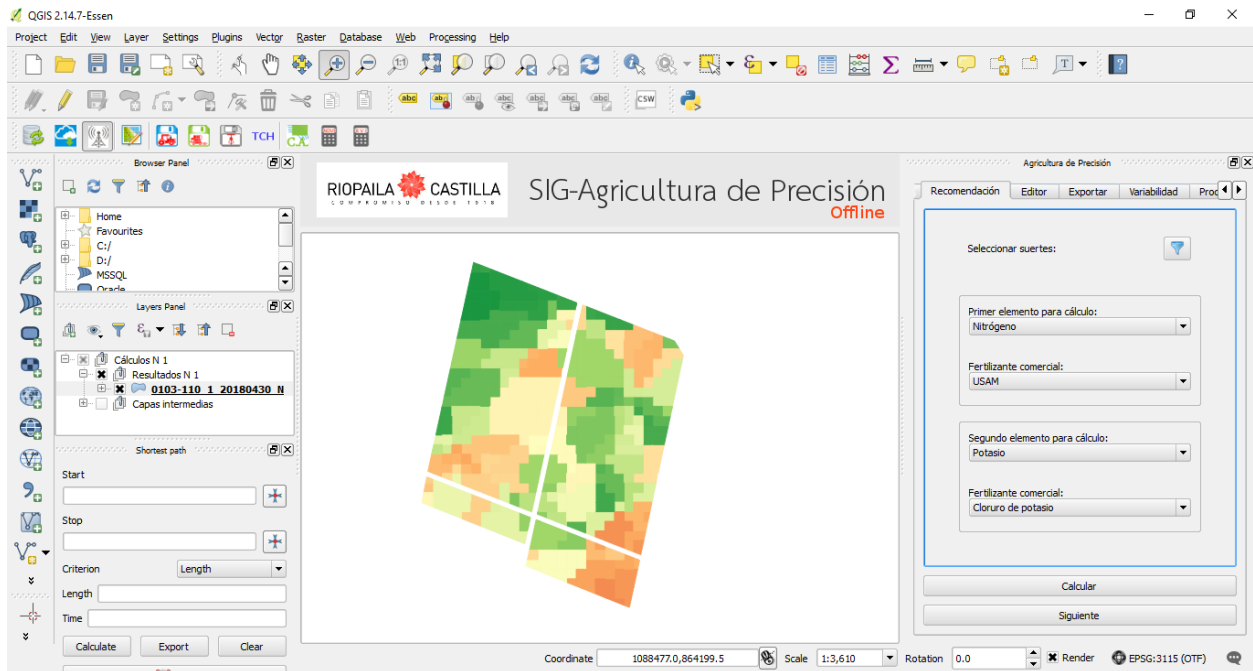
Fig 3. SIGAP Desktop

Due to the lack of a reliable Internet connection in the region, SIGAP desktop has two modes of operation: Online and Offline. Offline work requires downloading a subset of the remote database to an SpatiaLite (SQLite with spatial modules) database and then heavy data processing takes place. When ready, online mode can be enabled to upload processed data to the remote database.

SIGAP Desktop reflects a whole workflow that starts uploading productivity data, configuring fertilizer products, generating recommendations for variable rate fertilization, adjusting such recommendations according to specific land owners requirements, Recommendations can be generated for one or two soil elements, in the format that tractors can understand and operate with.

Besides recommendations for variable rate fertilization, SIGAP Desktop also generates Productivity and Variability maps.

SIGAP Web and SIGAP Mobile

Both SIGAP Web and SIGAP Mobile are built on top of the Django framework and on the Leaflet web mapping library. The aim if these applications is to make it easier to provide certain people within the organization with recommendation, productivity and variability maps directly in their web browsers or smartphones, without requiring them to install specialized software like QGIS. These maps are created by professionals using SIGAP Desktop.

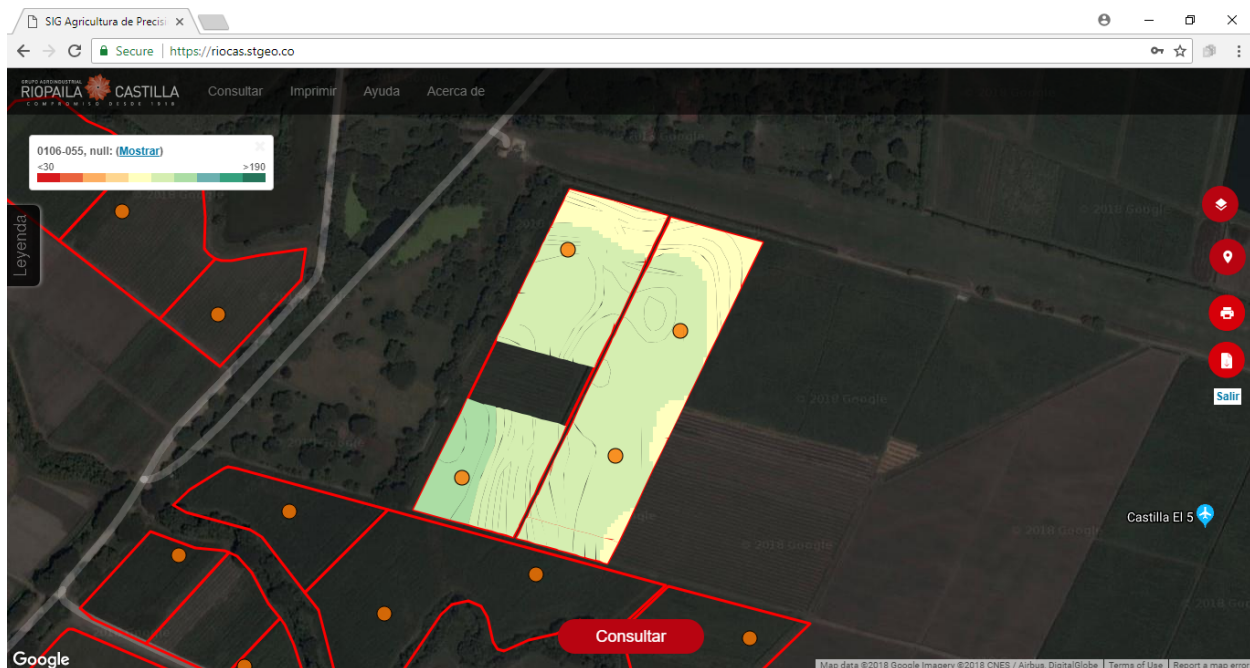SIGAP web and mobile preview is shown in the Figure 4.

Fig 4. SIGAP Web

SIGAP Web and Mobile users are seldom at the office and the application should address such scenario. By using service workers under the hood, the application is able to fully work offline. A local copy of allowed data can be downloaded before going outdoors, and based on such data, the application can respond to user queries and render maps as if it were online, giving users a seamless experience.

Conclusions

- Creating a geographic database for precision agriculture reduces the time ordering data and contribute for a better data quality and disponibility.
- Define a VRF model using spatial analysis algorithms is useful and can include another source of information to improve the results, so there is an important opportunity to continue researching about it and how to get results more accurate with other variables.
- QGIS software provides excellent developer tools and algorithms that allows to create a complete agriculture personalized solution.
- Web and Mobile GIS tools helps to the final users to navigate and explore the crop data in real time and in the colombian case is important to have the offline capability because there is not a good cell phone quality in the country areas..
- Exporting VRF data is a critical task but sometimes the internal tractor files are not easy to create, that is why is necessary to define an standar in all agriculture software.

Acknowledgements

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