MapOurForest – Designing a Volunteered Geographic Information Systems for Reforestation Associations

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SUMMARY

Portugal is continuously affected by highly destructive wave of wildfires, endangering ecological systems, habitats and cultures. At the same time, it lacks a robust and sustainable long-term project to address this issue. Small volunteer Non-Governmental Organizations (NGOs) relentlessly work on the ground mobilising local people to re-forest and provide solutions create more resilient green areas, that promote biodiversity, wildfire natural defences. MapOurForest is a prototype volunteer project, designed by the Young Surveyors Network-Portugal group, aiming to provide a fully oriented and user-friendly solution to help decision makers and works managers on small volunteer NGOs. The inclusion of a dedicated Geographic Information System (GIS) into their workflows shall greatly improve and optimise their efforts, once are a very powerful tool for decision making and strategizing. The integration of GIS in the work routine of reforestation associations allows them to carry out several integration routines, inventory, analysis, planning and management of your resources.

This project will allow, through the sharing of experiences between the NGO and mentors, unique skills to its members, allowing them to achieve a singular efficiency in this area. Having our volunteers on a constant evolution allows the further steps to be taken by themselves in full autonomy. On a later stage this project will also be scaled and made available for a broader market.

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1. INTRODUCTION

In Portugal, forests represent the largest usage and occupation's class of the national territory, taking 3.2 million hectares [ICNF, 2019], in a country where 92% of its territory is of agrarian and forest nature, while only 5% is artificialised. (Figure 1) [INE, I.P./DGT, 2020].

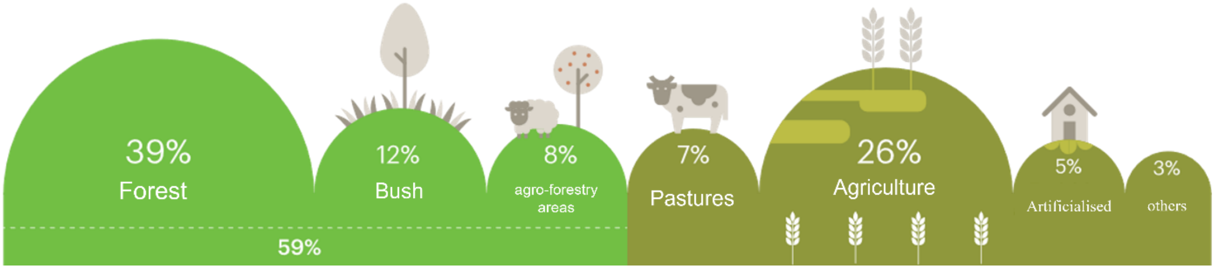


Figure 1. Distribution of land use classes according to the INE, I.P./DGT report, Land Use and Occupancy Statistics 2018. Source: Infografia Público [2020].

Only 3% of the total forest area (about 94000 ha) is in the public domain, being one of the smallest shares worldwide [Resolução do Conselho de Ministros n.º 6-B/2015].
It is relevant to understand the overall contribution of each soil usage class at a national scale. At the NUTS II level, it is very noticeable how the Centro region provides the largest forest proportion (41%), while Lisbon metropolitan area comes with the smallest at only 2% (Figure 2).
The Portuguese Forest is threatened by several factors, amongst them the urban migration, climate change, lack of land registry records and wildfires. The project aims to counter act this last factor, the wildfires, since "Portugal is the "European champion" of wildfires, and forth worldwide, having lost most of its forest mass since the beginning of the 21st century" [Hernández et al., 2020].
In the last 30 years, our country faced the biggest number of incidents, and had the most hectares burned. On average, it has around 17000 happenings, with a total of around 120000 burned hectares per year [ibid].
Despite of being uncommon, 2017 beat the record of the last 10 years, with 4 times more wildfires than normal. In total, more than 440000 hectares of forest and settlements were burnt [ICNF, 2017].
The wildfire of Pedrógão Grande, on the 17th of June 2017, along with the 523 wildfires of the following 15th of October (widely considered the "worst day ever" wildfires-wise), caused a total of 110 human deaths, 330 injured and over 1300 homes destroyed [Centro de Estudos sobre Incêndios Florestais, 2019]. These events opened the path for an environmental crisis without precedents.
In the aftermath of these happenings, the populations, with a pro-active mentality, gathered and started a long process of sustainable reforesting through voluntary initiatives. In order to support these works, several people's associations were created all around the territory, providing a

structure, organising the efforts and ensuring a long-term commitment. Currently most of them are still active.

If, in one hand, good will, entrepreneurship and solidarity are a common factor when facing adversity, on the other there's a need to address the issues with technical and specialised solutions. In this field, a robust tool for spatial planning and management is key. Geographic Information Systems (GIS) are an oriented tool that brings added value and direct improves these workflows.

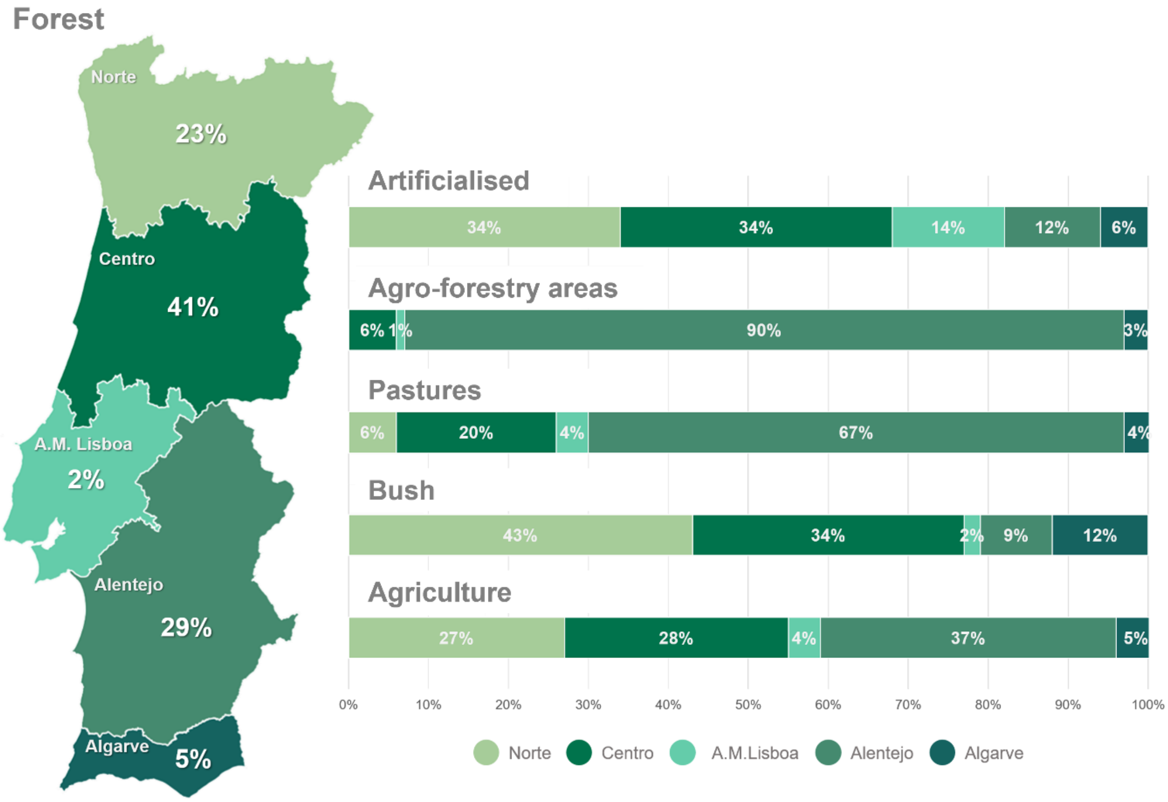


Figure 2. Contribution of each of the land use and occupation classes at the continental scale. Adapted from INE, I.P./DGT [2020].

2. MAP OUR FOREST

2.1 The application of GIS in the forestry sector

GIS can be defined in numerous ways and shapes, and provide a wide range of tools to analyse and process geo-data. As such, Aronoff [1989], suggests that, in broad terms, a GIS is "a computational system, composed by hardware and software, that provides the tools to manipulate, store, recover, analyse and visualise georeferenced data. Allowing that way, to solve complex issues of planning and managing, that encompass performing spatial tasks [Goodchild, 1997]."

GIS are potential tool for future sustainable foresting planning, since they allow to integrate in a single system, geographical data coming from a diverse range of sources, with different formats and scales. This way, GIS allow, through four dimensional (space and time) models,

evaluate environmental conditions, execute historical analysis, list resources, identify climate pattern changes, and also study common practices for soil occupation and usage.
In this sector, GIS play a crucial role and its utilisation has become a norm within the big environmental institutions, both private and public in Portugal (e.g., IDE-ICNF, GeoForest), having the following examples of application:

- Data georeferencing and integration (e.g., boundary delimiting for project implementation areas, burnt areas survey, infrastructures, etc.)
- Gathering land registry data, allowing the creation and manipulation of a Geographical Database (GDB);
- Production of themed cartography (e.g., forest projects, hunting areas, etc.);
- Forest zones listing;
- Photointerpretation and 3D territory modelling (through remote sensing techniques).

2.2 Objectives of MapOurForest

Since these small associations, "born" out the big wildfires, are not familiarised with the potential of GIS technology, this project was idealised with an educational component to capacitate the final users of the GIS (the associations and its members) to use it as an efficient tool of management and decision making.
Despite of being only a proposition, the authors believe in its importance, and as such, from now on, will refer to it as MapOurForest.
Being defined the main objective of MapOurForest, its ambition is beyond the technical challenges. There are some objectives of social nature that are inherently associated with it:

- Utilisation of Open-Source software, allowing cheaper solutions to everyone involved;
- Creation of an auto sufficient and reliable WebSIG application, in order to provide a user-friendly interface for the end-user;
- The development of the GIS will always follow the specific requirements of each association, following a "fit for purpose" philosophy;
- Application of engineering solutions as a support for foresting interventions;
- Development of managing, administration and communication skills of everyone involved with MapOurForest;
- Creation of a working team, with volunteer mentors: young professionals with expertise and geospatial students willing to learn and develop specialised skills and get ground experience;
- Ensuring continuity and knowledge transfer through all team members, providing a long-term sustainable solution of professional development;
- Active intervention on a structural problem of society.

As described above, there are several goals to be achieve within one approach. It's a set of ambitious complementary objectives, allowing a very positive outcome for everyone involved, always having long-term sustainability as a top priority, providing a robust foundation for the project to develop on its own and become permanent.

2.3 Methodology

The methodology is depicted on Figure 3. This process interactively incorporates several phases of the project, and on each step there's a review of the previous one, allowing potential adaptations without compromising the overall progress. Only this way it is possible to encompass all intervenient, and identify and control all problems and risks.

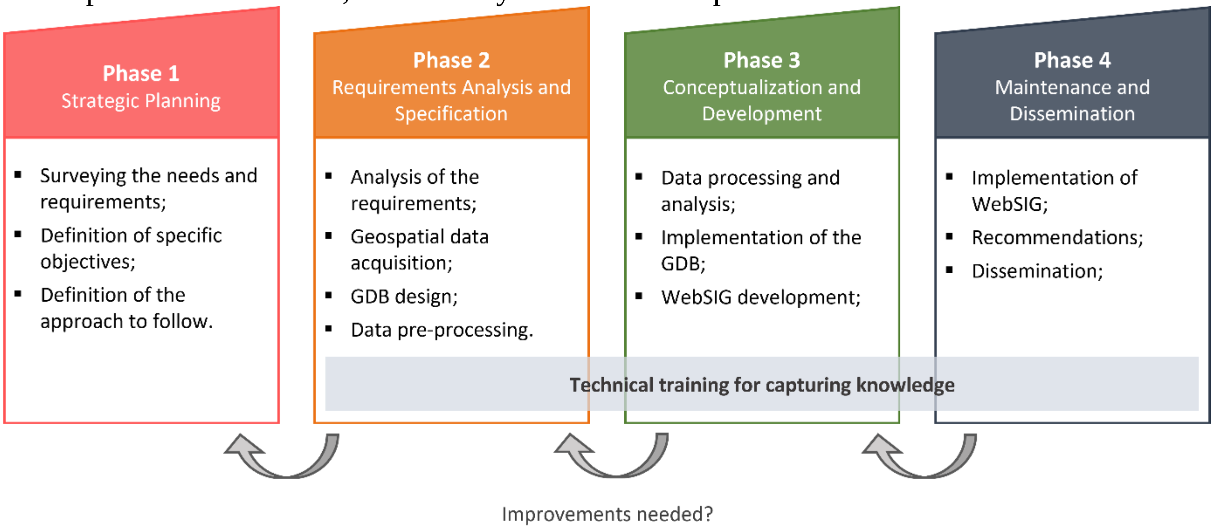


Figure 3. MapOurForest Methodological Process.

The first phase consists of surveying the needs and requirements of the association, allowing, this way, to properly justify the elaboration of the process, define which objectives to achieve, and which approach to take.
The second phase starts with the characterization and analysis of the requirements, where is decided which tools and data will be needed, as well as which analitical techniques will be used. Afterwards the data acquisition will be started, followed by its processing in order to be incorporated on the GDB.
The third phase is linked with the development of the system, where the final data is processed, the GDB is created and implemented, and the WebSIG app is developed.
On the fourth and last phase, the final app will have its first iteration with a functional shape, with a usable layout properly customised to the client.
During all phases technical sessions will be held, as well as progress meetings between all intervenient, and by the end of each phase it is suggested to organise a workshop where project's mentors will brief the association representatives, in order to maintain a close link and ensure the know-how is spread.

2.4 Development

Having described the general methodology, this next sub-chapter will focus on thoroughly explaining each forementioned phase. In order to make it more reader friendly, there will be a named virtual client "Associação Floresta Inovação", and the process will revolve around it.

2.4.1 Strategic Planning

The Strategic Planning will establish a bearing for the project before defining the technical details. This phase will allow to define strategic milestones to guide the whole developing, where the needs and objectives of the client will be identified, as well as the associated risks and opportunities that can influence the development.

In this step, the client will define its objectives, allowing the team to have a scope of the opportunities and risks associated with the project. "Associação Floresta Inovação" has as main objectives the following:

- Development of GDB relative to the geographical area of actuation of the client;
- Filling the GDB with all available data relative to the client;
- Incorporate in the GDB all available public data, among all different operative scales, from council to national level.

With the objectives well defined, it is possible then to do an overall evaluation of the strengths, weaknesses, opportunities, and threads, also known as a SWOT analysis (Figure 4).

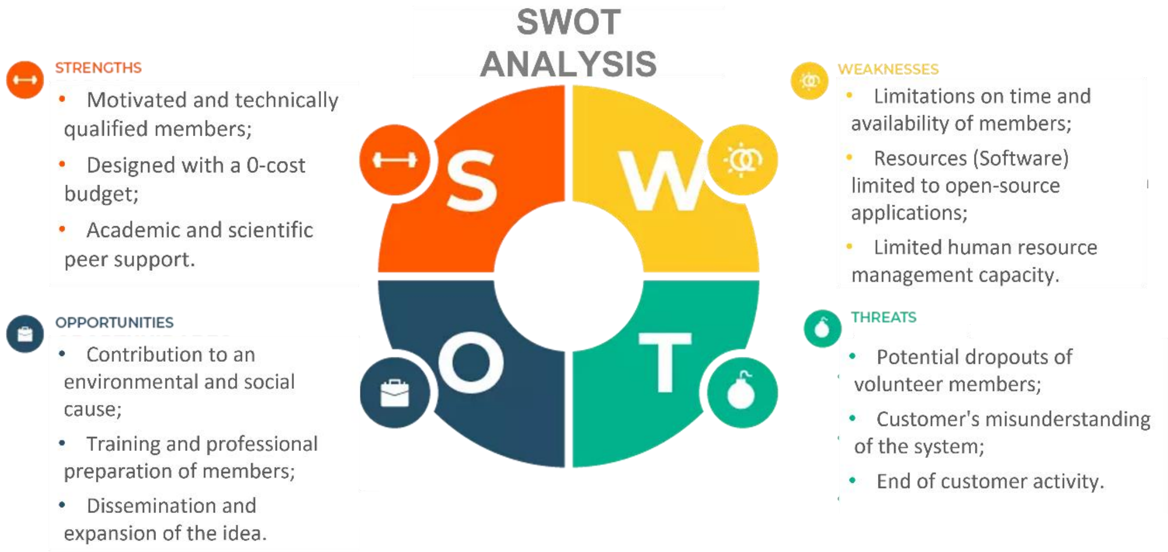


Figure 4. SWOT analysis of the MapOurForest project.

2.4.2 Requirements Analysis and Specification

In this phase it is required pick with data will be used, according to the purposed objectives, as well as the best tools and techniques for the job. Since there's an aim for Open Source solutions, the main preferred platform shall be QGIS, because it is robust, well developed, and has an environment that allows consultation, editing, and analysis of georeferenced data.

Afterwards there are two crucial tasks for the development of the project: acquisiton of geo-data to populate the GDB and its pre-processing.

The acquisition of the geo-data will be undertaken in two separate phases: First, by gathering all available data within the association database that is relevant. Secondly, gathering and organising a whole set of data that may be usable and may complement already existing data. Figure 5 shows four examples of potential data to be acquired to populate the GDB.

As usual, these small associations that are not focused on geo-data have their data sparsely organized and on different formats, sometimes digital, sometimes analogical, and potentially oudated.

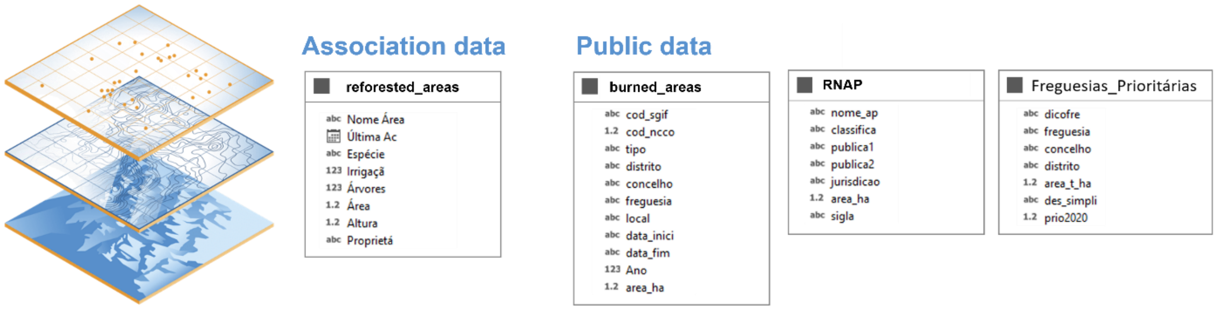
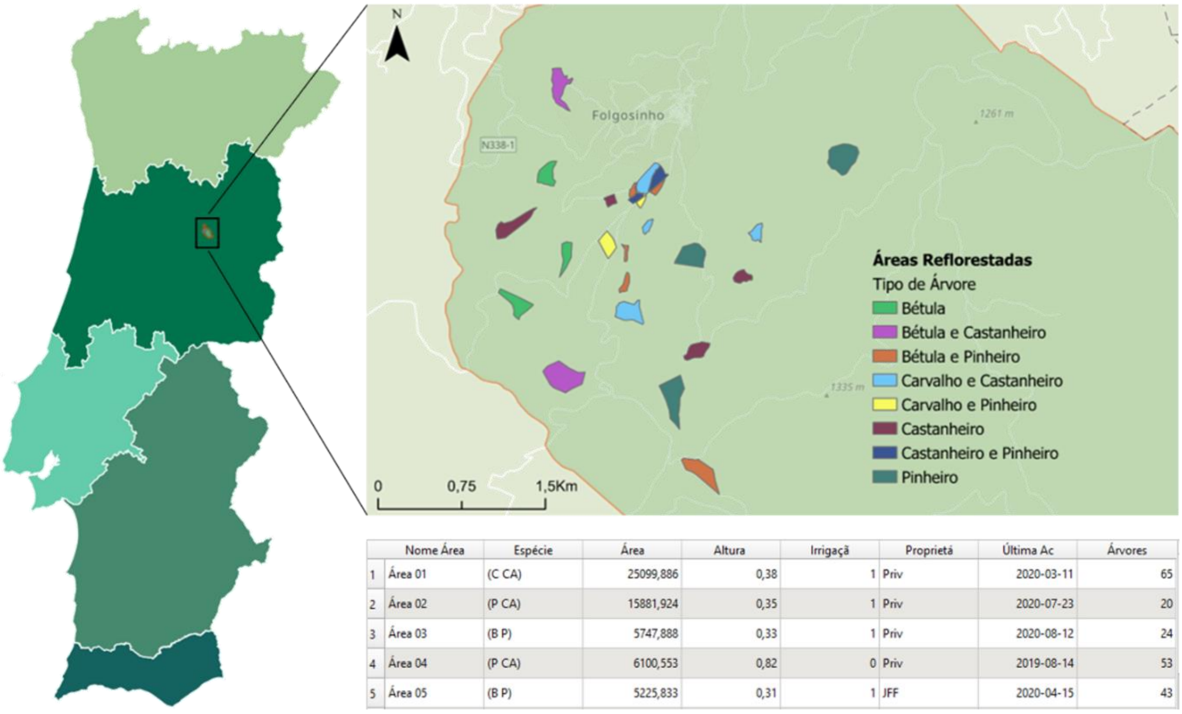


Figure 5. Examples of data for the construction of the GDB.

On Figure 6 there's an effort to simulate, along the lines of Figure 5's atributes, the reforested areas by "Associação Floresta Inovação", distributed within Folgosinho's village boundaries, inside Gouveia municipality.



	Nome Área	Espécie	Área	Altura	Irrigaçã	Proprietá	Última Ac	Árvores
1	Área 01	(C CA)	25099,886	0,38	1	Priv	2020-03-11	65
2	Área 02	(P CA)	15881,924	0,35	1	Priv	2020-07-23	20
3	Área 03	(B P)	5747,888	0,33	1	Priv	2020-08-12	24
4	Área 04	(P CA)	6100,553	0,82	0	Priv	2019-08-14	53
5	Área 05	(B P)	5225,833	0,31	1	JFF	2020-04-15	43

Figure 6. Example of reforested areas of the "Associação Floresta Inovação", according to the predominance of trees.

Being able to gather official geo-data from public institutions, such as DGT, ICNF, etc, it's a great feature to complement the already existent, and sometimes sparse, geo-data of the client. As such, merely as an example, Figure 7 contains the burnt areas in 2017 in Folgosinho, provided by the ICNF geocatalog.

Having gathered all the initial data, it's possible to design and build the GDB, that needs to be user-friendly and capable of storing and handling geo and alphanumerical data. This is one the most important steps of the phase since it will lay the foundation for all further developments. All the project requirements will be synthetised on a global model, where all entities, attributes and connections will be stated.

It is also in the step that different levels of access to the GDB will be defined, allowing to structure which users can consult, edit, or remove data in the system. The GDB will be supported by PostgreSQL Database Management System, using PostGIS spatial extension in order to allow spatial objects compatibility.

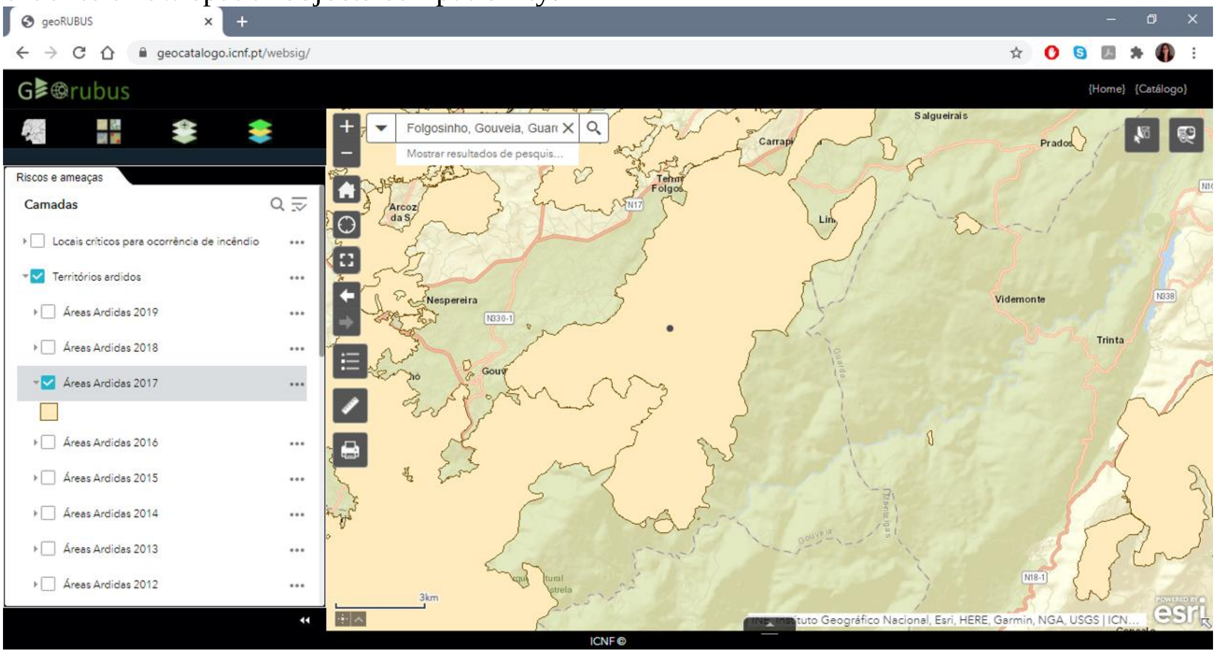


Figure 7. Burnt Areas in 2017, zoomed in on the Folgosinho area. Source: GeoRubus - ICNF. Available at https://geocatalogo.icnf.pt/websig/. Consulted on 22 February 2021.

2.4.3 Conceptualization and Development

This third phase as three associated tasks that address the final data processing, the creating and implementation of the GDB, and the WebSIG app development.

If data is not fully compatible with the system from the beginning, a normalisation process will be undertaken. As mentioned before, different data from different sources is expected, and it will be imported to the system through QGIS interface, where the following analysis and processing tasks will be carried out:

- Manipulating or normalising geographic elements' atributes;
- Editing geometric or resampling settings of geographic elements;
- Editing geographic elements' coordinate systems;
- Editing geographic element' stylings (e.g., the design and looks for the final user);
- Generating new data, based or derived from the geographic analysis or geometric editing.

During the lifespan of the project, data will be normalising, either manually or through smart methods of data loading on the WebSIG, plugins, or predetermined rules in the GDBS.

Following data processing it is possible to develop the GDB itself, where systems, tables and special rules are defined as well as permissions and access restrictions. In the end, everything shall be ready to receive the pre-processed and normalised geodata.

It is expected for the GDB to have a natural evolution during its lifespan, receiving updates and tweaks accordingly. This process could be carried out through the GDBS, however, due to the complex nature of geo-data, the most efficient solution is to resource to the tool that allows a clear and intuitive data analysis. Therefore, QGIS will have the advantage, since it provides a communication channel between who's responsible for the GDB maintenance and the final user, and on the other hand, allowing a confortable access to the data though the graphic interface. (Figure 8).

Figure 8. Scheme of interaction of the responsible person with the GDB through the QGIS interface.

The data present on the GDB can be edited on the attribute table or, its geometry (polygons, lines and points) can be edited through the graphic editing tools, a strong feature when addressing geographic bounderies.
The development of the WebSIG consists on the elaboration of a WebMap, composed by a graphic interface acessible to the client, where it can consult or share the normalised data in the system. It is a goal that the Web app is part of the system, and not only generated by the same, following the processed shown on Figure 9.

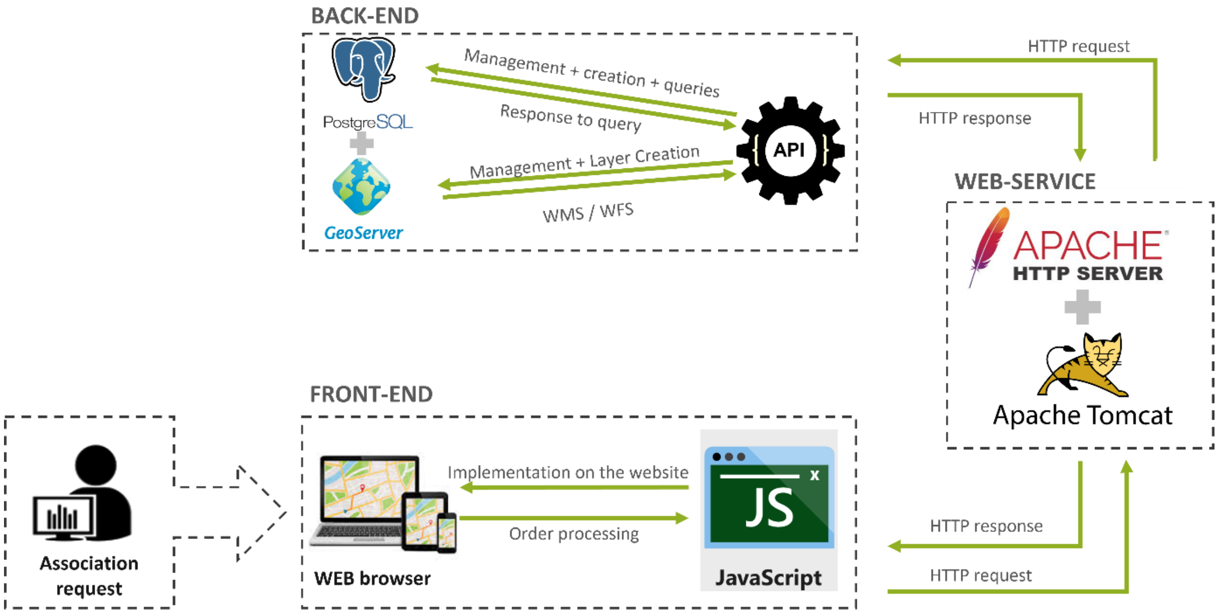


Figure 9. WebSIG application architecture.

This design has three main components: backend, frontend and web service:

- Backend is responsible for the communication with the available resources on server, that are hosted on a database and will be used to answer client's requests, and this way supporting frontend component [Fitzgibbons, 2019].In this component is the GDB, ran by PostgreSQL, Geoserver, and an app programming interface (API), responsible for managing server's resources, and following REST or GraphQL architectural principles.

- Frontend is responsible for introduced and requested data collection and consultation by the client, being the interface with the final user [ibid].
- The app will be accessed by a web browser. Web service is the service that provides a communication method between two components, devices or apps through the web. This service has the objective of allowing the communication between frontend and backend through a common language, as XML (Extensible Markup Language), GML (Generalized Markup Language) ou JSON (JavaScript Object Notation)/GeoJSON.

2.4.4 Maintenance and Dissemination

In this fourth and last phase, the final stage of the application will be achieved, with it's features made available and the layout approved by the client.
This kind of applications are aimed to be user-friendly, allowing consultation and analysis of the different layers of data the user requires. Following this logic, on Figure 10 there is a sketch of a potential layout that shall address the forementioned objectives.

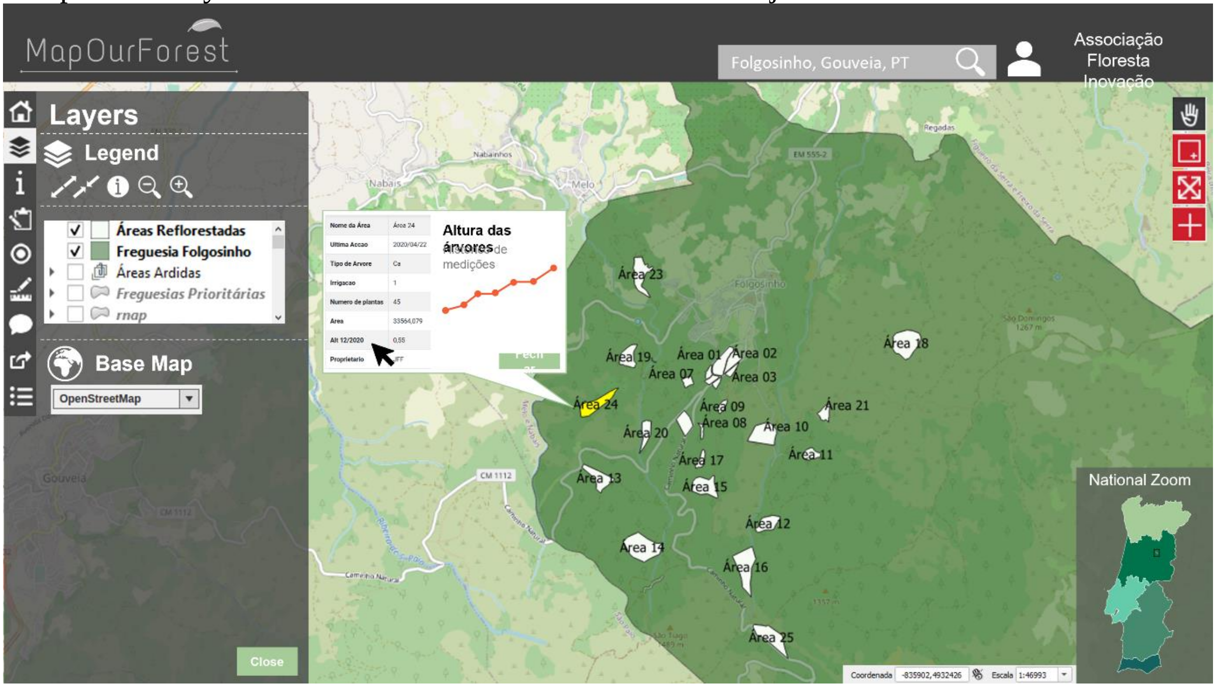


Figure 10. Example of the WebSIG application.

In terms of pure design, the authors opted for a minimalist high-contrast dark themed simple interface. This way the most important content is highlighted, promoting a focused interaction. Ideally, the app will be formed by 4 components: Header, Toolbar, Sidebar and main Map.

- Header – it contains the project logo and a search box, where the user can insert a village name, and the map will automatically zoom in to the requested area. There's also an authentication feature, allowing a secure access to all information potentially displayed in the main map.
- Toolbar – it shall have several available tools. They provide the ability for the user to select layers, as well as execute advanced functions, such as distance measurements,

drawing new elements, add markers or access data related to the objects through queries to the GDB.

- The Sidebar aims to be opened every time the user selects any icons on the toolbar. It shall present relevant information such as details about selected objects, allowing the user to choose what should be present in the main map area. On Figure 10 the user is able to select different layers of available data in the app, and choose a base map, in the case provided by an OpenStreetMap web service.
- Main Map – It presents an adjusted and scaled map representing the user's latest search. On the bottom right corner, it features a mini map of the national territory with the current main map area represented on a dark rectangle. In this area is also possible to consult the coordinates of the selected area.

In this step are also created the profiles and authentications necessary for the users to access and manipulate the data. The process of publishing the WebGIS around is for the client to undertake, always having the mentors available for any necessary guidance.

3. CONCLUSIONS

3.1 Conclusion

GIS are a very relevant tool for decision making and its usage should be highly promoted due to its most efficient way to integrate and classify geodata of different natures. The biggest challenge they face is the quality of the existent data since it's splited between public and private institutions, in different scales (micro and macro), slowing down the complex workflows that usually tend to use more and more quantities of data. The integration of a GIS on an association's working routine provides conditions for normalisation, indexing, analysis, planning and managing of their resources.

Because of the environment where this project is existing, where small local associations don't have the resources to take advantage of this technology, the authors consider the project to fit on a "Blue Ocean Strategy", where instead of fighting among pairs to succeed, it has to educate the client, and transmit the inherent need of its existence. This process will last the whole lifespan of the project, requiring a joint effort from all parts involved on getting the best out of the open-source opportunities, the collective implementation capacity, and the constantly changing needs of the client.

This project will also allow the share of experiences between the associations and the mentors, providing unique conditions to develop new skills in each one's area of actuation.

3.2 Practical applicability and future perspectives

MapOurForest will allow each association to integrate under one system all their relevant information providing a planning platform for strategising their efforts and managing their actuation territory.

GIS development projects are usually characterized by being relatively slow, especially the initial phases, and it is expected for this one to endure some long processes of relating to the client's needs and first acquisition steps. On the long term, the project will find one of its most special characteristics: being scalable to other associations/clients. There is a huge potential to recycle and re-adapt most of the features, which would also shorten the first steps with new clients, as well as experience sharing between associations.

With the proposal presented here, the creation of a specific application for the visualisation of geographic data referring to the forest spaces and that will be made available through the WebSIG platform, as an interface between the reforestation associations, of popular nature, and the GDB becomes a essential element of communication, as it fulfills the always complicated task of allowing users less versed in geographic sciences to take advantage of all the potential of GIS in an intuitive and expeditious way.

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BIOGRAPHICAL NOTES

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Carolina Rocha holds a master's degree in Geographic Engineering by the Faculty of Sciences, University of Lisbon (FCUL). Currently she is a PhD student in Geophysical Sciences and Geoinformation at the same faculty, where her research focuses on the coastal risk assessment due sea-level rise scenarios in mainland Portugal. Since 2020, Carolina has been an effective member of the Ordem dos Engenheiros of Portugal and a member of the Young Surveyors Network-PT.

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