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Decision Support Systems for Forestry in Galicia (Spain): SaDDriade

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1. Introduction

Ever since they were created in the 70s, Decision Support Systems (DSS) have been a great source of help with different management problems such as the optimization of travel times in airlines or train companies, medical diagnosis, business management, natural resource management, agriculture and forestry. Forest planning uses forest simulators that usually include growth and performance models in order to generate the different alternative management programs which will give rise to different production processes and programs. The selection of the best choice according to predefined criteria, which are generally related to the number of alternative management options, production programs and assessment criteria, require the use of optimization methods. These optimization methods range from whole linear programming, goal programming to heuristic methods, among which tabu search, genetic algorithm and simulated annealing are worth noting.

1.1 Development and current situation of forest DSS

In recent years, the aims for the development of forest DSS have changed. They used to have only one objective, which was to provide information about: Site index for reforestation (Hackett and Vanclay, 1998); soil fertility (Louw and Scholes, 2002); habitat requirements (Store and Jokimäki, 2003); tree growth (Hackett and Vanclay, 1998); forest management (Kolström and Lumatjärvi, 1999); wildfires (Kaloudis 2005 y Bonazoutas et al. 2008); trees brought down (Mickouski et al. 2005; Olofsson and Blennow, 2005; Zeng et al. ,2007); seed bank long-term planning (Nute et al. 2005 y Twery et al. 2005); river flow and its relation with trees (MacVicar et al., 2007) and profits (Huang et al. 2010).

More recent DSS methods have several aims. the management planning problem is focused on two or more objectives, some of which may be in conflict (Stirn, 2006). Næsset (1997) states the need for new tools to help planning aims related to biodiversity and wood production. The needs of sustainable forest management must be considered and included in the design of DSS for forestry (Wolfslehner and Vacik, 2008). Moreover, forest management actions cannot be considered in isolation or with just one objective in mind, despite the difficulties of integrating them spatially and temporally (Kangas and Kangas y MacMillan and Marshall, 2004). The aim is to offer a general view of alternative focus to face the uncertainty from the perspective of forestry and natural resource and ecosystem management (Rauscher (2000).

Some remarkable systems developed with multiple aims in forestry and natural resources are those developed for: hydrographic basins in Australia by Bryan and Crossman (2008); carbon in Canada by Kurz et al. (2009); plague control in Poland by Strange et al. (1999); landscape management in South Carolina by Li et al. (2000); visualization tool for landscape valuation by Falcão et al. (2006).

The prediction of forest activity future behaviour in its multiple dimensions is inherent to the main aim of forest DSS, therefore, the temporal scale is specially important in the development of this type of applications. Temporal scales are classified into three types: strategic, tactic and operational.

Long-term management planning or strategic is that which has a planning horizon of more than 15 years. Potter et al. (2000) state that forest ecosystem management implies the need to forecast the future state of complex systems, which often experience structural changes. It is by means of strategic planning that ecological integrity and sustainability (Gustafson y Rasmussen, 2002), risk management (Borchers, 2005 y Heinimann, 2010) and future landscape (Aitkenhead and Aalders, 2009) are guaranteed. Næsset (1997) stresses the importance of the integration of GIS with quantitative models for long term forest management. Some interesting examples of strategic forest DSS are those presented by Boyland et al. (2006) for a planning horizon of 250 years; Wolfslehner and Vacik (2008) for 120 years; Díaz-Balteiro and Romero (2004) for 100 years divided into periods of ten; Baskent et al. (2001) for 85 years; Huth et al. (2005) for 60 years and Lasch et al. (2005) for 50-year simulations.

In the case of strategic planning, it is not only the temporal scale that is higher, but also the spatial scale (Kangas and Kangas, 2005).

When the planning period is between 1 and 15 years long, it is called tactical planning or mid-term. Kangas and Kangas (2005) point that in tactical planning the number of alternative forest plans can be considered infinite. Different examples of this type of planning are those presented by Anderson et al. (2005) and Snow and Lovatt (2009). Anderson et al. (2005) present FTM (Forest Time Machine), which simulates the development of a forest area and calculates the stand development in five-year intervals. Snow and Lovatt (2008) examine the use of the general planner for agro-ecosystem models (GPAM) in pasture rotation length, building a decision tree.

Short-term or operational planning is that whose planning period lasts for a maximum of a year. Acuña et al. (1997) remark the usefulness of transparent, operative, easily validated processes provided by experts. Ducey and Larson (1999) state that sustainability assessment requires a careful balance between short-term and long-term goals. Mowrer (2000) considers that the temporal scale on which the operative tool or DSS works will have an effect on the level of uncertainty of the analysis. Uncertainly is lower in short-term planning. The more empirical the models, the more accurate they will be (Porté and Bartelink, 2002). Some remarkable examples of operative forest DSS are: Vacik and Lexer's (2001) which assesses nine species mixes and seven multiobjective regeneration methods at stand level. Newton (2003) tabulates the annual management of spruce plantation. Thomson and Willoughby (2004) present a web system of forest management consultancy. Kurz et al. (2009) comment a version on operative scale of the model of carbon-dynamics. Newton (2009) shows the usefulness of the modular-based structural stand density management model (SSDMM) for decision-making in operational management.

Another relevant aspect in forest DSS analysis is the spatial scale of the unit of analysis. The highest level is on a regional or, in some cases, national scale. In this type of works planning is strategic and establishes the guidelines (Anderson et al. 2005; Ascough, 2008; Carlsson et al. 1998; Crookston and Dixon, 2005; Heinimann, 2010; Kurz, 2009; Mathews,1999; Mowrer, 2000, Potter, 2000; Maitner et al. 2005; Nute, 2005; Reynolds, 2005; Thompson et al. 2007). These works have been developed mainly in the USA and in different regions in Scandinavia.

A second scale is the lanscape or forest that has been the unit of analysis for the studies carried out in the USA (Rauscher in 1999, Twery and Thomson et al. in 2000; Twery and Hornbeck in 2001, Bettinguer et al. 2005; Borchers, 2005; Gärtner et al. 2008 and Graymore et al. 2009). In Scandinavia some remarkable studies are those by Anderson et al. 2005; Kurttila, 2001; Leskinen et al. 2003; Store and Jokimäki, 2003, among others. In other countries, the works by Seely et al. 2004; Stirn, 2006 and Wang et al., 2010 are worth noting. It is at this scale when the need to integrate GIS within DSS arises. It should be easy for regional managers to carry out forest zoning effectively in the areas where initiatives are necessary for sustainable progress (Martins and Borges, 2007). It is also necessary to integrate 3D visualization tools (Falcão et al., 2006).

The main planning scale so far is the stand, where units are homogeneous regarding ecology, physiography and future developments. Some remarkable works are those by Aerstenet et al. 2010; Anderson et al. 2005; Crookston and Dixon, 2005; Ducheyne et al. 2004; Huth et al. 2005; Kolström and Lumatjärvi, 1999; Mathews et al. 1999; Mette et al. 2009; Torres-Rojo and Sanchez-Orois, 2005; Seely et al. 2004; Snow and Lovatt, 2008; Twery et al., 2000 and Varma et al. 2000. They have been applied in different areas such as Scandinavia, Australia, Austria, Canada, Malaysia, Scotland, Germany and Turkey for mixed stands of different species such as firs, spruces and tropical species among others. Works on this scale with differenciating characteristics are those by Baskent et al. (2001) about simulated stands; by Vacik and Lexer (2001) and Kurttila (2001) applied to stands from natural regeneration; and those by Chertov et al. (2002) and Goldstein et al. (2003) which analyze the consequences on natural ecosystems. The studies by Nute et al., (2005), Twery et al. (2005) and Salminen et al. (2005) enable the user to update the investment assessment on a stand level and on a whole exploitation level, developing thus scenarios of one or more treatments for management units. Martins and Borges (2007) point out that the search for sustainability of woods belonging to a high number of non-industrial private forest owners (NIPF owners) requires devising tools of the appropriate size for the properties and decision scale.

Flexibility in decision-making has become an essential element in the development of forest DSS in recent years. There has been a development from methods that allowed only unilateral decisions, only one person has the decision-making power (Thomson et al. 2000; Leskinen et al. 2003; Kaloudis et al. 2005). Even if unilateral systems have been maintained , new ones have been developed where decision is collegial, that is, multiple participants express their preferences to support an only actor in the decision-making. In Kangas and Lekinen (2005), some experts choose the explicative variables that will be used in the model after a careful study of the forest area. The software for damage reduction by fire proposed by Kaloudis et al. (2010) has been initially tested and evaluated by three different groups of users.

The most recent, interesting and complex issue in forest DSS are those with participative decision-making by several stakeholders who must reach an agreement for a final decision. In Nute et al. (2000) decision-making is developed with a social participative and environmentally sensitive methodology in Central America. Mendoza and Prabhu (2003) use MCA methodology to carry out an assessment of the Criteria and Indicators (CandI) structure in an environment of participative decision-making. In a context of public participation, Sheppard and Meitner (2005) describe the managers needs in sustainable forest planning, outlining the criteria for the design of support processes for these decisions. According to Mendoza and Martins (2006) the qualitative method allows a more participative decision-making process. In public participation processes, Kangas et al. (2006) state the importance of questions such as equity, representativity and transparency. Martins and Borges (2007) interprets the design of a forest management plan as a case of participative planning. Ramakrishnan (2007) uses participative management methods in sustainable forestry. Other illustrative examples are those presented by Vainikainen et al. and Wolfslehner and Vacik in 2008 and Anderson et al. in 2009.

It is important to highlight the development of mathematical tools and their implementation by means of information technology for efficient problem solving. Díaz-Balteiro and Romero's work entitled "Making forestry decisions with multiple criteria: A review and an assessment" (2008), makes an excellent assessment of the different issues in forest management and the different problem-solving tools. Finally, there are some references that haven't been used in the afore mentioned work and that have incorporated some different types of relevant techniques for forest DSS: Aitkenhead and Aalders (2009) use Bayesian networks; Martín-Fernández and García-Abril (2005) and Zeng et al. (2007) use genetic algorithms and tabu searches; Stirn (2006) uses dynamic programming and fuzzy techniques; Chertov et al. (2002) use data mining; Wolfslehner et al. (2005) use AHP and ANP; and MacMillan and Marshall (2004) use lineal programming.

2. Forestry sector in Galicia¶

The forestry sector is crucial in Galicia from a strategic, social and economic point of view, Figure 1 (Marey-Pérez and Rodríguez-Vicente, 2008). In recent years, Galicia has produced half the wood in Spain, becoming in some periods the ninth country in the wood harvest rank in the EU, even above the United Kingdom (FEARMAGA, 2009). In the past ten years, forest producers in Galicia have perceived 1,000 million euros due to wood selling. Due to this production capacity, Galicia has a wood transformation sector with around 3,500 companies, mostly family business, which employs 26,000 people directly and 50,000 indirectly. In fact, it is overall the third most important industrial activity and in twenty out of the fifty-six forest regions it is either the first or the second. These forest regions are located mainly in rural environments, so it is one of the main assets for the sustainability of rural population (Marey-Pérez and Díaz-Varela, 2010).

One of the most serious problems for this sector is its atomization (Marey-Pérez et al. 2006). This stems from the small size of the property of each owner and of each parcel. This results into 700,000 forest owners with less than 3 ha of average property divided into more than 8 parcels (Rodríguez-Vicente and Marey-Pérez, 2010).

3. A supporting decission forest system: SaDDriade

3.1 Origins

New information and communication technologies are currently, and will be to a higher extent in the future, the basic pillar on which the economic development of our society will lie. In rural areas in Europe the currently-existing digital divide will be overcome by different means: public funding, training and the initiatives of organizations and companies

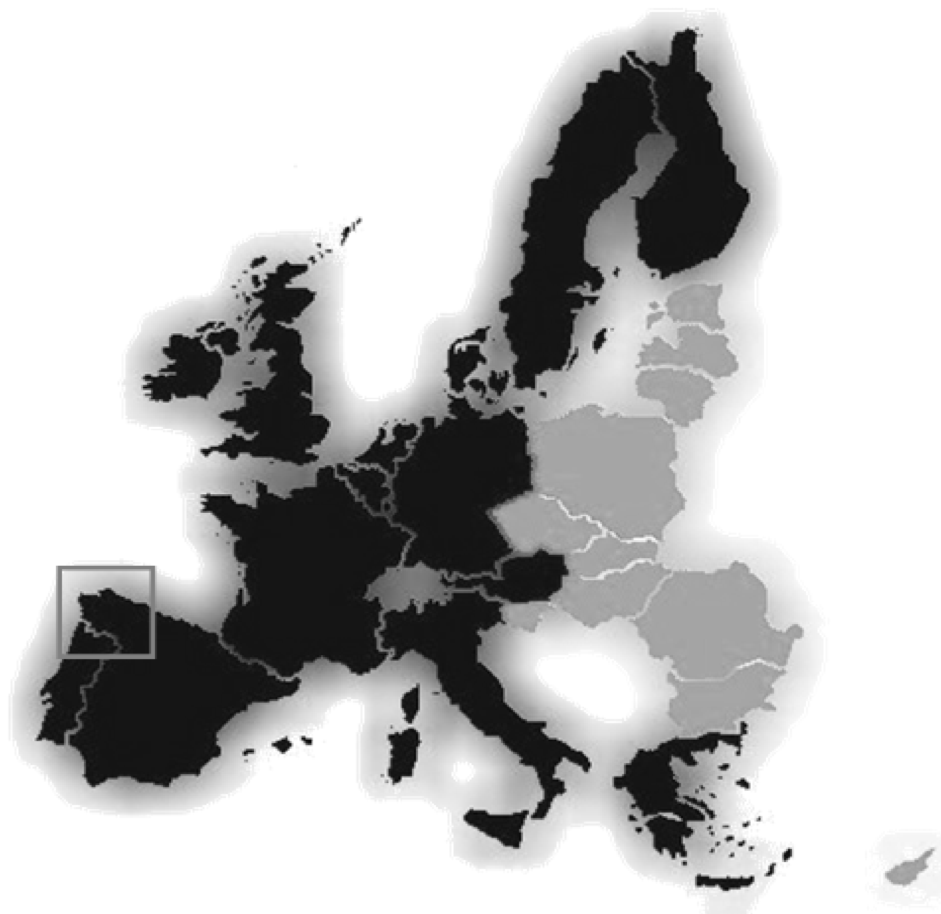

Fig. 1. Location of Galicia in Europe and Spain

regarding these types of activities. These initiatives are going to depend on the DSS problem-solving capacity.

In the Research group "Proyectos y Planificación de la Universidad de Santiago de Compostela (GI-1716)" we have been working on solutions to the problems experienced by agricultural and agroindustrial sectors in Galicia and in other rural areas in Europe and Latin America. SaDDriade is the result of a process that started with the analysis of the weaknesses and strengths of the forestry sector. Strategic plans regarding forest industry were revised, wood, furniture, energy, environmental preservation and land planning, among others. Special emphasis was placed on the revision of information technologies and sustainable development with the idea of gathering as much information as possible. The experience of the research group was incorporated to the corpus of knowledge, providing it with a scientific and practical dimension.

Symposia, conferences, forums and meetings with owners associations, industry, administrations and scholars have been organized in recent years. This provided very valuable reflections for the definition of a DSS adapted to the reality of our region. Finally, financial, technical and scientific support to start the project has been obtained as a result of the combination of the Xunta de Galicia research Project "*Sistema de apoio a decisión para montes veciñais en man común (SadMvmc)*" (*07MRU035291PR*) and the different collaborations with public administrations, forest associations and private companies within the framework of the project *COST Action FP0804 - Forest Management Decision Support Systems (FORSYS).*

3.2 Motivations

The study of the data gathered provided the keys about the demands that SADDriade should answer and also of the way in which this should be done to provide the right answers to potential users. Below, there is a selection of weak points of different aspects within the forestry sector from different reports chosen due to their different degrees of usefulness for the development of the system.

- Make information available to facilitate strategic decision-making by the companies in the forest chain and guide the definition of public policies.
- Promote the activities of support services (researcher training or services to companies) that encourage industries' main activities.
- Decrease the lack of appropriateness of the formative level of the general population to the requirements of the companies. Despite the recent efforts and advances, there is still an imbalance between the needs of the companies and the development of technologies.
- Collaborate in a rational exploitation and use of natural spaces and in the reduction of industrial impact on the ecosystem.
- Encourage the collaboration of universities, technological centers and companies.
- Promote forest as a source of income for companies and private owners. Forest smallholder property poses difficulties for sustainable developments since forest areas are considered a secondary source of income and specific forestry is not developed.
- Provide businessmen with competitive advantages in tangible resources such as financial, technological or natural resources to counteract the competence in Price of markets with cheaper labour.
- Promote the implementation of technology in companies where the presence of technology is not enough, which limits their competitivity and the development of forest activities.

In our proposals, our aim was to make a forest DSS of immediate use for companies. It would have no cost for them in implementation and in licenses, and it would not require specific training for its users or an equipment update. It would also reach the highest possible number of users in the shortest possible time, which made it necessary to have a fluent transmission of knowledge. Our experience as university instructors enables us to identify the most efficient means in which users acquire knowledge. After considering different possibilities, we reached the conclusion that the only option that fulfilled all the requirements was the world wide web, using a web application.

Within the creation process of a software tool, the choice of a certain development platform is a key issue that conditions the rest of the actions. It is necessary to make a detailed analysis of the weaknesses and strengths of each programming environment and compare them with potential user profiles and the requirements for a satisfactory user experience. Currently, the technological developments and the increase in telecommunications favours the development of web applications and their merge with mobile ones, instead of with desktop applications, which are becoming less important. Some of the reasons to choose a web platform are:

- Multi-platform compatibility: Several technologies such as PHP, Java, Flash, ASP and Ajax allow an effective development of programs supporting the main operating systems.
- Update: Being always updated without pro-active user actions and without calling the user's attention or interfere in his/her working habits.

- Immediacy of access: Web-based applications don't need to be downloaded, installed or configured. They can be accessed via an internet address and be ready to work, regardless of their configuration or hardware.
- Easy trial: There are no obstacles for easy and effective tool and application trials.
- Lower memory requirement: They have more reasonable RAM memory requirements for the end-user than programs installed locally. Since they are stored and run in the provider's servers these web applications use these servers' memory in many cases.
- Fewer errors: They are less likely to 'freeze' and cause technical problems due to hardware conflicts with other existing applications, protocols or internal personal software. In web applications, they all use the same version and all the errors can be corrected as soon as they are found.
- Price: They don't require the distribution infrastructure, technical support and marketing required by traditional desktop software.
- Multiple concurrent users: These applications can be used by multiple users at the same time. There is no need to share screens when multiple users can jointly see and even edit the same document.
- Usability: Web browsers are by far the computer application with the highest presence in computers around the world due to the expansion of internet as a channel of communication for businesses and particulars.

3.3 Who made SaDDriade?

The SaDDriade team is made up of ten people with the collaboration of different professionals and technicians from the forestry sector, the administration and more than twenty well-known international experts in the field.
Gradually, technical-economical models have been built for the different forest species and their different locations in Galicia. These models include the most advanced techniques in forestry and individual tree or forest growth, together with the parametrized financial component of the different forest management phases or tasks: land preparation for planting, tasks linked to forestry and the use of wood or biomass.

3.4 Users of SaDDriade

During the development of all its components, we considered the potential users, their demands and their previous knowledge. In this way, we have developed a user-friendly, accessible, usable application, with a clear presentation of results. It also enables the user to determine in which phase of the work he/she is without being trapped within the program. The characteristics of the potential clients and the demands that SaDDriade answers are outlined below:

- Forestry business: Companies related to reforestation, forestry, wood and forest biomass harvest, first transformation industry (sawmills, wood plank industry, paper and pulp industry and biomass power generation) and consultancies and engineering technical offices that advise owners.
- Forest owner associations: their needs and demands are very similar to those of the previous group. However, most of them lack the qualified technical staff to rigorously go through the planning process. SaDDriade has been conceived with the idea of helping them improve the quality and quantity of their forest product.
- Research groups in universities and research institutes: SaDDriade can perform the role of a lab and database with useful information to understand how forest reality works.

All this knowledge and experience will result into new studies that will contribute to quality forestry based on multifunctionality, energetic use and rational resource planning. Its ultimate aim is the excellence and sustainability of forest farms that will secure the financial future of small forest farms in short, middle and long term.

- Forest training centers. Forest training centers and specially those departments at universities devoted to forest activity can use this application for teaching. Students can acquire experience in forest planning and management and use forest simulators in their area seeing the possibilities of evolution and acquiring practical knowledge that would be impossible otherwise.

3.5 Objectives of SaDDriade

The main objective is to provide information about the productive cycles of the different forest species in Galicia. The data provided are going to enable the knowledge and assessment of the different steps to be taken in the productive processes, the costs associated to each of them and the expected final yield.

Users receive answers to queries regarding different aspects of forest management such as:

- Forecasts: They are obtained from data of potential stock for the different models in the different parcels where the simulation is carried out. They provide information about: the works to be done, the costs associated to them, the forecast profits for different years and for the end of turn or cycle of the technical and financial model developed.
- Situation reports: They are "snapshots" of the state and value of wood or biomass at a certain moment. They help determine the investment to be made over a certain period of time, the value of existing products in the parcels and the years and operations necessary to get profits from the proposed models.
- Investment and profitability analyses: They provide knowledge beforehand about the effort necessary to be made in forest activity in a certain parcel. Indicators such as IRR and NPV will be useful to calculate the expected profitability in each scenario or technical-economical model developed and the aspects that have more influence in such profitability.
- Improvement of training procedures (training/extension): The use of this application requires user training. Using this program improves the knowledge of the implications of forestry and forest management.
- Stock control: Users are able to consult the volume of wood that their parcels have at any given moment. This enables them to forecast their production or report losses in case of fire, wind or snow damage.
- Cost reduction: The availability of information entails a possible cost reduction. Two factors are key in this fact: first, the knowledge of average costs of the operations enables the management of the provider and contractor offers according to contrasted terms of reference; second, the knowledge of the optimum production models for each technical-economical models avoids unnecessary operations.
- Market transparency: The availability of accessible information has a direct influence in flux transparency and commercial relations that contribute to the clarification of a sector, which is traditionally considered to lack transparency. Knowing the real average cost of obtaining a product and its market value simplifies the buying and selling process and the accessibility to raw materials.
- Technical documentation and management system: Being an application based on a central server with all the security protocols, it is going to provide the users with a

space where they can make and store their operations with the guarantee of recovering and using them in the future.

- Help for administrative processes: A high number of activities related with forest activity productive processes are either publicly-funded or regulated by the administration. This administrative process comes with the need for technical documentation, which can be obtained with the format suitable for administrative use. In the future, electronic administration will be wide-spread so this application will be essential.
- Database with legislative information. The application has an associated database with legislative information (Lexplan module), with all the legislation regarding forest activity in its different phases. The user has access to all regulations and public funding that he or she can be eligible for according to the activity carried out in each particular moment

3.6 How does SaDDriade work?

The different sections below explain how SaDDriade works. We will start by the explanation of the programming language(s) used, the operative environment, the architecture goals and how it actually works.

3.6.1 Programming language

SaDDriade has been designed using more than one programming language. This was due to the complexity of the calculation processes, the web environment, the diversity of data sources, the need to have a GIS WEB tool and the different formats of exporting results. The languages used are: PHP (PHP Hypertext Preprocessor), Javascript, Mapscript and SQL (structured Query Language) All the components used in this application are open source components. They have been selected not only because of our agreement with the social philosophy and support of knowledge of the open source movement, but also for the financial advantages for both users and developers.

3.6.2 Operating environment

The main component of the Geographic Information System (In Spanish Sistema de Información Geográfica, SIG) integrated in the application is the open source platform Mapserver. This application was created in order to publish spatial information and to create interactive applications for maps. SaDDriade uses a combination of servers of relational databases of different kinds: on the one hand MySQL, and on the other hand PostgreSQL, with support for spatial data by means of the extension POSTGIS. Such services, together with a variety of files in shape format are the ones that feed the map server. The graphic interface was made in XHTML (eXtensible Hypertext Markup Language), a markup language whose specifications are developed by the World Wide Web Consortium (W3C).

3.6.3 Architecture

SaDDriade is a web application, so it can be used by accessing a web server by means of a client, typically a web browser. Through this client-server scheme, there is no need for a specific installation client side. It also makes it easier to install and maintain the application without having to distribute specific software to the clients.

The model-view-controller (MVC) design pattern was used to develop an internationalizable modular application which is easily extensible and has the capacity to access different database management systems. Three different frameworks were used, each of them with specific functions to optimize the general work of all the decision support system. **Codeigniter** framework is the base of the structure. Some of its advantages are: its speed, its excellent documentation, PHP compatibility backwards, small software and hardware requirements, native support for user-friendly URLs, drivers for a wide range of server database (MySQL, PostgreSQL, SQL server, SQLite, among others) extensible by helpers, plugins and libraries.

Codeigniter optimizes its performance eliminating non-essential distribution elements. Thus, its functionalities are more limited than those of other frameworks. In order to solve this problem, SaDDriade includes **Zend Framework**. Its main features are: low coupling among its components, wide unit test code coverage, multipurpose (capacity to generate PDFs, Access to LDAP, SOAP, Lucene, DOM, JSON, ACL system, email, authentication, automatic pagination, among others), use of design patterns, access to database by PDO and possibility to have an ORM (Object Relational Mapping), interoperatibility with the most important web services (Akismet, Amazon, AudioScrobbler, Delicious, Flickr, Nirvanix, Recaptcha, OpenID, Technorati, Twitter, Yahoo, Google, Youtube and Picassa) and high frequency of updates and new versions.

The third framework used is **Jquery,** a javascript library oriented to objects in the form of a resource collection that facilitates the reuse of the code and ensures the compatibility between different versions and types of browser. Special care was taken so as not to make an intrusive use, following the recommendations of the World Wide Web Consortium regarding accessibility. Within the general scheme of the application Jquery is responsible for the improvement of the user interface such as sortable tables and asynchronous communication with the server to increase the speed by the development of the XmlHttpRequest API (Application Programming Interface), a wide-spread technique known as AJAX (Asynchronous Javascript And XML).

SaDDriade GIS WEB structure revolves around Mapserver, which can process geographical information from different sources (WMS servers, WFS, shapes, databases, raster,…) and create very complex representations (depending on their configuration) which are shown in a client map. This configuration is normally done via GET parameters through a URL to a CGI script. It is an easy way to send requests to be analyzed by the server. A downside is that the possibilities of a dynamic answer using this method are limited and don't allow a complex application creation. To avoid this problem Mapserver has its own language, mapscript, which can access its API directly. In this way, programmers have all its library of functions to create interactive applications or RIA (Rich Internet Applications).

Mapserver itself can show the maps it generates or use a client to do so. SaDDriade uses a client. Maps are visualized using pmapper, a set of libraries made in PHP, jquery and mapscript, that offer more possibilities than those included in mapserver as a light client map. Pmapper has General Public License, so it can be used for free. It was chosen for its capacities, for being user-friendly and its integration with other program components. For instance, they share the jquery framework and the TCPDF library to create PDFs.

From the data obtained in the parcel shape and the zoning ecological criteria, pmapper displays a GIS client with capacity to add orthophotos of the SIGPAC project, parcel and municipality search, measurements, identification, zoom, annotation and map downloads as image or PDF. The user can choose a parcel, by clicking the "Identificar" button on the right side menu, and start the simulation process using the link offered by pmapper.

3.6.4 Work description

In SaDDriade, there are forest management models implemented for twelve different species (see table 1). In this way, 146 models have been parametrized in the forty areas in which Galicia has been divided. This has encompassed 13,108 tasks and subtasks, and the use of 160 different types of materials, machinery and so on.

Species	Number of models
Pinus pinaster	17
Pinus sylvestris	9
Pinus radiata	15
Pseudotsuga menziesii	8
Quercus robur	8
Quercus rubra	12
Quercus pyrenaica	6
Juglans regia	6
Populus sp. (hybrid)	8
Eucalyptus nitens	7
Castanea sativa	23
Castanea hybrid	27
TOTAL	**146**

Table 1. Species and number of models developed for each species.

Designed according to technical criteria:
- Possible ways of mechanization.
- Selection of the best available technique.
- Limit of appropriate densities.
- Programming activities on land and trees.
- Programming of intermediate harvests.

Financial criteria:
- Establishing technical shifts.
- Maximum rent shifts.
- Expense minimization.
- Benefit estimate.

Model choice

The first thing that the user must do is to choose which available SaDDriade module he/she would like to use: SAD Castanea, SAD Eucalyptus, SAD Pinus, SAD Populus and SAD Quercus.
Starting from the GIS-WEB, as stated above, the actual process starts once the user selects his/her parcel. Once the link shown is clicked, a window appears with basic data regarding the choice. Questions guide the user throughout the decision support process. By the location of a chosen parcel, a first filter of qualities and species has been set, so only those technical-economical models considered ecologically and financially viable are accessed. Models are classified by species and production destination to simplify the choice. The user must select a model among all the options to continue the calculations.

Fig. 2. SaDDriade initial screen.

Management variables

After the basic characteristics of the model are presented, some parameters that influence the task development and performance of the chosen model are shown: Characteristics of the place: slope, percentage of rocks, stone content, soil type; Initial state of vegetation: type, height, density and presence of stumps; Management alternatives: choice between base-root

Fig. 3. Characteristics of a selected model.

and pot planting, work line and plant and plantation protection; other management alternatives: characterization of protection and grubbing.
Options arise parallel to the simulation process and the user always has the option that the SaDDriade "remembers" his/her answers throughout the process just by clicking on the checkbox beside each answer. Twelve thousand possible combinations of profits, 13,000 yearly subtasks (that generate more than 4,300 partial products), 38 types of different machinery, 72 types of inputs and 47 different types of final outputs. They are all associated to prize, restriction, modelization and classification databases.

Results

Once the simulation is finished, a screen appears with the results in different formats.

- **Interactive support graphs.** They are interactive graphs that show the financial evolution of planting in time, broken down into expenses and income and cost distribution of labor and machinery.
- **Economic indicators. Total expenses:** result of the sum of all labor, machinery and input expenses. Total income: sum of the income obtained by product sale. Profits: Difference between income and expenses. NPV: Net Present Value. IRR: Internal Rate of Return calculated by the Newton- Raphson method.

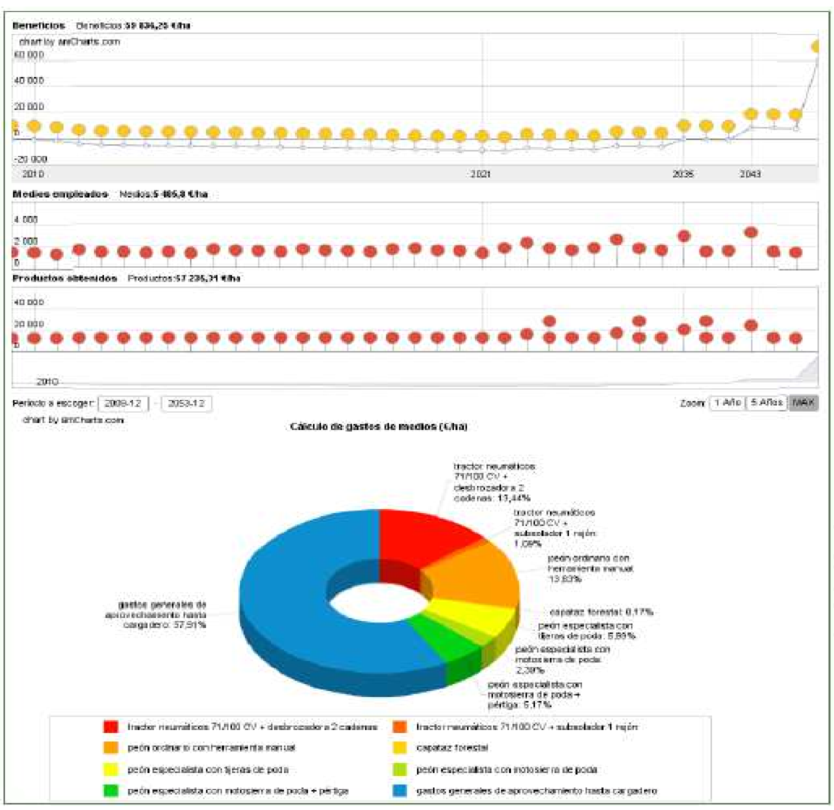

Fig. 4. Different economic indicators for a simulation.

- **Planting visualization with Google Earth**: The evolution of the planting of the parcel is shown by means of a Google Earth plugin (at this moment only available for Windows and Mac OS X 10.4 +). This enables a landscape analysis of the different decisions and operations carried out. It is a 3D representation of a planting on the square of the whole parcel or just a section, where the user can fly virtually into the trees, “walk” between them or make visualizations within a wider context.

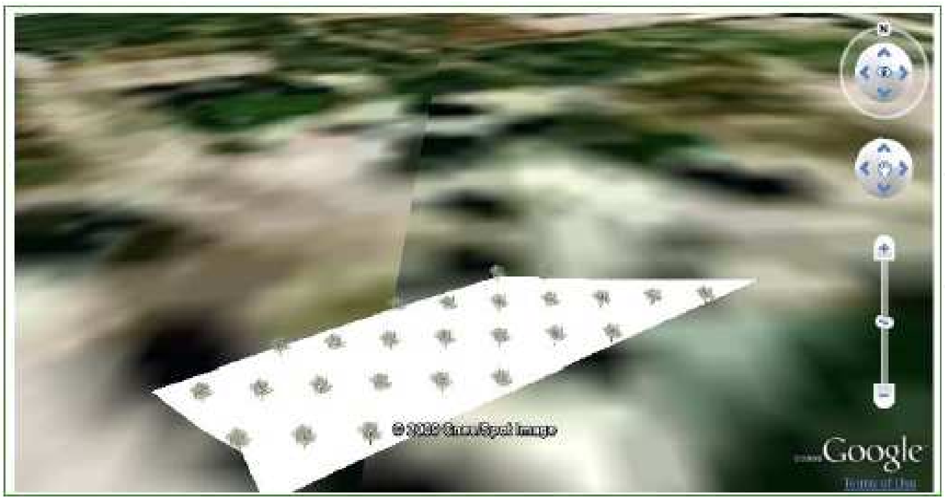

Fig. 5. Location of trees in a parcel and selected model.

Exportation

Exportation can be made in three formats, depending on the interest of the user: **kmz (**Compressed file containing geographical data and tridimensional models used to present the evolution of time in the planting. It can be opened with Google Earth), **pdf y xls.**

4. Conclusions¶

Decision Support Systems have proven to be useful in the different economic fields in which they have been developed because of their capacity of simulation and optimization. Forest DSSs have evolved over time thanks to IT, on the one hand, and due to the need to introduce higher social and environmental restrictions to forest management, on the other hand.
The development presented in this chapter includes the most advanced techniques in IT (web application and virtual reality simulation). It is also easy to use, which would allow a higher number of users to have access to it without much IT or forestry knowledge. Thus, it could, and it should, become a tool for forestry extension, which would make this type of management more sustainable and will give the possibility of increasing its level of technification.
New lines of development that will result into a better tool to the service of owners and forest managers are: the inclusion of optimization options and stochastic processes, the resolution by heuristic methods in which the risk of forest activities in different geographic environments will be taken into consideration and an improvement in the visualization options of virtual reality.

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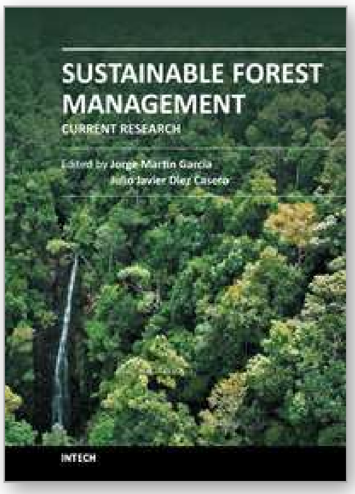

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