



Original papers

A compiled project and open-source code to generate web-based forest modelling simulators

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ABSTRACT

Sustainable forest management requires decision support systems to evaluate possible scenarios and anticipate the consequences of decisions. Forest modellers typically develop complex systems of equations to predict the behaviour of forests which makes the use of forest models difficult for end-users in general, affecting transfer of knowledge and technology. To overcome these difficulties and facilitate their practical use, models can be integrated into software to generate user-friendly forest simulators. In this paper we introduce and describe ForestMTIS, a cloud computing compiled and editable open-source project to generate forest simulators which was developed for statistical, non-spatial, deterministic, disaggregated, single species even-aged stand growth and yield models. We demonstrate the use of ForestMTIS based on the development of FlorNEXt®, its first practical application, based on a collaborative approach to make growth and yield modelling and sustainable forest management available to a large community of users in the Northeast of Portugal.

1. Introduction

Sustainable management of resources has been a widely studied topic in forest research (MacDicken et al., 2015). Forest management is a set of spatial/temporal decisions to achieve one or several goals under a sustainability framework (Borges et al., 2014). The management of resources demands anticipation of the consequences that decisions might have on the forest ecosystem (Hynynen et al., 2015). Decision-makers need, therefore, based on the best available information, to evaluate the current condition of the forest and to predict the future short and /or long term state of the system based on simulations of possible scenarios (Ludwig, 1993).

Defining the state of the forest involves increasing information levels because more and more factors and actors require consideration (Lidskog and Löfmarck, 2016). Decision Support Systems (DSS) have become progressively useful in decision-making to design and implement proper sustainable forest resources management schemes (Gadow and Pukkala, 2008). Moreover, DSS are useful for researchers and students to better understand forest dynamics and how forests can be affected by human management (Kulakowski et al., 2017).

Forest growth and yield models developed for natural or planted single species even-aged stands can be a DSS or a subset in a more complex DSS. These forest models, and in general DSS, are usually comprised of a large number of equations and algorithms with the

purpose of producing useful estimates. This complexity often makes it difficult for end-users to apply forest modelling in management or even research, inhibiting effective transfer of knowledge and technology. To facilitate the practical use of forest models, these can be integrated into software able to generate simulators (Lorek and Sonnenschein, 1999) with user-friendly application forms and automated processes for execution and display of results. In these forest simulators, models are fixed and the end-user can adapt them to his/her needs by setting inputs. Simulators are best suited to meet the needs of end-users who work with existing models (Larocque et al., 2015). The development of forest simulators has been increasing in the last decades. For example, various pieces of software are combined in several DSS tools described in the FORSYS Wiki (Packalen et al., 2013), in the ForestDSS web page (ForestDSS, 2016), the Capsis platform (Capsis, 2016) or in the Tools & Applications webpage of the USDA Forest Service (2016). Most of these are desktop tools but hypertext technology developments in the late 20th century, such as ASP or PHP, opened the possibility to apply simulators in cloud computing. Briefly, hypertext technology allows embedding text scripts that can run on the user's computer, enabling interaction with the server (Adebukola and Kazeem, 2014). Cloud computing presents many advantages over desktop computing, such as adaptability to different platforms, independence of operating system, and easy ways of improving and updating existing versions (Dillon et al., 2010). Nevertheless, some disadvantages can be pointed out such

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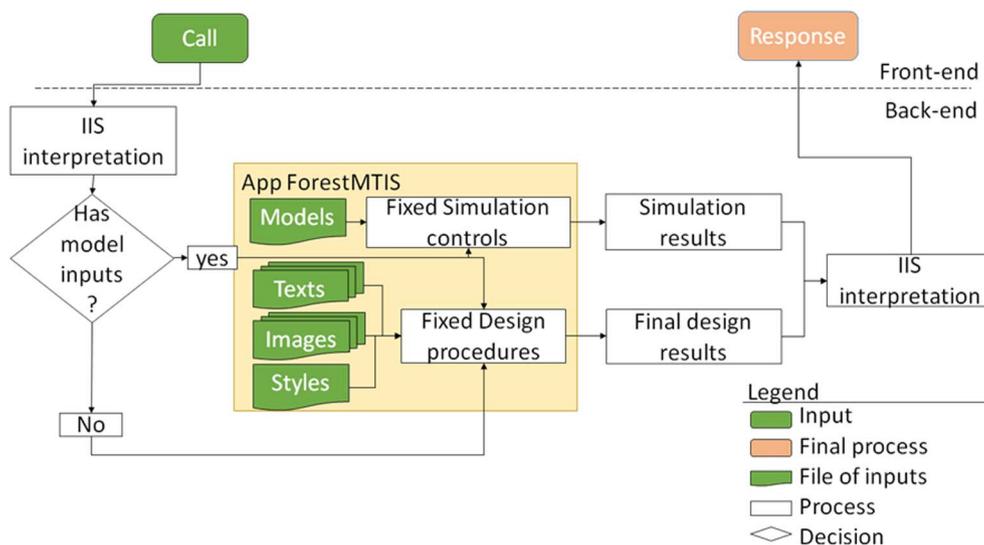


Fig. 1. Flux diagram of the generic ForestMTIS project.

as the requirement for periodic maintenance and computational capacity limitations, depending on the server capacity (Nwobodo, 2016). EucaTool® (Rojo-Alboreca et al., 2015) and WEB-Globulus (Palma, 2016) are good examples of cloud computing applications in the Iberian Peninsula.

Forest modellers are usually not programmers and costs of developing software or license issues may prevent them to develop simulators. However, the increasing availability of free or open-source software facilitates integration of models into modelling and simulation platforms. According to Larocque et al. (2015), modellers and end-users must spend more time on model development or analysis of simulation results than on programming. Nevertheless, there is a gap between modellers and end-users which is recognized in forestry and in many other fields (Folke et al., 2005). Forest modellers should make all efforts for an effective knowledge and technology exchange and transfer, especially when it can be applied in improving sustainable management and decision making in natural resources (Vacchiano et al., 2012).

In this context we developed ForestMTIS (Forest Models, Texts, Images, and Style), a compiled and editable open-source project to generate simulators. The objectives were (i) to assist forest modellers in the transfer of stand models to end-users, (ii) to provide end-users with an user-friendly simulator interface to support sustainable forest management, and (iii) to publish the code to open future improvements by programmers.

2. Materials and methods

2.1. ForestMTIS project, abstraction and generalization

ForestMTIS was created as a generic forest simulator open-source project that can be synthesized in simple procedures to facilitate interactions of end-users with forest growth and yield models. Briefly, this synthesis can be hierarchized in: (i) input forms, (ii) transformation and calculation procedures, and (iii) output forms. In the particular case of web development, the input and output forms are part of the front-end (Lara et al., 2013). The front-end of a website is where users interact with the webpage, in the case of ForestMTIS where data is inputted by users in controls like text boxes and output data is displayed in graphics or tables and where it can be downloaded from. The transformation and calculation procedures is the back-end of the development that often runs in a server. Here, controls or procedures call the models inputting data and producing output results of the simulations. The interaction between the front-end and the back-end is based on request and responses transferred by Hypertext Transfer Protocol (HTTP).

These kinds of developments follow the same functioning of desktop tools in the sense that the application is executed by the set of files that comprise the application but, as web developments, they differ from these since the application runs in a server using an interpreter like Apache or IIS to connect front and back end. These interpreters deploy, manage and run the web applications, establishing the interaction with the client using remote calls to public IP addresses or URLs (Talwar et al., 2005). This philosophy of software development is known as Software as a Service (SaaS) (Ma, 2007) because the owner of the application offers the service without the possibility of modifying the architecture of the development and maintaining the security and integrity of the procedures. This kind of cloud applications do not, therefore, require specific installation and can be freely accessed from any internet-connected device (desktop or laptop computer, mobile phone, smartphone, tablet, etc.).

The ForestMTIS project was developed in ASP.Net using MVC 4.5 technology. It is hosted in Open Source Repository (<https://sourceforge.net/projects/forestmtis/>) in two forms: (i) the editable project (*ForestMTIS_Project* folder) and (ii) the compiled project (*ForestMTIS_Compiled* folder). The editable project requires programming knowledge to be handled because it contains all the application procedures code and it requires an Integrated Development Environment (IDE) of C#, such as Visual Studio, to be opened. By providing the full code we intend to keep open the possibility for potential users to modify the architecture of the development, reuse the code or interpret and translate it in other languages. The compiled project requires less technical knowledge to be used. The compilation includes fixes and editable files (Fig. 1). The fixed files resulted of the compiled C# project that are not allowed to be modified to maintain the stability of the procedures (Fixed Simulation controls and Fixed Design procedures). Editable files are organized according to the following sections: (i) Models, containing the developed models, (ii) Texts, a set of files containing all texts of the application, (iii) Images, used to define the front-end appearance, and (iv) Style, or Cascading Style Sheets (CSS), that contains the formats of each of the elements in the tool (i.e., colours, font type and size, width and height of panels, etc.). The fixed files are dynamic-link libraries (*dll*) run by the deployment application IIS. These files include all procedures required to call and use Models, Texts, Images and Styles files in the project.

2.2. Forest modelling requirement

ForestMTIS was developed to generate simulators which work with disaggregated statistical non-spatial deterministic even-aged stand

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