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Teaching Water Management to Future Engineers: Using R to Blend Programming Needs and Gis

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Abstract

The University of the Basque Country (http://www.ehu.es) is the most important University in the Autonomous Region of the Basque Country, Spain. The students of the Faculty of Engineering (Bilbao) in the last year of their studies, before becoming engineers, have the opportunity to select a block of subjects intended to enhance their knowledge on generally speaking, Fluid Mechanics.
One of the subjects in this stream is called "Management and Maintenance of Hydraulic Systems" and is devoted to different aspects of the water cycle management. In this subject, state-of-the-art operation and management techniques are taught to the students. Apart from the transmission of good practices and standard applied protocols, the focus is practical and is based on hands-on computer real-life exercises, which involves not only intensive programming using a high-level software, but also the spatial representation of results.
Additionally, all the information on water management and associated spatial planning, is usually freely available and made public by regional, national and European institutions using Geographical Information Systems (GIS) standards, usually .shp files. For this reason, students need to effectively read this information, calculate results and finally, yield a spatial representation of the same.
R (https://www.cran.r-project.org/) is a freely available software that provides an optimum answer to these combined needs and challenges due to its modular structure. R has a core module and nearly 8000 packages specifically developed for different purposes are also available. Packages like "sp" "rgeos", "rgdal", "maps", "maptools" and "mapdata" have been developed to make R work with full functionalities just like any GIS software, while exhibiting all the capabilities of any high-level programming software.
R has been adopted as a standard by many scientific communities and more and more recent developments in the field of water management are defined in the frame of R as gathered in the scientific literature.
Incorporating R into the teaching activities of the subject in the last edition of "Management and Maintenance of Hydraulic Systems" has represented an important step forward in the education of future engineers while providing them with real-life tools used in water management.

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1. Introduction

The University of the Basque Country (EHU/UPV) is the most important University in the Autonomous Region of the Basque Country (Spain) and the one with the widest range of educational offer, with almost one hundred qualifications.
The thirty faculties and university colleges, located in campuses in Alava, Bizkaia and Gipuzkoa, cater for more than 60,000 students, 3,500 lecturers and a thousand professional staff.
Bilbao's Faculty of Engineering is more than 100 years old, belongs to EHU/UPV and is located in Bilbao (Basque Country), in the heart of one of the most dynamic and wealthiest areas of Spain. Bilbao`s Faculty of Engineering is a unique institution particularly intended to bridge high-level education, research, industry and social leadership.
Since its beginnings our School of Engineering has inspired and been closely linked to the economical development of the region, while providing local institutions with leaders that through history have shown their full commitment with this task.
Historically, the Fluid Mechanics Department has been in close connection with the Water Supply public services in the Basque Country and the most talented students of Engineering from our School have had a leadership in this field.

2. Water management studies at Bilbao's Faculty of Engineering

2.1. General scope of the studies of Engineering

After the Bolonia reform, the engineering studies in Spain take place in two steps: a degree of Engineering (4 years) and a Master on Engineering (2 additional years).
During the first four years, students have two major compulsory subjects on Fluid Mechanics and Hydromachinery. If they decide to go for the additional two years of the Master, they have the option to select several streams in which apart from a major group of common subjects, they can attend different groups of a few interconnected subjects, each of one constitutes an optional stream. One of these groups is the Hydraulic Stream with subjects ranging from Computational Fluid Mechanics (CFD) to Oleohydraulics-Pneumatics and also a specific subject on water management.

2.2. Management and Mantainence of Hydraulic Systems

This is the title of the subject that within the framework of this Hydraulic Stream, deals with all the aspects of water management. The focus is practical and the syllabus includes visits to water treatment facilties (Fig.1) and beyond explaining widely used good practices of water managements, students have to learn to solve real-life problems.

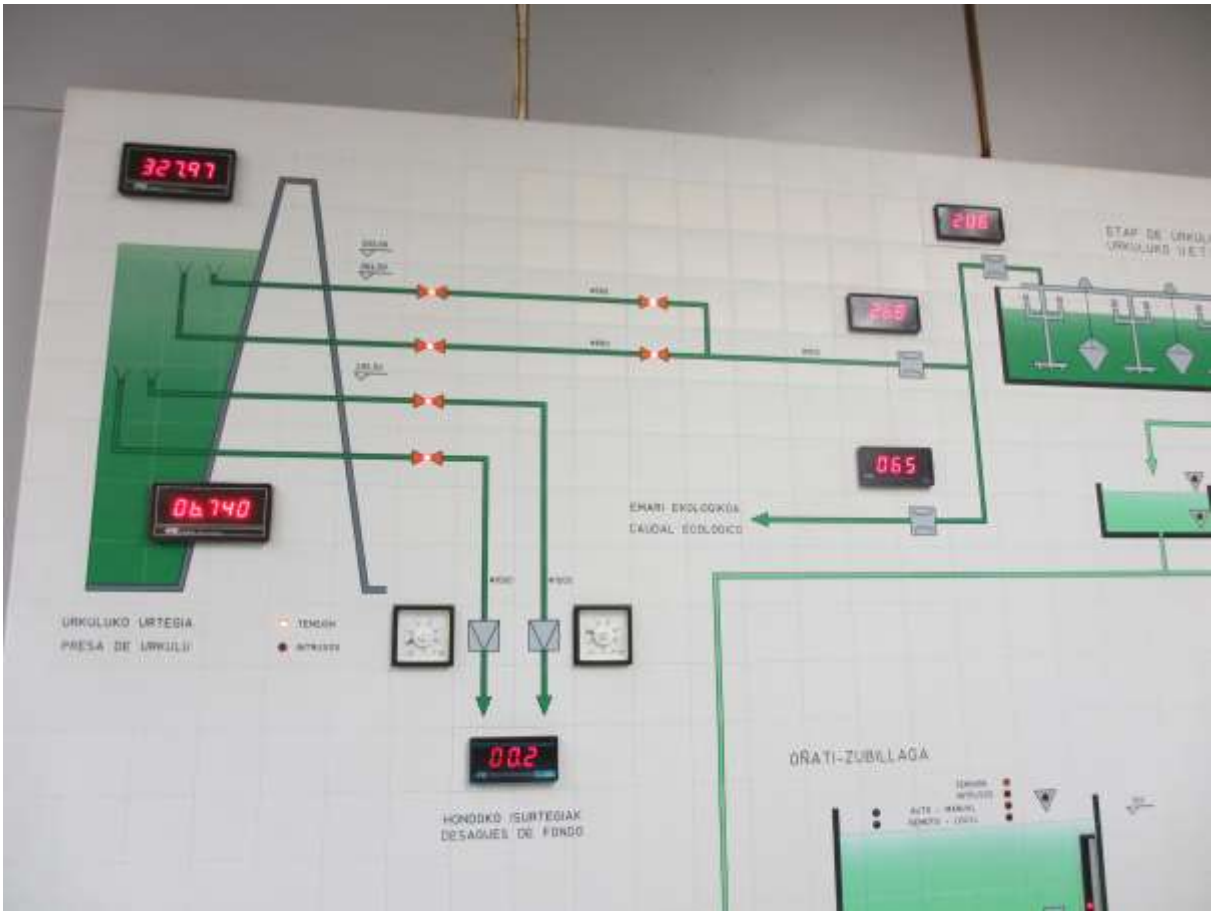

Fig. 1. Control panel at the water treatment plant of Urkulu

This includes handling two groups of skills:

1. Solving real life problems like the correct design of water supply tanks, optimal selection of wells and pipes diameters, overall planning for a given area and water availability estimation under several climate change scenarios This involves the use of a high-level programming software.
2. Spatial planning and geographical characterization of available water resources. This implies the use of a geographical information system (GIS) software.

In many occasions, solving real-life problems involves effectively combining both types of skills, so that results can be also georeferenced and available information on water systems can be incorporated.

3. R a multipurpose software tool

R (https://www.cran.r-project.org/) is a freely available software that provides an optimum answer to these combined needs and challenges due to its modular structure. R has a core module and nearly 8000 packages specifically developed for different purposes are also available. Packages like “sp” “rgeos”, “rgdal”, “maps”, “maptools” and “mapdata” have been developed to make R work with full functionalities just like any GIS software, while exhibiting all the capabilities of any high-level programming software. In this line, R represents the perfect blend between a GIS and a programming software, thus enabling users to extract all available information expressed in geographical terms and then combine and elaborate it to yield operational results.

4. R: an appropriate tool for water management

In the last years, more and more tools are being developed regarding water management that are designed to be operated in the framework of R [1],[2],[3],[4],[5],[6]. All these works as gathered in the scientific literature, include several tools for resource evaluation in the frame of climate change or decision making, in most occasions in combination with geographically referenced information.

5. Teaching water management to future engineers using R

In view that many recent developments in the field of water management are taking place in the framework of R, students of the “Management and Mantainence of Hydraulic Systems” subject receive intensive training on R to keep up with state-of-the-art techniques.

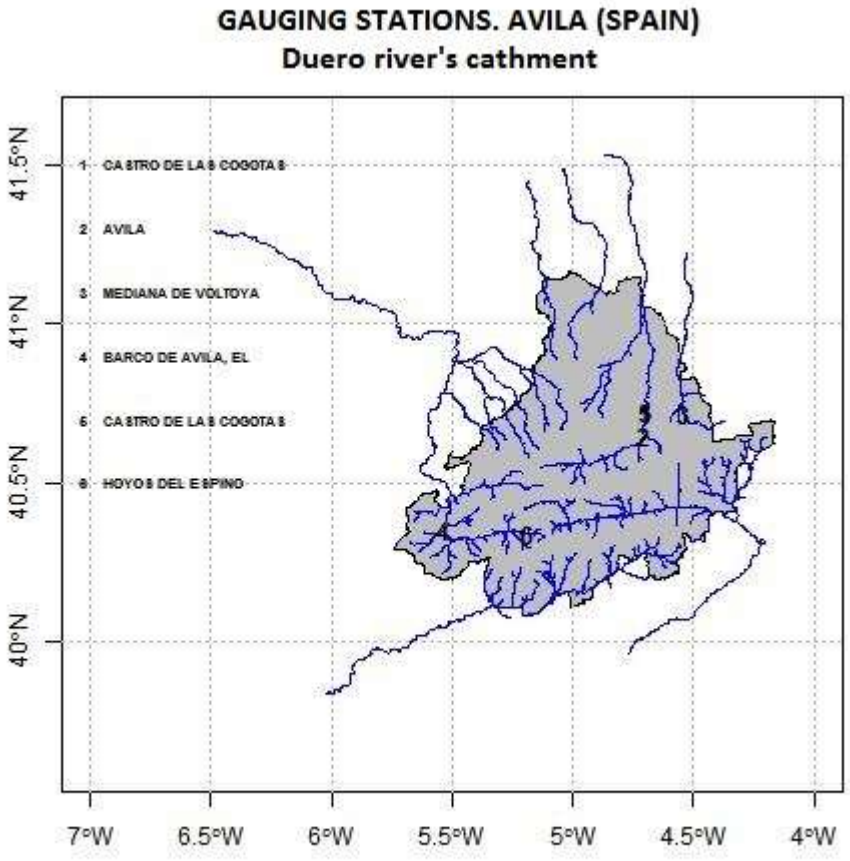

Fig. 2. Location of gauging stations in the Duero catchment in the province of Avila

The Spanish Ministry of Agriculture and Environment offers relevant information for water management in GIS format as ENRI .shp files. http://www.magrama.gob.es/es/cartografia-y-sig/ide/descargas/agua/default.aspx. Many other institutions at regional level ftp://ftp.geo.euskadi.net/cartografia/ , http://www.mirame.chduero.es/DMADuero_09/index.faces http://iber.chebro.es/geoportal/ or European level http://inspire-geoportal.ec.europa.eu/ do the same. By the end of the course students are taught to effectively import and retrieve information using R as both, a GIS and a programming tool (Fig.2 and Fig. 3).

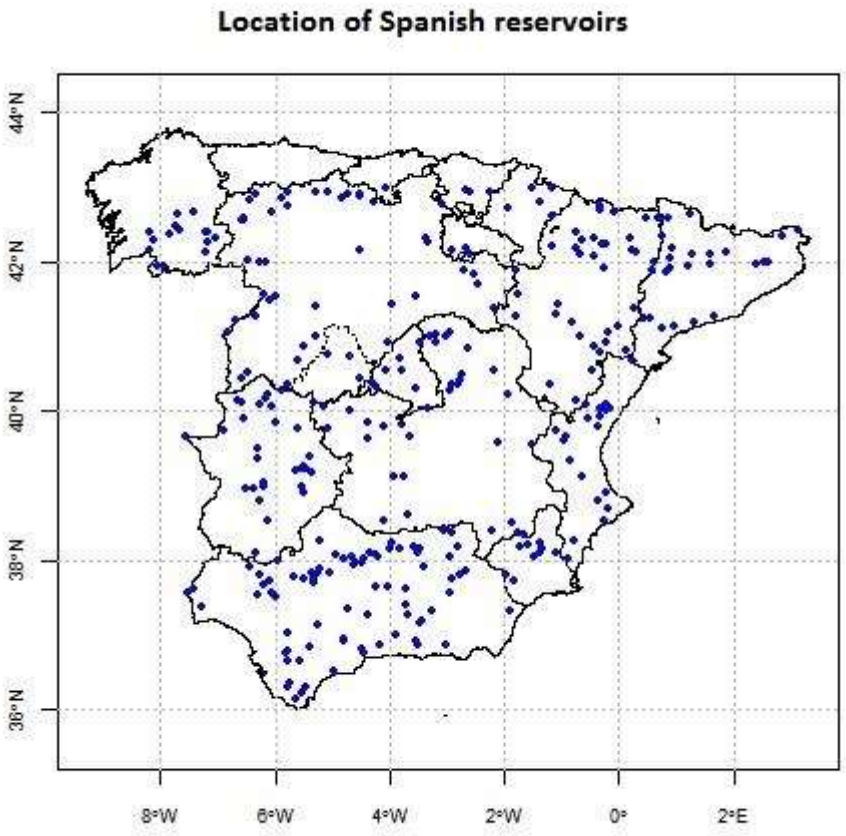

Fig. 3. Georeferenced location of Spanish reservoirs

6. Conclusions

Incorporating R into the teaching activities of the subject in the last edition of “Management and Maintenance of Hydraulic Systems” has represented an important step forward in the education of future engineers while providing them with real-life tools used in water management.

It is important to stress the idea that this is the only subject that incorporates R as a programming tool and also the only subject that teaches students to import and understand georeferenced information. This is due to R’s capabilities to work as a full GIS software while holding all the capabilities of any high-level programming software. The structure of R (a core module+specific packages for different applications) enables all this and beyond the specific use for water management, R is being adopted by an increasing number of scientific communities and is being used in more and more engineering problems, either related to water management or otherwise. This means that the concepts introduced in this subject will also be helpful for students that in their future professional career work in any field of engineering.

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