Towards Accurate Traceability of Water Reaching the Reservoirs

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***Abstract*— Drinking water is one of the natural resources most consumed by human beings and an important transmitter of diseases if it is not subjected to adequate quality controls. In Spain, much of the drinking water comes from reservoirs whose watershed is often occupied by farms. This means that part of the reservoir water has been in contact with phytosanitary products used on these farms. In this work, a methodology is being developed to determine the origin of the water flow that reaches certain areas of the reservoir. It is a 3D modelling and simulation methodology for the advance of the flow after a given rainfall event. To this end, work is being carried out on an improved version of the D8 algorithm, in which an extensive hydrological analysis is carried out, allowing more input parameters to be controlled in a more detailed manner. This allows 3D modelling and simulation of the rainwater trajectory until it reaches the reservoir.**

Keywords- Extended D8 algorithm; Drainage Network,; Chemical Monitoring.

I. INTRODUCTION

The use of crop protection products in agriculture is a common practice in agriculture to increase crop yields. However, the extensive use of these products mainly affects the soil, and sooner or later these substances end up in rivers and aquifers. In some countries in the Mediterranean basin, many rivers and aquifers flow into reservoirs whose water is also used for irrigation and human consumption. Soil conservation is therefore a key point for obtaining good agricultural yields and at the same time eliminating dependence on chemicals. Technicians and public administrations are looking for effective mechanisms to control these discharges and to carry out water traceability, especially in the case of water intended for human consumption. At present, the use of chemicals is not banned in agriculture or in the European Union (EU). They are widely used to fertilize the soil or to eradicate pests. In fact, it is difficult to find a balance between increasing production and preserving the environment. Food supply and food security are key objectives at EU and United Nations level.

A number of organizations have committed themselves in the coming years to address efficient soil management to meet the major challenge of increasing food production while minimizing soil degradation through sustainable development plans. In this regard, the 2030 Agenda and the Sustainable Development Goals (SDGs) adopted by all United Nations (UN) member states in 2015 call on all nations to combine economic prosperity, social inclusion and environmental sustainability with peaceful societies. They are closely linked to the Paris Agreement (United Nations, 2015) on climate change, which is incorporated into SDG 13 (Climate Action). These goals and targets entered into force on 1 January 2016 and will guide government decisions in the coming years.

The present work focuses on developing a methodology for the traceability of rainwater reaching a reservoir and determining its possible origin considering the crop areas of the basin it supplies. Specifically, the study focuses on the water reaching the Rumblar reservoir in the province of Jaen (southern Spain). This reservoir is mainly fed by river water from the Guadavelín and Pinto rivers. This reservoir supplies drinking water to a large part of the inhabitants of the province of Jaen. The water from this reservoir is subject to quality controls by governmental companies, which carry out regular chemical analyses. The company's technicians have observed that, after a period of rain, the chemical analyses reveal a higher concentration of nitrates. These components come mostly from olive groves, which are predominant throughout the catchment area. Therefore, an exhaustive study on the origin of the discharges should involve the study of the catchment basins, land use and orography of the terrain. Drainage networks have been used to study chemical tracing [1], as well as GIS techniques [2]. However, 3D simulations have also been used for similar purposes [3], but employed as stand-alone techniques.

In this work, an improvement of the D8 flow model algorithm is being developed in order to establish a workflow in which different scenarios can be simulated in the course of rainwater from its precipitation to its arrival at the reservoir. This simulation is also used to determine the concentration of substances at specific locations and to make a comparison with the agricultural use of the land. In this aspect, GIS tools provide the capacity to cross-reference all

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this information on the drainage network with the different land uses and to be able to focus the analysis on specific farms.

The document is structured as follows. Section 2 describes the methodology carried out and the data processing carried out jointly in QGIS and the D8 algorithm enhancement. Section 3 shows the first results with a plugin that has been implemented in Qgis to make it easier to use the extended D8 algorithm. Section 4 describes the conclusions and future work to be developed.

II. METHODOLOGY

This section describes the process to obtain the traceability of water runoff along its path to the reservoir. The objective is to know which areas the rainwater comes from and arrives at specific points in the river basin that finally discharge their water into the reservoir. The aim is also to obtain the percentage of water that each of these areas contributes to the points under study. It is important to know whether this origin is agricultural or not in order to be able to carry out a more detailed study of the areas that contribute water to the reservoir. Therefore, this study helps to identify which farms contribute to the concentration of discharges or make inappropriate use of fertilizers or plant protection products. Fig. 1 shows schematically the process. The first two steps identify a series of representative points on which to focus the study and in the second phase (steps 3 and 4) a detailed study of the traceability of the water flow in these representative points will be carried out.

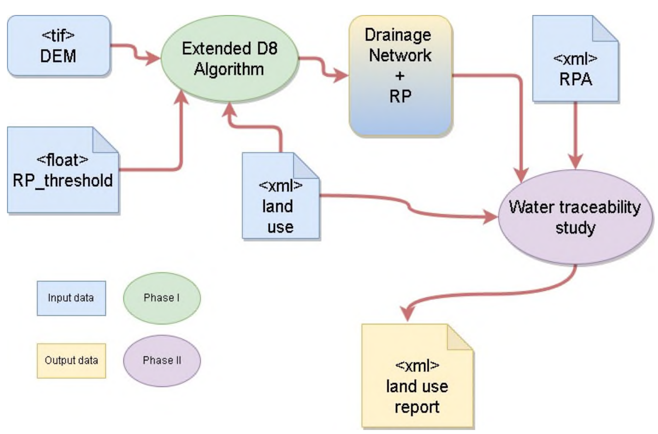

Figure 1. Flow diagram of the methodology proposed.

A. Research Area

The study was carried out in the area around the Rumblar reservoir, which is a storage reservoir built on the course of the river of the same name (38° 09′ 42″ N 3° 48′ 15″ W, ETRS89), in the municipality of Baños de la Encina, in the province of Jaen, southern Spain. This region has a semi-continental climate with a mean annual temperature of 25.1ºC, a mean relative humidity of 70% and a mean annual precipitation of 1341 mm. The capacity of the reservoir is 126 hm^3 although it is currently at 16 % of its capacity [4]. The reservoir is located in the heart of the Sierra Morena mountain range, surrounded by Mediterranean woodland with holm oaks and cork oaks, and is an ideal habitat for species such as the Iberian lynx. In the surrounding area it is possible to observe a large group of birds of prey and carrion-eating birds, as well as some mammals such as otters, foxes and huntable species such as mouflon, fallow deer, wild boar and deer. A few kilometers from the reservoir, the relief and vegetation change considerably, with olive groves alternating with hilly pastures where wild cattle graze. For the purpose of our research, we covered an area of 56497 ha. Fig. 2 shows the location where the research has been carried out.

B. Data set

In the first phase of the work, the hydrographic elements of the study area were obtained from the Digital Elevation Model with a spatial resolution of 2x2m that forms part of the Spanish Spatial Data Infrastructure (IDEE) platform which follows INSPIRE Regulation (EC) No 1205/2008. This model was downloaded from the Download Center of the Autonomous Section of the National Center for Geographic Information [5]. It is a model obtained by interpolation from the terrain class of the LIDAR flights of the second coverage of the National Aerial Orthophotography Plan (PNOA) [6]. Another important layer of information to be integrated into the system and which will allow the identification of areas to monitor the dumping of phytosanitary products is that of land use in the Rumblar basin. The land uses established in the information layer have been obtained from the information compiled by CORINE Land Cover, a cartographic inventory of land use and a basic instrument in environmental and land-use planning policy in the EU.

C. D8 extended

The D8 method for obtaining the drainage network needs the DEM (Digital Elevation Model in tiff format) file of the area associated with the reservoir basin. This process works similarly to the D8 algorithm introduced by O'Callaghan and Mark [7]. Initially, the method codifies in each cell C(i,j) one of the eight directions where C(i,j) drains its water accumulation. Then, an iterative process makes in parallel that all cells drain their accumulated water to its neighboring cell, depending on this specific direction. The process finishes when no more water is drained along an entire iteration. Those specific points whose accumulated water exceeds a threshold (RP_threshold in Figure 1) at any moment of the process, are considered representative points (RP). The set of RPs is the input of this first process, which in fact works similarly to the original D8 method. However in a second phase, the algorithm is processed again and for each representative point and for each iteration of the process, the following information is stored in a set of tuples <id-plot is the identification number of the plot and accumulated-water the amount of water from this plot>.

There is one tuple for each different plot pouring water sooner or later into this RP. The plot is represented by a specific identification number, and for each of these plots we maintain information about the water traversing the RP. The algorithm finds these representative points (RP) automatically, however the user can add specific ones (RPA) if additional strategic locations are decided to be used for chemical analysis. This information is the input for further processing that can be done in QGIS.

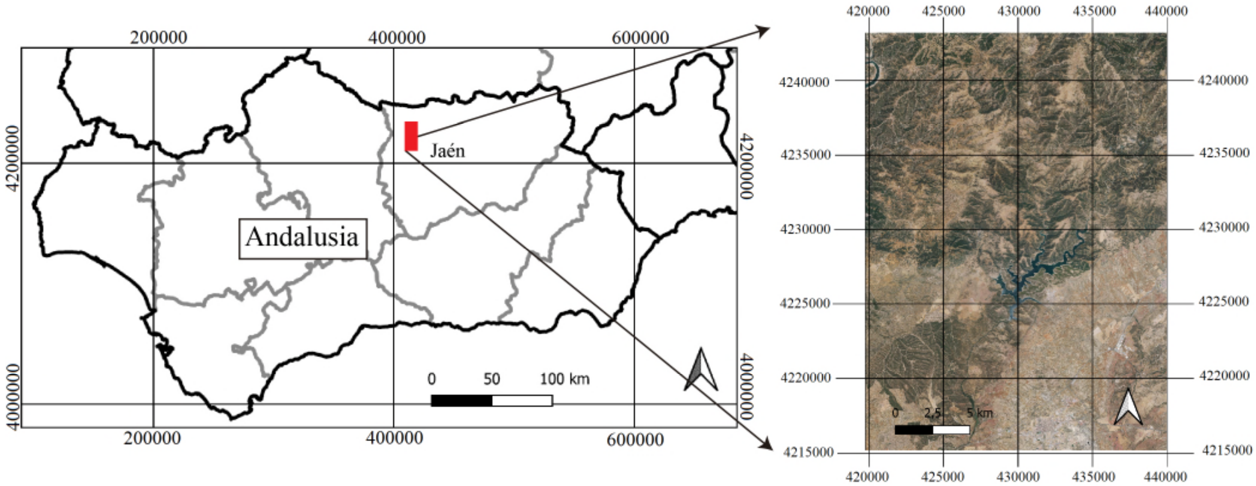

Figure 2. Location of the research area. The left image represents the south of Spain (Andalusia). The right image is the map of the Rumblar reservoir in Jaen. The coordinates (m) are UTM, zone 30 referred to ETRS89.

III. RESULTS

Once the extended algorithm has been implemented, the idea is to be able to identify a drainage network according to different previously established conditions, Fig.3.

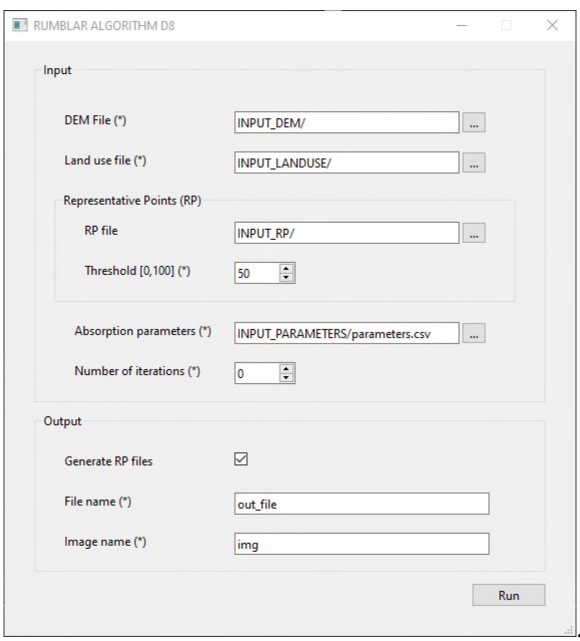

Figure 3. Interface to the main menu of the system in which the extended D8 algorithm has been implemented.

First of all, our algorithm needs the DEM and the land use layer of the working area, which is necessary information to be able to carry out the traceability analysis, which is the main subject of this work. Secondly, an interesting functionality is to be able to add new RPs to the system, not only those generated by the classical D8.

On the other hand, the classical D8 algorithm simulates the same amount of precipitation at each pixel. However, in the extended version of the algorithm, the amount of precipitation is also an input parameter depending on the areas. From the zonal cumulative precipitation maps, each pixel can be assigned a different precipitation value, which is very interesting when working with large areas of land, as the amount of precipitation is different in each zone. It is also possible to define different levels of water absorption by the soil, depending on the underlying soil type. The absorption capacity of the soil depends not only on the slope extracted from the DEM, but also on the type of material on which it rains.

The number of iterations is another input variable of the extended algorithm. This parameter controls the whole execution process of the algorithm. By default it runs completely, until the rainwater runoff ceases. But it is possible to set a certain number and control the progress of the process at intermediate stages. It will also be possible to overlay land use and query the system to see which areas have received the most rainwater. An Qgis plugin has also been implemented to allow interaction between the user and the system. The system automatically selects on the map the plots that have contributed water to that point, and the percentage that it represents with respect to the total water accumulated in it.

In this case, a provisional result can be displayed. Fig. 4, which shows a screenshot in which it can be seen how, when clicking on a characteristic point, the algorithm identifies

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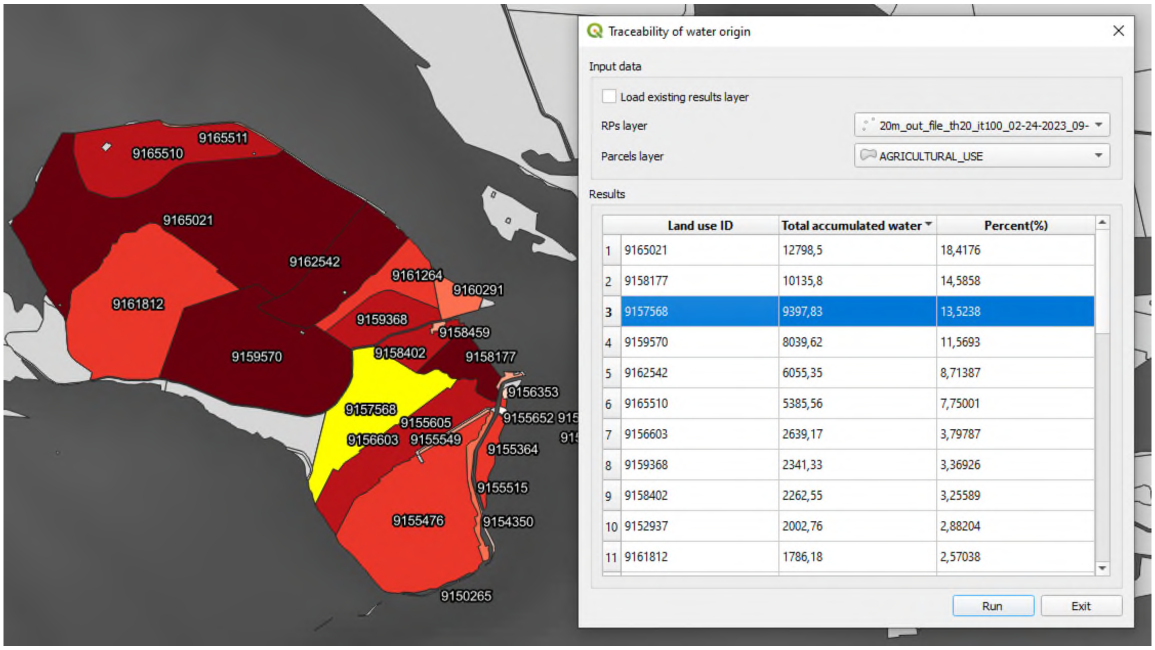

Figure 4. Example of a query executed with the Plugin.

from which plots the water that has reached that point comes from, and the information related to each plot. This information is essential for water treatment plant managers, since by analysing water samples in specific areas, if they detect abnormal values of certain chemical substances, they will be able to know from which farms these pollutants may be arriving.

Finally, it will be possible to consult from which areas rainwater reaches the reservoir and which are absorbed by the soil and do not reach it. It is therefore a question of having a system in which we can use different configuration parameters of the drainage network to achieve the most accurate traceability possible of the water that reaches the reservoir, with the added value of using an easy-to-use application.

IV. Conclusions

In this work, a methodology has been developed to determine the origin of the water flow that arrives at certain points in the reservoir basin. It is a methodology for modelling and simulating the advance of the flow once it has rained using an improved version of the D8 algorithm. The resulting developed work is an easy to use tool by managers of drinking water treatment stations. The spatial information uploaded into a GIS software joined to the run of the extended D8 algorithm helps us to extract information about the study area with just one click on the screen. The algorithm is still undergoing debugging and validation. It needs to be tested against field data in different parts of the study area. However, the tests carried out so far show promising results.

Acknowledgment

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