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Flood modelling and citizen observatories: analysing pathways for data collection in the Sontea-Fortuna case study

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Abstract. Accurate flood models require large amounts of data inputs which are not always available. Recently data coming from other sources, such as crowdsourced data, have been increasingly explored in the scientific literature. However, there is no clear methodology showing where willing citizens could go for data collection. Thus, this study proposes an optimization framework to generate and prioritize pathways that citizens could take while collecting data. The proposed framework is tested on the Sontea-Fortuna area, part of the Danube Delta, where water stagnation is threatening the local ecosystems. Among the pathways generated, results analysis showed that pathways closer to the starting point were more effective.

Keywords: Citizen Observatories; Danube Delta; Flood Modelling; Optimization; Pathways Design.

1 Introduction

Floods are a natural phenomenon that can be seen as risk or benefit. For the latter, floods can balance ecosystems by maintaining flow rate in certain ranges and in certain times, so that water quality and nutrient concentration are adequate for ecosystem survival [1]. Human interventions can disrupt such ecosystems, with consequences in biodiversity loss. Flood models have been used in management to characterize problems and propose solutions, e.g. design structural measures or perform scenario analyses. Such models require large amounts of data that are not always readily available [2]. One data source that has received increasing attention in the scientific

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community is crowdsourced data. Citizens can contribute by providing water levels, velocities, flood extent, land cover and even topographic information [3]. Citizens' contributions mentioned in the literature generally evaluate either data collected at random times and locations or in few selected points [4]. One study evaluated where water level collection should be done in a catchment, although citizen contributions were synthetically generated [5]. Within the four H2020 Citizen Observatory projects approved by EU, SCENT project is directly connected to the use of such data for flood modelling. Moreover, in the SCENT project field campaigns are planned, hence the present study proposes an approach for identifying pathways for citizens to collect data. The case study where the approach is tested is located in the Danube Delta, which is of international importance due to its biodiversity (RAMSAR site). In the delta, water stagnation is an issue for water circulation and quality, and flood modelling could be used for further investigation if improved with additional data.

2 Case Study

The present study is carried out in Sontea-Fortuna, part of the Danube Delta (Figure 1). The area has 350 km^2 of an intricate system comprising 259 km of internal channels and 11 major lakes. Three main branches of the Danube River bound the region. The main supplier of water to the system is Canal Mila 35, an 11 km constructed canal for navigations purposes. The flow in the Danube River is seasonal, with low flows in the autumn and high flows in the spring. The average flow of the Danube River is 6283 m^3/s [6]. The land cover is basically wetlands and the area is mostly flat, with an average slope similar to the one of the Danube Delta, which is 0.043% [6].

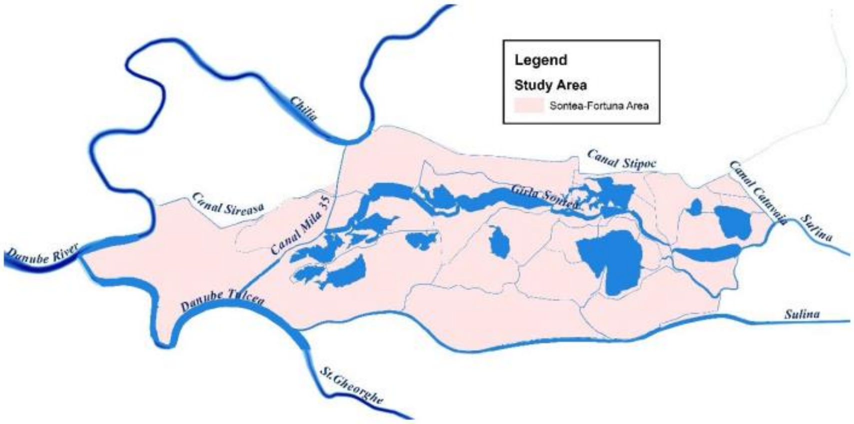

Figure 1 Sontea-Fortuna area schematic

3 Methodology

This study is divided into three main parts: model development, pathway approach development and implementation of the approach. The implementation is restricted to scenario analysis. The model was used to identify stagnation points and also to define regions that are not accessible (criteria are presented later). A hydrodynamic model was developed in HEC-RAS, simulating the network as 1D channels and the lakes as storage areas. Overall, 341 cross sections were used for model building and the interpolation interval was 200 and 500 m for internal and main branches. Different downstream boundary conditions were tested: rating curves obtained from an existing Danube Delta 1D model; rating curves from applying the Manning equation at the same points; and constant water level by extending the river network up to the sea. Due to high uncertainties in the first two cases, the latter was selected. The Black Sea constant water level is 0.6 m. Finally, the time step used was 1 min. The model was calibrated and validated with upstream boundary conditions of 3034.7 m^3/s and 2380.3 m^3/s, respectively. Data for calibration and validation included 9 and 6 discharge values, respectively. Used performance measures were Root Mean Square Error (RMSE) and absolute differences. The RMSE for calibration and validation were, respectively: 1.37 m^3/s and 22.6 m^3/s. Absolute differences were satisfactory small for both types of channels. Due to lack of data only low flow situation was calibrated. With the calibrated models three scenarios were simulated: dry (2300 m^3/s), average (7000 m^3/s) and high (15800 m^3/s) flows. Points and stagnation level were found based on simulated velocities. Overall, 39 out of 101 reaches were stagnant.

4 Pathway selection approach

As the study area is a wetland, the access to observation points (pathways for citizens) is done by boat. It is considered that citizens will be able to collect water level, velocity and land cover data. The pathway selection approach is developed as an optimization problem, where the decision variable is the pathway location, the objective function is a score and the constraint is the maximum transit time for the boat. The approach's first steps are to select specific purposes for data collection and to select the location sets, where data can be collected for such purposes (Table 1). Then, scores are used to prioritize pathways, scoring each reach according to the previously defined purposes. The next step is to define parameters: 8h maximum travel time; 5 minutes necessary for data collection; the velocity of the boat (15 km/h) and the need to go 500 m within a reach to do the measurement. Subsequently, accessibility is evaluated. Accessibility analysis involves: restricted access to preservation areas and minimum water level for boat passage (0.5 m draft). In the dry scenario, 27 out of 101 reaches and 7 out of 11 lakes were not accessible. In the average and wet scenarios, all reaches and lakes were navigable, except one lake due to preservation. Using all this information, a pathway is generated and its travel time is computed, in function of its length and number of observations collected. The pathway time is compared to the maximum time and, if the pathway time is higher, the pathway is rejected. When there is compliance with the constraint, the pathway score is calculated by summing the scores of the reaches it passes through. The optimization stops when the pathway with the highest score is found.

Table 1 Scores for sets of reaches for data collection

Purpose	Improve model accuracy		Investigate modifications	Investigate water stagnation
Location sets	Downstream reaches (BC*)	All reaches (calibration)	Canal Mila 35 reaches	Stagnant reaches
Scores	2	2	2	0-4

* Boundary Conditions

5 Results and discussion

Three pathways were generated starting at Tulcea city, for the dry scenario. The aim was to evaluate how the pathways performed by varying their distance from the start point and number of observations. Pathway 1 went far (Figure 2a), Pathway 2 made the same path but entering every connected reach to collect data; and Pathway 3 was generated closer to the start point but also making observations at connected reaches. For the average/wet scenario one pathway was generated, Pathway 4, using the same approach as for Pathway 3 (Figure 2b). The results from these pathways are shown in Table 2. It can be seen that the effort to increase the number of observations by going into connected reaches is valid, but it comes with a heavy penalty in observation and transport time, resulting in the constraint not being attended. Only 3 observations could be added to Pathway 1 to remain in time (with a maximum score of 74). By looking at Pathway 3, as the pathway is close to the start/end point and thus the time spent in transit decreased, more observations could be collected. In consideration of Pathway 4, it is clear the scenario's importance, as it got a higher score by exploring stagnant areas that were not accessible in the dry scenario.

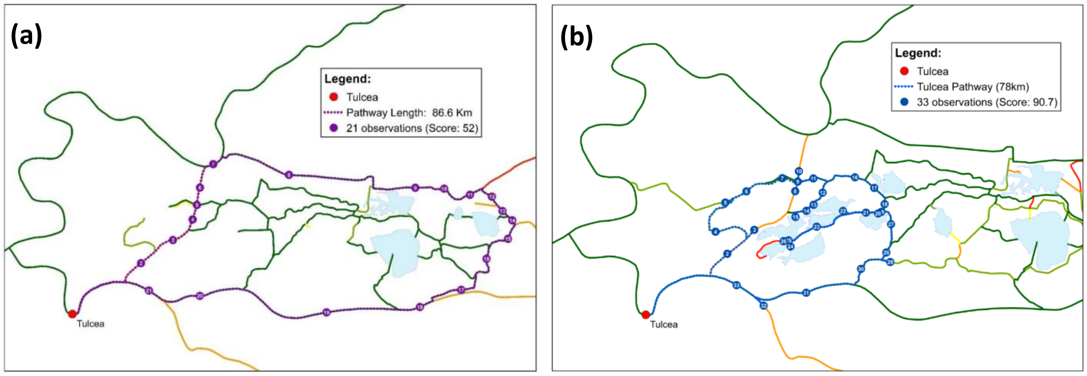

Figure 2 Pathway 1 for dry scenario (a) and Pathway 4 for average/wet scenario (b). Reaches colours reflect stagnation level (from green to red). Inaccessible reaches and lakes are not shown.

Table 2 Generated pathways characteristics

Pathway	Scenario	Length [km]	Time	# Observations	Score
1	Dry	86.6	7:29	21	52
2	Dry	104.6	10:17	39	99.5
3	Dry	79.2	7:57	32	78.6
4	Average/wet	78	7:57	33	90.7

Additionally, six pathways were generated, one for each surrounding city, aiming to achieve high scores within the time constraint. The cities are fairly well distributed on the boundary. By collecting observations at every possible reach, the pathways were located relatively close to their start/end point. Pathways starting from 2 cities obtained the higher scores, because they included BC and high stagnation points of interest. The most populated city scored worse, because larger distances needed to be covered to reach more observation points. Lastly, existing touristic routes were scored. The highest score was 60 and the route did not cover stagnant reaches. None of the touristic routes fitted the time frame of 8 hours, although constraints could be reconsidered because boats are not operated by the same authorities and there is no control regarding stops.

6 Conclusions

An approach for pathway generation and prioritization for citizen data collection has been developed in this study. Collection of data is done with the aim of improving flood modelling. The case study where the approach was applied is the Sontea-Fortuna area, located in the Danube Delta, in Romania. Several points of interest were identified and the accessibility analysis based on model results was not restrictive.

Hence, there are many possible pathways. By calculating an overall score for some selected pathways, the scoring system proved robust and provided a proper variation in the scores to enable prioritization. In conclusion, it is not possible to cover a large part of the study area in the time frame delineated. Pathways with high scores tend to cover thoroughly more concentrated parts (close to the start/end point) and to include reaches with high scores. Pathways based on touristic routes should not be prioritized. Lastly, as the cities are well distributed, involving more than one city for citizen data collection would yield better results than multiple pathways starting from only one, in case more than one pathway is desired. Moreover, more cities means more citizen involvement, more awareness about environmental concerns and more encouragement of citizen participation in delta planning and policy. The pathway analysis approach is proposed as an optimization problem, which in this study was analysed through scenarios. Further work lies in testing such approach in a full optimization framework, by searching the best (optimal) solution.

Reference

[1] A. A. Whipple, J. H. Viers, and H. E. Dahlke, “Flood regime typology for floodplain ecosystem management as applied to the unregulated Cosumnes River of California, United States,” Ecohydrology, vol. 10, no. 5, pp. 1–18, 2017.

[2] S. Grimaldi, Y. Li, V. R. N. Pauwels, and J. P. Walker, “Remote Sensing-Derived Water Extent and Level to Constrain Hydraulic Flood Forecasting Models: Opportunities and Challenges,” Surv. Geophys., vol. 37, no. 5, pp. 977–1034, 2016.

[3] T. Herman Assumpção, I. Popescu, A. Jonoski, and D. P. Solomatine, “Citizen observations contributing to flood modelling: opportunities and challenges,” Hydrol. Earth Syst. Sci. Discuss., in review, 2017.

[4] L. Smith, Q. Liang, P. James, and W. Lin, “Assessing the utility of social media as a data source for flood risk management using a real-time modelling framework,” J. Flood Risk Manag., Apr. 2015.

[5] M. Mazzoleni et al., “Can assimilation of crowdsourced data in hydrological modelling improve flood prediction?,” Hydrol. Earth Syst. Sci., vol. 21, no. 2, pp. 839–861, 2017.

[6] C. Bondar and N. Panin, “The Danube Delta hydrologic database and modelling,” in Internal Workshop on Modern and Ancient Environments and Processes, 2001.