An integrated methodology to estimate the contribution of environmental factors controlling the spatial variation of total dissolved solids. Application on Jiu River Basin (Romania)

Moroşanu G.A.[1,2,3,*], Zaharia L.[1], Ioana-Toroimac G.[1]

[1]University of Bucharest, Faculty of Geography, Bucharest, Romania

[2]University of Grenoble Alpes, CNRS, IRD, Grenoble INP, IGE, Grenoble, France

[3]Institute of Geography of Romanian Academy, Bucharest, Romania

*corresponding author: e-mail: gabriela.adina.m@gmail.com

Abstract

Through this research, we aim to develop a methodology for estimating the contribution of the natural and anthropic factors to the spatial variation of Total Dissolved Solids (TDS). The study area is Jiu River Basin, a Danube tributary from SW Romania.

TDS content was measured on Jiu River and its main tributaries, in periods of low waters in the summer of 2017 and 2018. For the area upstream each point, the following factors considered as primarily responsible for the TDS concentration were mapped and integrated in GIS and statistical analysis: geology, vegetation, soil textures, relevant human activities (coal-mining industry and agriculture in the valleys and in the catchments upstream the measuring points).

Using the principal component analysis (PCA) and regression models, scores were assigned to quantify the contributions to the spatial variation of TDS in the rivers. The results showed that coal mining and lithology (marls' dominance) play the main role in explaining the TDS variation.

The development of such an integrated methodology improved the understanding of the relationship between the rivers' TDS and the environmental drivers.

Keywords: total dissolved solids, GIS, PCA, Jiu River

1. Introduction

The variation of Total Dissolved Solids (TDS) in river water is highly dependent on the natural and anthropogenic features of the source areas upstream of the measuring points (Niekerk *et al*., 2014). Although the chemical elements that can lead to TDS increase are well known, the quantification and modelling of the different environmental variables influencing the TDS are still at an early stage of development.

The total dissolved solids (TDS) is a quality parameter that reflects the degree to which river water is more concentrated in solute ions. It is sensitive to local and upstream geological and pedological substrate, weathering, erosion potential and anthropogenic activities (Braul *et al*., 2011). Starting from these theoretical considerations, we intend to quantify the contributing factors to TDS variation, taking as a case study the Jiu Hydrological Basin.

The ***objective*** of our study will be to estimate the degree of influence of the most relevant physical-geographic or anthropogenic factors on the variation of TDS, so that in the ultimate goal we can achieve a predictive model for other measurement points within the Jiu river basin.

2. Study area

The Jiu River catchment (~10,070 km^2) is located in SW Romania. Altitudinal variation from 2509 m (N) to 24.1 m (S - at the confluence with the Danube), features a diversity of landforms, geological facies (siliceous rocks – metamorphic or sedimentary shale; limestone in the upper mountainous and piedmont), soils (predominantly clayey and loamy textures) and land use (most prominent being coal mining).

Coal mining areas can be found both in the upper Jiu Valley, Petroșani Depression (bituminous coal mostly) and in the middle sector, Getic Piedmont (lignite in Motru – Rovinari basin).

3. Methodology

3.1. Field measurements

For setting and validating the predictive model, field measurements took place in two years. The values underlying the predictive model setting were measured in the summer of 2017, and those that were later used for validation and implementation of the model were measured in 2018. In both years, the measurements were done on approximately the same hydrological water conditions (low water regime).

In total, TDS (ppm) was measured in the field at 70 points located on the Jiu River and its tributaries. The device used was an EC/TDS/Temperature Hand-held Tester. The measurement points were chosen to cover evenly the hydrographic area and to be downstream of various geographic factors that could contribute to the increase in the TDS, including downstream of mining areas. Spatial autocorrelation was verified and reduced by the Moran index (Moran, 1950).

3.2. Spatial data acquisition and preparation

Spatial survey of the main factors leading to the increasing of TDS comprised the following characteristics of the watersheds upstream each TDS measurement point (**Figure 1**):

(1) Geological maps – explain the erosion potential and the ions making up TDS content, typically released by carbonate rocks, marls and clayey facies;

(2) Soil map – identifies the textures with potentially high conductivity leading to higher TDS;

(3) Data on anthropic influences (based on CLC 2012): industrial and mineral extraction areas, irrigated lands, urbanized areas, non-point pollution sources.

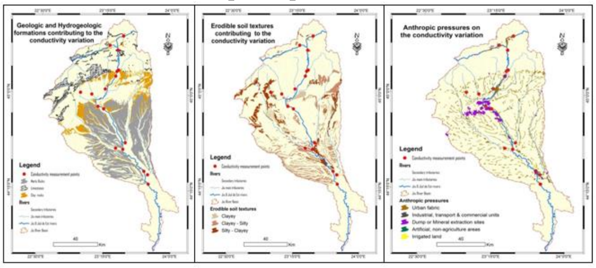

Figure 1. Maps of the spatial variation of the predictor variables used in the multivariate analysis (geology, soil, anthropic activities)

3.3. Predictive model development

For every measuring point the percentages occupied by each spatial factor were determined. For the 2017 measurements, a multivariate analysis method, Principal Components Analysis (PCA), and a linear regression were used to determine the degree of influence between environmental factors (geology, soils, and anthropic activities) on the TDS variability.

To estimate the degree of TDS prediction from similar configurations of input variables, the model was tested and validated on the second series of measurements from 2018. Uncertainty in data measurement, TDS variability independently of any environmental factors and model setup errors was evaluated by conducting Monte Carlo based sensitivity analyses.

4. Results and discussions

The number of principal components (the first two components) further used in the PCA was established by analyzing the scree plot (**Figure 2.a.**). The spatial projection of the six variables shows a significantly positive correlation between marls, clayey soils, erodible rocks and anthropic influences (**Figure 2.b.**).

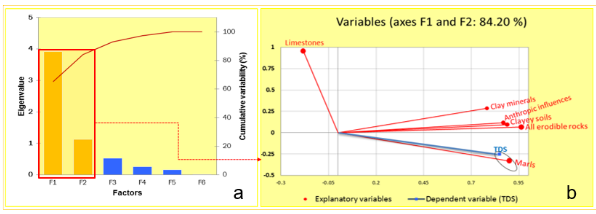

Figure 2. a. Scree plot of PCA; **b.** Rotated values of variables' contribution to PC_1 & PC_2

Marls contributed the most to the first component, being dominant in the regression (Durbin-Watson factor was 1.5-2.5, with one statistically significant serial correlation at a *p* value <0.0001). They were followed by mining areas variable, particularly in Jilt sub-catchment.

In the biplot (**Figure 3**), simultaneous representations of TDS and observations in the PCA space allow for mapping the main groups of points according to their shared characteristics influencing the TDS.

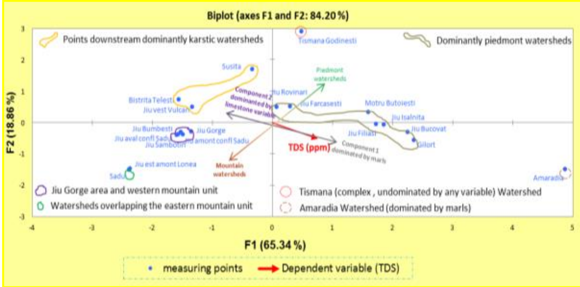

Figure 3. Patterns in sharing common characteristics of the watersheds upstream the measuring points

Linear regressions allowed to accurately predicting the leading variables contributing to most of the variation in the TDS values. TDS is very much correlated with marls (r = 0.95), mining areas (r = 0.91) and erodible rocks (r = 0.87). In the predictions, the expected average error of TDS ≈42 ppm.

5. Conclusions

The principal components and regression analyses quantified the variations of the contributing environmental factors to the variability of TDS content in the rivers of Jiu Watershed. The results indicate that the erodible rocks (particularly marls) greatly influence the TDS, as they alone formed the main factors in the regression model. The following positions ranked anthropic influences (coal mining in particular) and erodible rocks as controlling factors.

In the multivariate analysis, the findings of the first component of PCA are consistent with the outcomes of the regression model, indicating the role played by the geology (especially marls) and the mining areas in the variation of TDS and the existence of some spatial patterns.

A limitation of the study would be the number of measuring points used in the analysis, which requires a greater data collection consistency for further applications of this method.

References

Braul I., Desrosiers J., Watson M. (2011), An Analysis of Downstream Changes in Temperature, Electrical Conductivity and Total Dissolved Solids of the Illecillewaet River and Asulkan Brook in Glacier National Park, B.C. Geog, 477 Research Report, 33 p

Moran P.A.P. (1950), Notes on Continuous Stochastic Phenomena, *Biometrika*, **37**, 17–23.

Niekerk H., Silberbauer M.J., Maluleke M. (2014), Geographical differences in the relationship between total dissolved solids and electrical conductivity in South African rivers, *South-African Water Research Commission*, 133 – 138.