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Using Partial Triadic Analysis (PTA) to Assess Spatiotemporal Variation in Water Quality

Noura Slimani, Eric Guilbert, David Sánchez-Fernández, Moncef Boumaïza, Malika Trabelsi-Ayadi, Kais Nahdi, and Jean Thioulouse

Abstract

In this research, multivariate data analysis method called partial triadic analysis (PTA) were derived to unravel spatiotemporal variations in water quality and to identify potential sources of water pollution in the Northern Tunisia. The sampling was conducted in ten sites located in the north-eastern Tunisia part at the Cap Bon-Meliane watershed. We collected 16 environmental parameters of which were find significant spatial variations, suggesting the issue of anthropogenic activities by multiple stressors such as organic pollution and nutrients (agricultural activities); oxygen-consuming organic pollution (industry wastewater), salinization (agricultural activities, organic decomposition and geologic deposits). Therefore, the identification of the main potential environmental hazards in north-eastern of Tunisia by this study is a useful way of reporting the water quality status and developing better water resources protection.

Keywords

North-eastern basin • Tunisia • Water quality • Multitable analysis • Ordination • K-tables analyses • PTA

1 Introduction

Among freshwater ecosystems, streams and rivers in semi-arid regions are one of the most threatened habitats in the Mediterranean basin (Hershkovitz & Gasith, 2013). Anthropogenic disturbances including urbanization, industrial and agricultural activities lead to a rapid deterioration in the surface water quality (Slimani et al., 2020). Some of the most relevant questions to avoid the alteration of freshwater ecosystems are to evaluate spatial–temporal variations in surface water quality, to inform important information the pollution sources and highlight the status of surface water quality.

Recently, multivariate statistical techniques, such as partial triadic analysis (PTA), have been used in water quality assessment, playing an important role in water resources management (Slimani et al., 2020). The Cap Bon-Meliane watershed in the north-eastern Tunisia were exposed a major importance overexploitation for industrial and agricultural practices (e.g. irrigation and drinking) and ecological because of the richness aquatic communities that they support and due to interacting environmental factors (e.g. climate change). Since freshwater resources availability is rapidly lowering, surface water quality assessment in Tunisia has become a remarkable issue in current years. Therefore, applying PTA can be more effective to describe spatially and seasonally changes in the surface water quality of watershed. Plus, a comprehensive study may be needed facing a greater risk of water issues. We purposed at (i) assessing the spatial–temporal variations in surface water quality and (ii) identify potential factors influencing water quality condition of the

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watershed adapting PTA. Furthermore, the results highlight the importance of multivariate statistical techniques such as PTA to determine water quality status and pollution sources of Cap Bon-Meliane watershed, thus ongoing important insights to improve the surface water quality.

2 Materials and Methods

The study area is situated in the north-eastern of Tunisia and represents the Maghrebian Alpine and the Pelagian domains (Brahim et al., 2013).

Ten sites along the Cap Bon-Meliane watershed have been the subject of sampling seasonally during one year. Sixteen water quality parameters were measured. Five of them were recorded in situ using portable Multiparameter (WTW, MPP350) is temperature (T), pH, electrical conductivity (EC), salinity (S), and dissolved oxygen (DO). In laboratory, Na^+ , K^+ , Ca^{2+} , and Mg^{2+} concentrations are determined by inductively method as coupled plasma optical emission spectrometry (ICP-OES). NH_4^+ , NO_2^- , NO_3^- , Cl^- , and SO_4^{2-} concentrations are determined by liquid chromatography of ions. PO_4^{2-} is determined spectrometrically by colorimetry. Determination of COD is based on measuring the amount of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) consumed by the dissolved solids in suspension. BOD_5 is measured by incubation of the water sample in the presence of a solution of phosphate and allyl thiourea after five days in darkness and at 20 °C.

Spatiotemporal variability was achieved with partial triadic analysis (PTA), which allows for depicting of temporal variability of the multivariable spatial structure and/or the spatial structure of the temporal trajectories. PTA comprises three steps: the interstructure, the compromise, and the trajectories (Thioulouse, 2018).

3 Results

3.1 Spatiotemporal Pattern at the Meliane-Cap Bon Watershed

3.1.1 Interstructure

The first principal component of the interstructure analysis explained the 63.3% of the total inertia, while the second one only explained the 17.3%, characterizing a segregation of two seasons groups (Fig. 1A). This indicated that only the first axes can be emphasized a powerful common spatial structure. The correlation circle showed all the sampling dates displaying the same sign on the first

interstructure factor (axis 1), explaining a positive correlation among the corresponding set of matrices identified (Fig. 1A).

3.1.2 Compromise

The built of eight out the 10 sampling stations were grouped on the first axis of the factorial plane (Fig. 1B) while a unique, highly mineralized, sampling site (Chiba wadi; 10) was located in the opposite extreme. In the same way, all sampling sites were grouped in the second axis excepting one site located in an urban area Lebna wadi (9).

Regarding environmental factors (Fig. 1C), the first axis revealed a positive association with OD and a negative association with Na, K, Ca, Mg, Cl, EC, and S, indicating a mineralization/salinization gradient. The second axis was mainly (positively) associated with the BOD, COD, and PO, but negatively associated with pH, indicating a pollution gradient.

3.1.3 Trajectories

In the last step, the trajectories factor maps indicated that positions of the four season on the compromise plan 1–2. The graphical illustration has been showed the weakest structure in Spring and Summer (Fig. 1D), which means that the environmental factors indicated lower values of dissolved oxygen (DO) and higher values of nitrates, reflecting higher pollution within those two seasons compared with Winter and Autumn. On the whole, the upstream sampling sites (half of the positive side of the first axis) of the watershed presented a clearly lowest pollution, whereas the downstream sites that receive sewage and fertilization inputs have higher pollution.

4 Discussion

This study revealed that the mean concentrations of water quality parameters in the north-eastern streams were showed increasing trend from the upstream sites towards the downstream sites as the nutrient loadings, salinity, and conductivity identifying the first axis a gradient of natural stress due to the proximity of Chiba wadi aquifer to the sea (coastal aquifer), while the second one would represent a anthropization gradient due to human activities. These water quality issues reflect the increasing anthropogenic problem, such as the intensification on agricultural land production, the construction of several irrigation dams downstream leading to hydro-geomorphological alterations, hampering the soil fertility that increase trophic resources, and increasing amount of wastewaters.

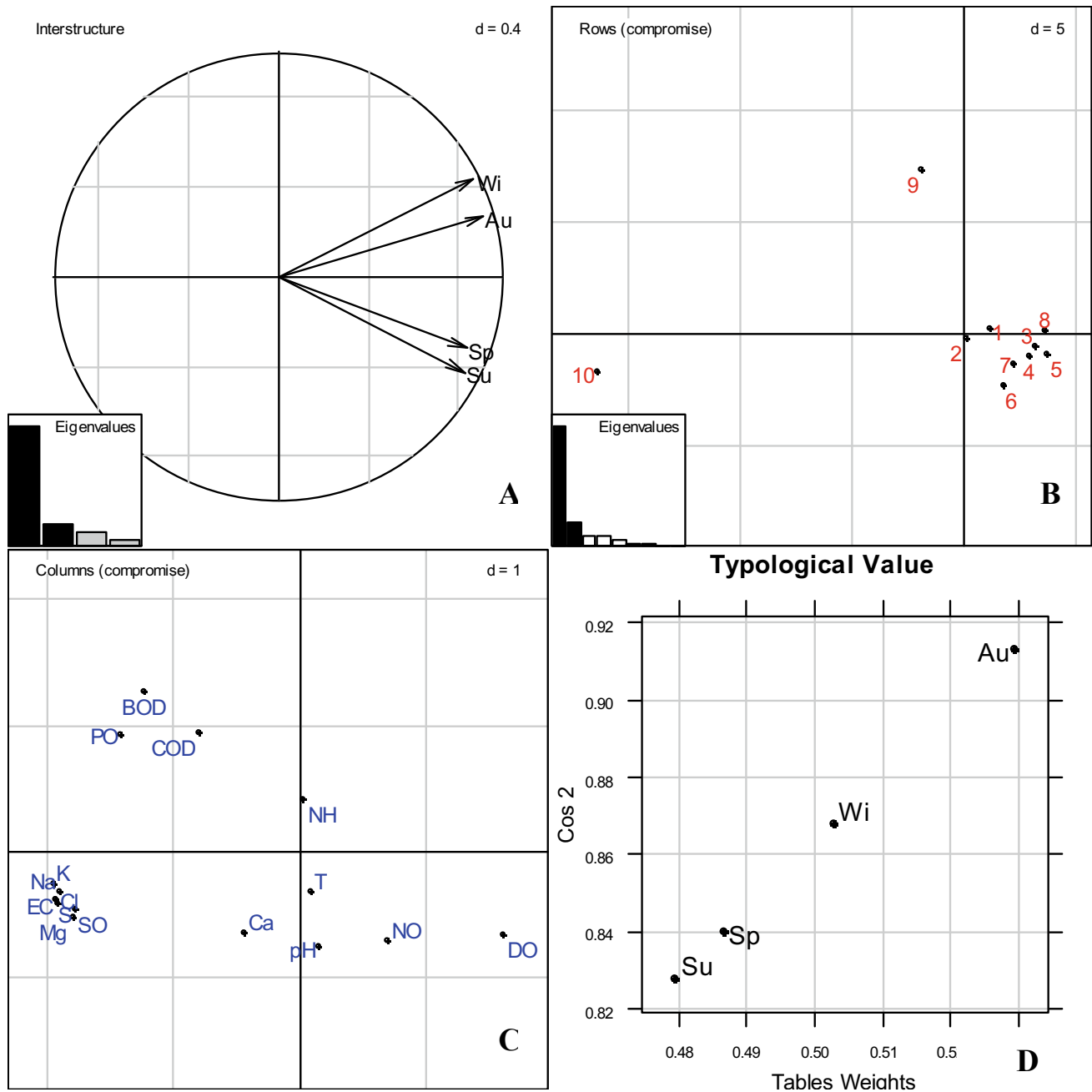


Fig. 1 Factor maps of the PTA on the data of the ten sites in the Meliane-Cap Bon watershed from Winter to Autumn 2013

5 Conclusions

Partial triadic analysis (PTA) was successfully applied to assess temporal and spatial variation in surface water quality of the Meliane-Cap Bon. The obtained results allowed to identify the main problems for the conservation of freshwater ecosystems from the north-eastern region of Tunisia.

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