Poster: Multivariate Point Data Visualisation - Geographical Information Systems Developments to Aid in Water Quality Management

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INTRODUCTION

In arid regions, the effect of pollutants on the quality of water resources is much greater than under hydrological regimes that have an abundance of water for dilution, and the monitoring of water chemistry becomes a very important component of water resource management. Currently in South Africa the problem of acid drainage from abandoned mining works is receiving attention, with €23 million budgeted for state intervention during 2011-2013. A characteristic of acid mine drainage is an increase in the proportion of sulphate in downstream rivers and dams. Spatial visualisation using multivariate point symbols can assist managers by pinpointing areas where anomalies in chemical composition of solutes occur.

METHODS

The multivariate point symbols provided by commercial and open source GIS are usually limited to pies and bar charts, which are difficult to compare visually on a map. Fortunately, the venerable Maucha ionic diagram (Maucha, 1932; Broch, 1969; Day, 1995) is fairly easy to program, with variants in Pascal, ArcInfo AML, ArcView 3.x Avenue, ArcGIS VBA and R (DWA, 2011). These scripts read in potassium, sodium, calcium, magnesium, sulphate, chloride and bicarbonate data from a water quality database, convert them to milliequivalents per litre and plot them as an eight-pointed polar symbol. The symbol size is scaled proportionately to the total solutes. A common deviation from the original symbol is to combine carbonate and bicarbonate as the more common total alkalinity, which leaves the top left-hand ray blank (figure 1).

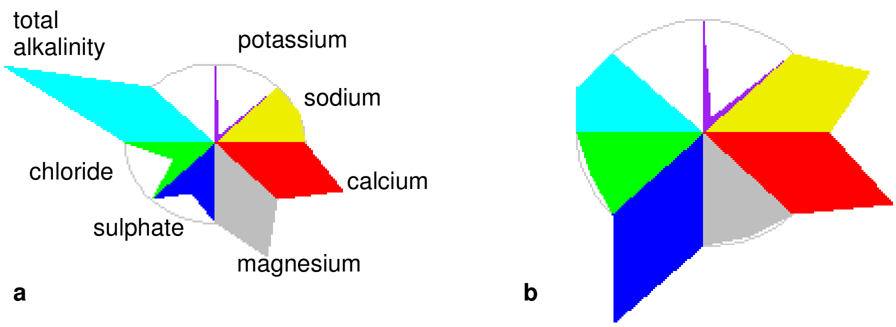

Figure 1. Maucha diagrams from sites in the Vaal River system, South Africa, a) C1H012 upstream of major pollution sources and b) C2H140 downstream of acid mine drainage and urban effluent sources. Drawn using an R script (DWA, 2011).

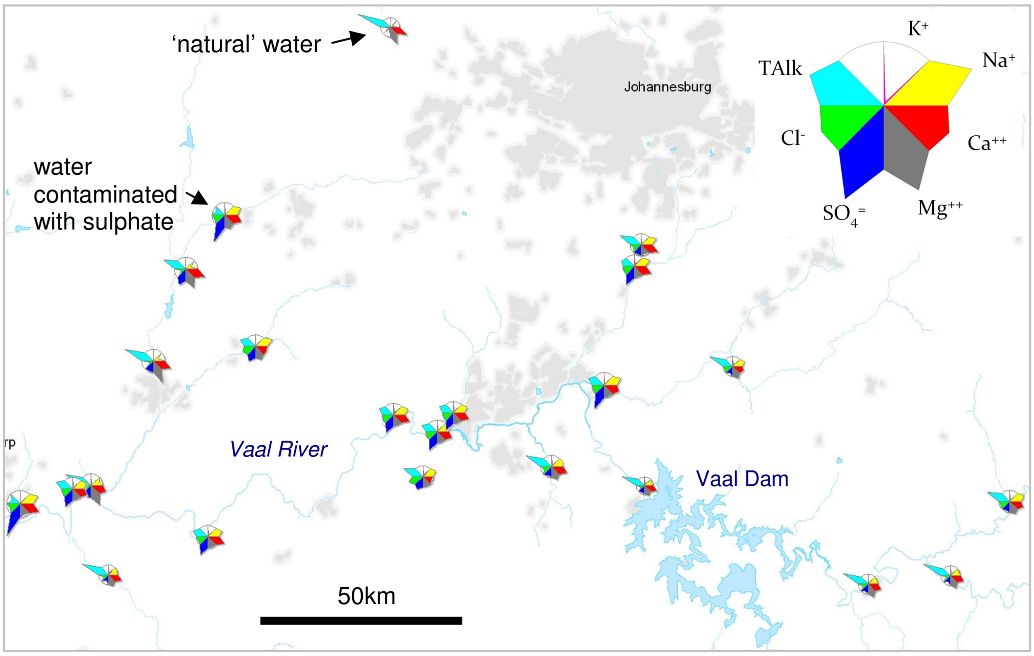

Figure 2: The river systems around Johannesburg, South Africa, with Maucha diagrams showing where sulphate ($SO_4^=$) from mining operations has contaminated the surface water. Flow direction right to left. Generated in ArcGIS 9.2 using VBA script Maucha09.bas (DWA 2011).

RESULTS

Figure 2 is a map centred on southern Gauteng Province in South Africa with Maucha multivariate chemistry markers summarising the ionic composition of water samples at monitoring sites on rivers in the region. The characteristic sulphate spike in the lower left of some symbols shows where the ionic balance has changed from the natural ratio, dominated by calcium and bicarbonate, to an abnormal, sulphate-dominated ratio. Note also the excess sodium at these sites.

DISCUSSION

Multivariate symbols such as the Maucha diagram are a powerful tool for analysing point data sets in a spatial context. The radial diagram with fixed alignment of each variable is more consistent than the ubiquitous pie diagram and makes better use of the human visual system's ability to detect angular displacement quickly and accurately. The symbol combines the 'pop-out' visual cues of angle, colour and size that trigger an automatic response in the visual cortex (Ware, 2008). Once users make the connection between a particular shape and a water chemistry type, they can immediately make spatial comparisons across a map or along a time series (Silberbauer, 2009).

Surprisingly, the main suppliers of commercial and open source GIS software make little provision for multivariate data visualisation at points, yet this type of representation can provide valuable insights, as demonstrated here. The only symbols commonly available are pie and bar charts. Rarely is smart symbol placing available to avoid overlap, and the automation of callouts is hardly functional. Even the simple process of using the colour and shape of a symbol to represent two variables requires extensive manual intervention (Esri, 2006). Statistical graphics systems such as R (R Development Core Team, 2011) and Rockware (Rockware, 2010) provide more advanced symbology. Although applying R to spatial representation involves a steep learning curve, it opens up an environment of rapid batch processing that is extremely cost-effective.

The customised solution shown here suggests that spatial data analysts already have alternative options for visualising multivariate point data. However, the large GIS software developers could make the process much more efficient by equipping their software with advanced, built-in symbology that has selectable attribute-driven characteristics of shape, size, colour, texture, shadow, transparency, offset, callout and jitter. Schnabel's elegant online map symbol brewer has shown that this is achievable (Schnabel, 2007; Schnabel and Hurni, 2009).

CONCLUSION

Multivariate spatial analysis of point data can reveal important trends, for example in the changes in ionic composition of water samples as a result of pollution. While modern GIS packages have a wide array of features for representing spatial information, the development of multivariate point symbols has stagnated. The GIS that can provide more than the outmoded pie chart will immediately have a competitive advantage in the field, and will provide its customers with a method for gaining powerful insights into their multivariate data.

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