Marine and Freshwater Research
https://doi.org/10.1071/MF21086

Supplementary material

Attribution of river water-quality trends to agricultural land use and climate variability in New Zealand

T. H. Snelder[A,E] *C. Fraser*[A], *S. T. Larned*[B], *R. Monaghan*[C], *S. De Malmanche*[D] *and A. L. Whitehead*[B]

[A]LWP Ltd, Christchurch, New Zealand.

[B]National Institute of Water and Atmospheric Research, Christchurch, New Zealand.

[C]AgResearch, Mosgiel, New Zealand.

[D]Ministry for the Environment, Wellington, New Zealand.

[E]Corresponding author. Email: ton@lwp.nz

Censored and missing values

The analysis in the main document were based on quarterly or monthly observations of six water quality variables. Some of these observations were censored values indicating that the reported values were below the analytical detection limit or above the reporting limit. In additon, for some quarters or months the observations were missing either because the observation had not been made or the data had not been properly recorded.

Censored values were consistently identified in the data by the combination of the reported values and a flag indicating the type of censoring. The subsequent trend analysis handled the censored values robustly using the methods described by Helsel (2011). However, censored values are less informative than non-censored values and their presence in the data decreases the level of confidence that can be achieved in trend analysis. Figure S1 indicates the proportion of observations that were censored for each time window for which the site trend was assessed for all six variables and the 10- and 20-year durations.

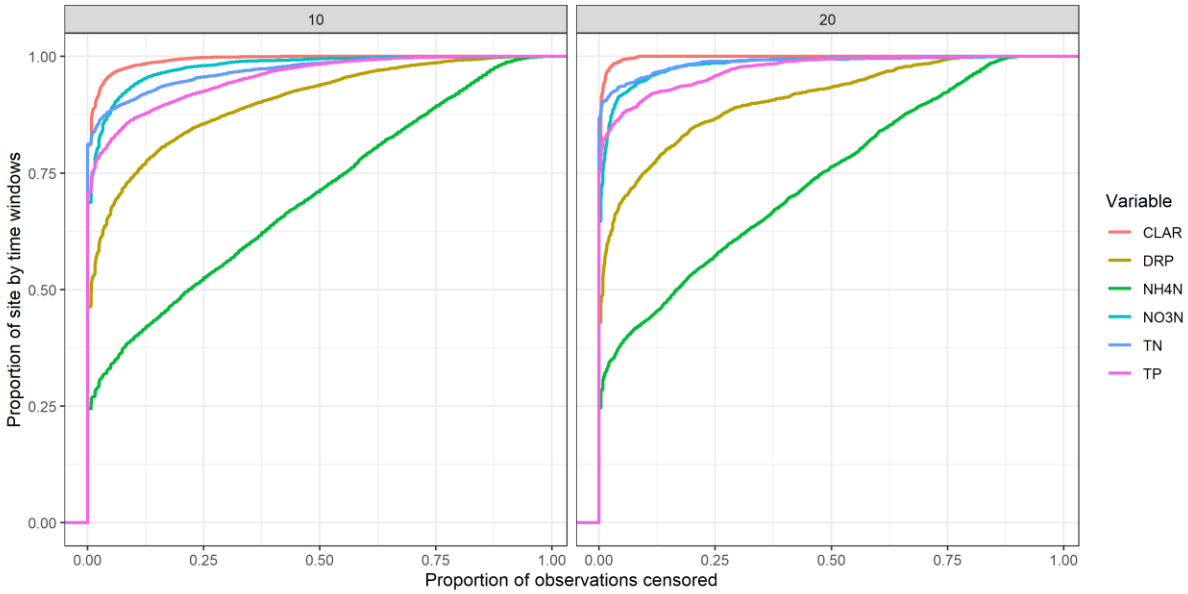

Fig. S1. Cumulative distributions of the proportion of observations censored by variable (line colours) and by time period (left and right plots). The *x*-axis indicates the proportion of observations censored and the *y*-axis indicates the proportion of site by time windows that had less than or equal to the proportion of censored observations.

The method of trend analysis used is robust to missing values (Hirsch *et al*. 1982). However, there are several reasons why it is generally important to restrict the proportion of missing values to ensure that the observations are adequately distributed over time. First, because variation in many water quality variables is associated with the time of the year or 'season', the robustness of trend assessment is likely to be diminished if missing observations occur in the time series at certain times of the year. Second, a trend assessment represents a time period; essentially a window of time that has a set starting date and duration. An assessment of the behaviour of a variable over the time period will be hindered if the observations are not reasonably evenly distributed across the time period. For these reasons, we only included site, variable and time window combinations for which at least 80% of sample intervals (i.e. quarters or months) had observations. For the site, variable and time window combinations that were retained for trend analysis there were differing proportions of sample intervals with observations (i.e. between 80 and 100% of intervals). These proportions are shown in Fig. S2 for all six variables and the 10- and 20-year durations. The plot shows both site by time windows analysed based on quarterly and monthly seasons. The proportion of observations available for the monthly seasons was calculated as the number of months with observations divided by the maximum number of months in the time-period (120 or 240, for the 10- and 20-year periods respectively). The proportion of observations available for the quarterly seasons was calculated as the number of quarters with observations divided by the maximum number of quarters in the time period (40 or 80, for the 10- and 20-year periods respectively).

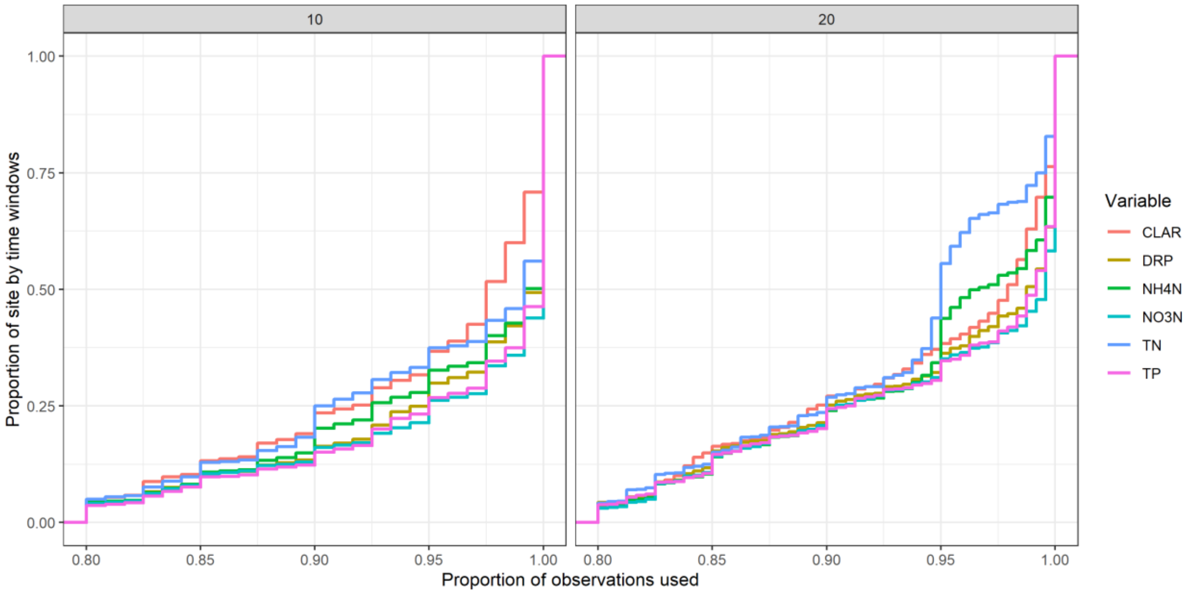

Fig. S2. Cumulative distributions of the proportion of observations used in the trend analyses by variable (line colours) and by time period (left and right plots). The *x*-axis indicates the proportion of observations used while the *y*-axis demonstrates the proportion of site by time windows that are less than or equal to the proportion of observations available.

Spatial patterns in the residual values of regression models explaining between site trends

Geographic patterns in the residuals of the models explaining between site trends would suggest environmental drivers of trends that were not represented by the models. We inspected maps of the sites coloured by their model residual values and formally assessed the strength of the geographic patterns, using the Mantel test (Mantel 1967). The Mantel statistic (Mantel's *r*) is the Pearson correlation coefficient between two dissimilarity matrices and is used to quantify geographic clustering (i.e. whether there is greater similarity between sites that are geographically close than between widely separated sites). The first matrix described the dissimilarity in the model residuals between pairs of monitoring sites. The second dissimilarity matrix defined the geographic (Euclidian) distance between all pairs of sites. The significance of Mantel's r was established by permutation (1000 permutations) (Legendre and Legendre 1998). We controlled for false discovery by adjusting the *P*-values (Benjamini and Hochberg 1995).

An example of the mapped model residuals is shown on Fig. S3. This map shows the residuals of the model of DRP trends for the 10-year period ending in 2007. These residuals had the strongest Mantel *r* value (0.14, *P* = 0.016).

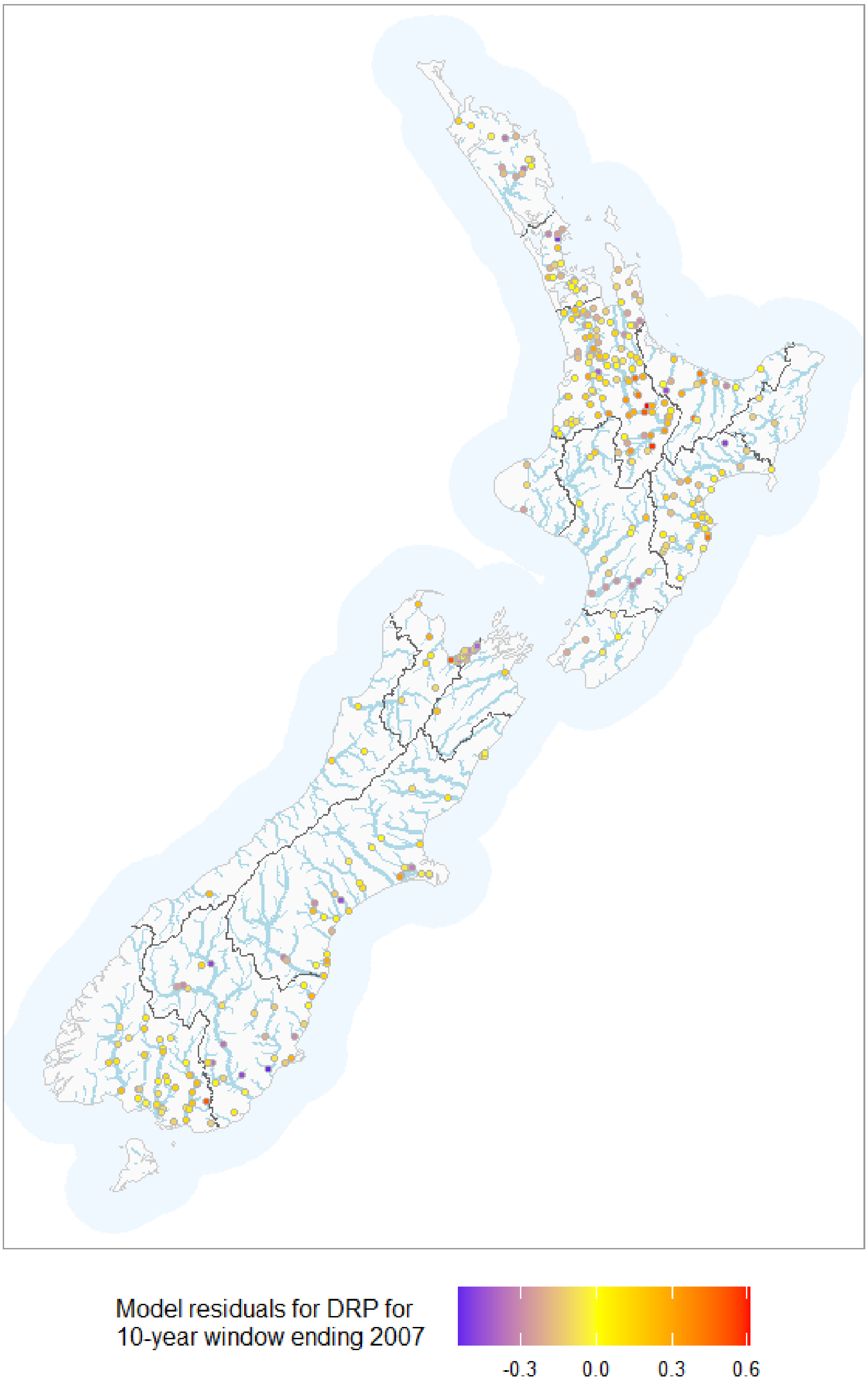

Fig. S3. Example of the mapped model residuals for the model explaining between site variation of DRP trends for the 10-year period ending in 2007.

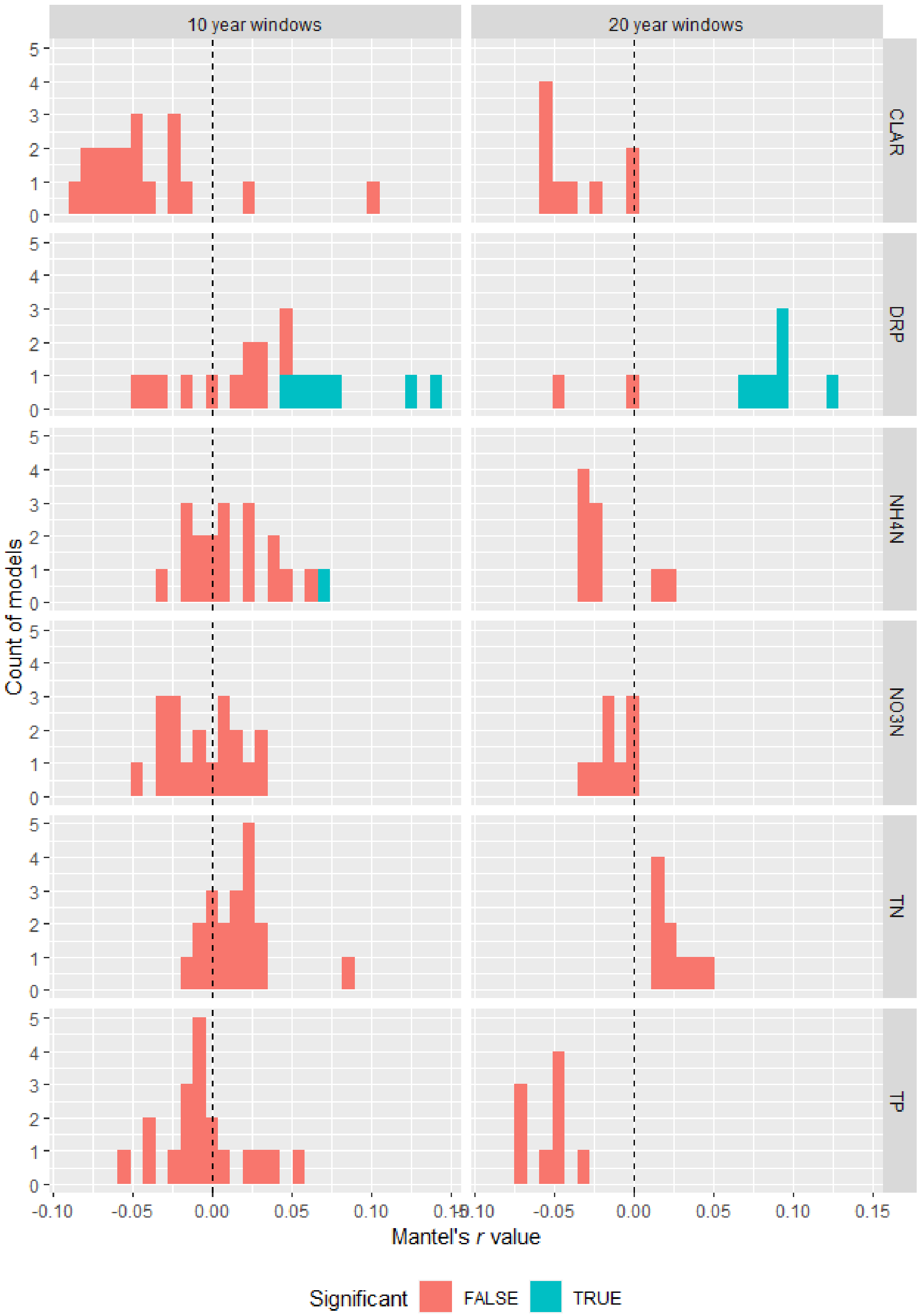

Fig. S4. Histograms showing the distribution of Mantel's *r* values used to quantify the degree of geographic clustering of the residuals of the regression models explaining between site trends. Each panel shows the results of individual Mantel's test performed on the models pertaining to the six variables and the two durations (10 and 20 years). The significance of the Mantel's *r* values at the 0.05 level is indicated. The dotted black line indicates a Mantel's *r* value of zero.

References

Benjamini, Y., and Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society – B, Methodological* **57**, 289–300. doi:10.1111/j.2517-6161.1995.tb02031.x

Helsel, D. R. (2011). 'Statistics for Censored Environmental Data Using Minitab and R'. (Wiley.)

Hirsch, R. M., Slack, J. R., and Smith, R. A. (1982). Techniques of trend analysis for monthly water quality data. *Water Resources Research* **18**, 107–121. doi:10.1029/WR018i001p00107

Legendre, P., and Legendre, L. (1998). (Numerical Ecology.' (Elsevier: Amsterdam, Netherlands.)

Mantel, N. (1967). The detection of disease clustering and a generalized regression approach. *Cancer Research* **27**, 209–220.