Does meteorological drought have immediate effect on low flow in Northland rivers?

Date: November 2019

Author: **Hoa Pham & Jean-Charles Perquin**

Contents

Northland has been experiencing dramatic reduction in stream water level over the past year, and in particular low flow drought conditions. The most direct connection is likely to be between deficit rainfall and stream flow during both brief and prolonged dry periods.

Northland meteorological drought tool well defines the degree of dryness (rainfall deficit) and the length of the dry periods. However, the gap remains in quantifying the impact of dryness on stream flow.

Aims

This study aims to investigate the best practice to identify drought events with reference to a particular flow site.

Specific objectives are:

- Investigate dry periods as well as the severity of these occurrences, and
- Examine the relationship between meteorological and hydrological droughts

Methodology

Literatures demonstrate that droughts cannot be simply characterised by a lack of precipitation via meteorological drought, especially when dealing with complexity of hydrological processes (Loon, 2015; McKee, Doesken, & Kleist, 1993; Wilhite & Glantz, 1985) (Figure 2).

Hydrological drought is most often associated with low flow periods in rivers and low levels in lakes, reservoirs and groundwater resulting in lack of available water in the hydrological system (Nalbantis & Tsakiris, 2009).

Literatures also reveal quantitative links in the arrival time and/or period between meteorological and hydrological droughts which can be estimated through drought indices (Tokarczyk, 2013; Ye Zhu, Wen Wang, Vijay P. Singh, & Liu, 2016).

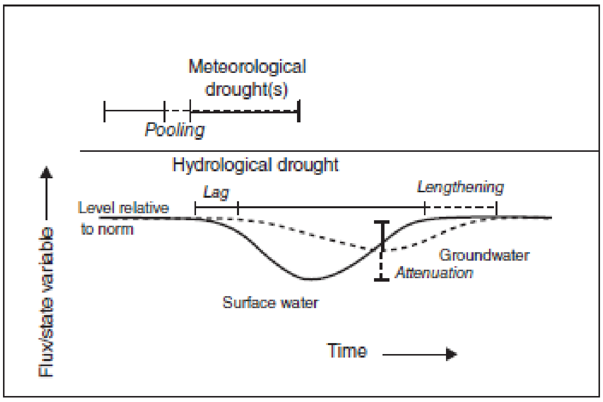

Figure 2 Features characterising the propagation of meteorological drought(s) to hydrological drought: pooling, lag, attenuation, and lengthening (Van Loon, 2015).

In this study, Standardised Precipitation Index (SPI) and Standardised Discharge Index (SDI) as indicators of meteorological and hydrological droughts, respectively were selected. Pearson test with different time delays were employed to examine the relationships between the two drought types, and linear regression equations were established where appropriate. Comparison of intensity and duration were also made between meteorological and hydrological droughts.

SPI and SDI allow comparison to be made between current and historic drought events as well as among monitoring sites (WMO, 2012) which are computed using equations below:

$$SPI_{ik} = \frac{R_{ik} - \overline{R_k}}{S_k}$$

$$i = 1,2,\ldots \qquad k = 1,2,3,4,5,6$$

where: $\overline{R_k}$ and S_k is monthly mean rainfall/streamflow and its standard deviation for time step (k) for year (i).

Table 1 Drought classification

No drought	SPI/SDI > 0.0
Mild drought	-1.0 ≤ SPI/SDI < 0.0
Moderate drought	-1.5 ≤SPI/ SDI < -1.0
Severe drought	-2.0 ≤ SPI/SDI ≤ -1.5
Extreme drought	SPI/SDI < -2.0

Results

Daily rainfall and flow data were collected at 16 rain and flow gauges within seven small- to -medium- sized catchments. SPI and SDI-1, 3, 6, 9 and 12 are computed for one, three, six, nine and twelve months, respectively.

Annual pattern of rainfall is similar for the investigated rain gauges. Rainfall is generally high in winter and low in summer seasons. The longest period of rainfall deficit occurs in summer months. Runoff regime for the investigated catchments is seasonally influenced with the lowest runoff also occurring during summer.

Conventionally, the main parameter used to define drought low flow is threshold discharge, which was adopted at 1 in 5 year 7-day low flow (Q5) and presented in Table 2. The number of days stream flows are under Q5 threshold differs from site to site, depending on catchment natural and artificial processes. Flows at selected gauges may or may not be representative for the catchments due to water abstraction, diversion, etc. In this traditional approach the mutual relationship between rainfall deficit and low flow is not explicitly explained.

Alternatively, the use of SPI and SDI indices can successfully quantify the duration and severity of meteorological and hydrological droughts. Figure 3 presents the variability of SPI and SDI for one month, SPI-1 and SDI-1, at all study sites. Table 3 shows the relationships between SPI and SDI which vary with different lag times. The significant correlations are found between SDI-1 and SPI-1 and gradually decrease for SPI-3, 6, 9 and 12. This would suggest that meteorological drought has immediate effect on the hydrological drought. These relationships are clearly demonstrated in Figure 5. A specific example is also represented in Table 4 and Figure 4 for Mangakahia catchment for current dryness. Figure 6 also reveals historical meteorological and hydrological droughts are similar in timing and pattern for Hatea.

Table 2 Summary on conventional drought low flows

Flow recorder sites	Start year	CA (km^2)	Q_5 (l/s)	Number of drought low flow days	Drought flow days (post-2009) ((%)
Maungaparerua at Tyrees	1967	11.1	23.2	313	35
Hatea at Whareora	1986	38.5	87	108	0
Mangakahia at Gorge	1964	246	1210	301	8
Ngunguru at Dugmores	1969	12.5	61	401	16
Opouteke at Suspension	1984	105	497	105	5
Waihoihoi at Marrys	1984	25.1	61	185	5
Whakapara at Cableway	1959	162	602	416	24
Awanui at School Cut	1958	222	472	301	37

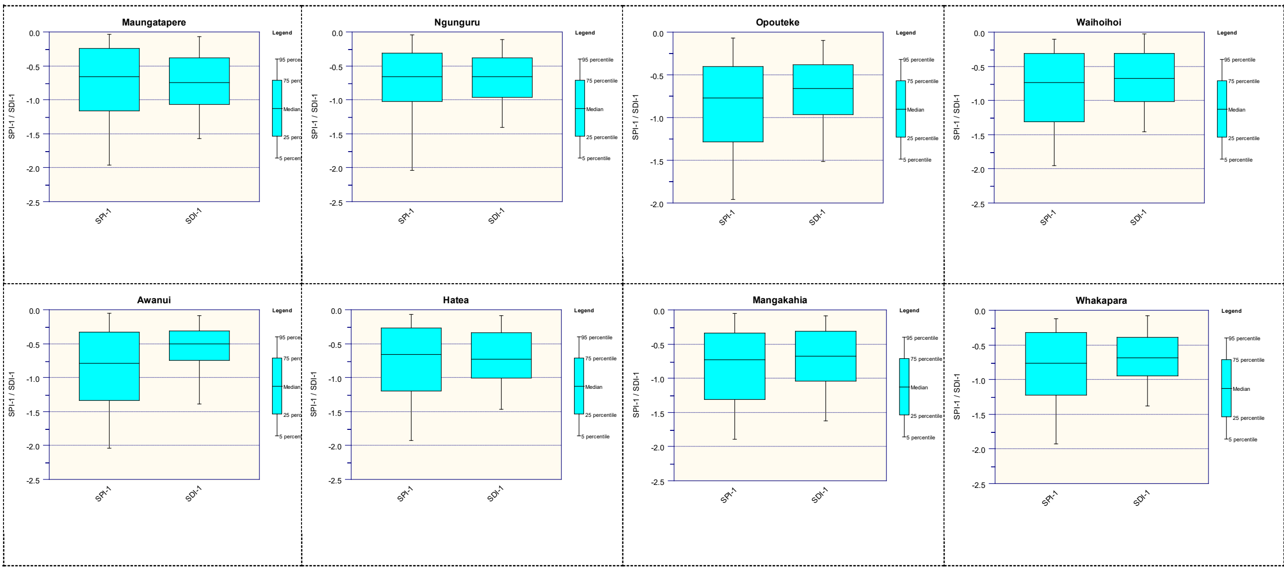

Figure 3 Variability of SPI-1 and SDI-1 during dry periods

Table 3 Correlation coefficients between SDI and SPI for different lag times

Flow recorder sites	Rain gauges	SDI(1)				
		SPI(1)	SPI(3)	SPI(6)	SPI(9)	SPI(12)
Maungaparerua at Tyrees	Kaeo at Bramley	0.82	0.75	0.60	0.43	0.40
Hatea at Whareora	Hatea at Glenbervie	0.80	0.71	0.63	0.48	0.40
Mangakahia at Gorge	Mangakahia at Twin Bridge	0.82	0.61	0.49	0.41	0.36
Ngunguru at Dugmores	Ngunguru at Dugmores	0.73	0.72	0.66	0.53	0.23
Opouteke at Suspension	Opouteke at Brookvale	0.81	0.63	0.49	0.38	0.36
Waihoihoi at Marrys	Waihoihoi at Brynderwyn	0.78	0.65	0.46	0.41	0.35
Whakapara at Cableway	Whakapara at Puhipuhi	0.80	0.69	0.58	0.47	0.38
Awanui at School Cut	Kaitaia EWS	0.54	0.36	0.395	0.28	0.28

Note: Pearson test was performed at 95% of confidence

Table 4 Linear regression equation developed for Mangakahia at Gorge

Mangakahia at Gorge	SDI (1) = -0.1 + 0.703 * SPI(1) + 0.247 * SPI(3) + 0.0416	R^2 = 0.71

Note: This equation may change with consideration of more different variables and longer data time series

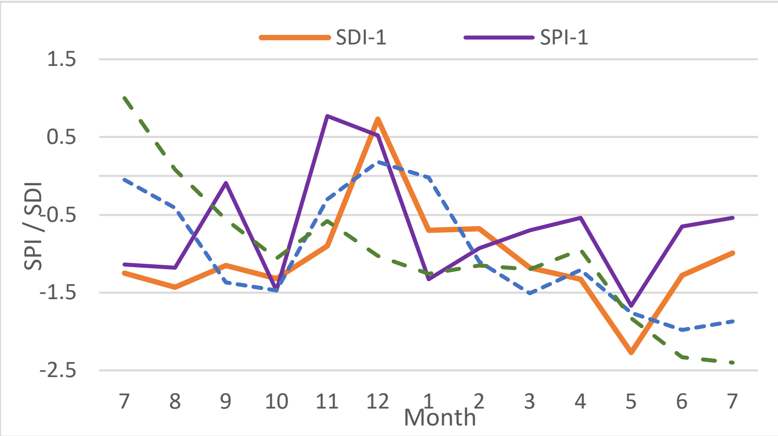

Figure 4 Relationships between SDI-1 and SPI-1-3-6 at Mangakahia during July 2018 – July 2019

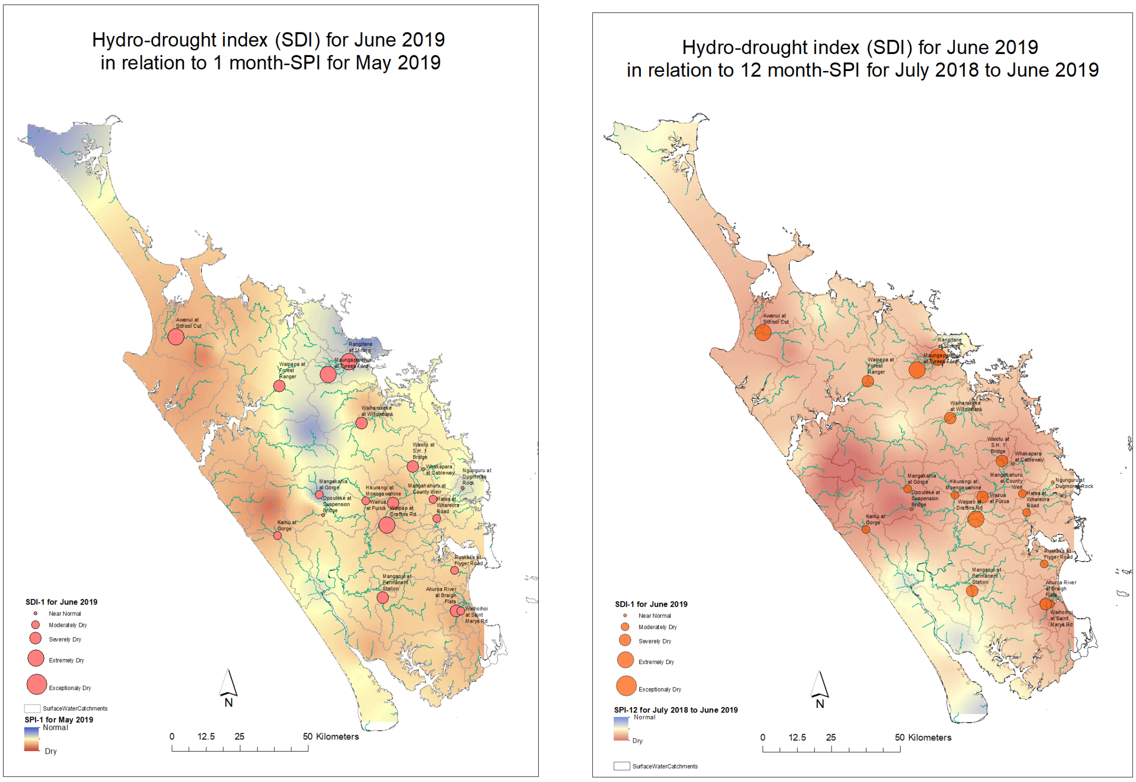

Figure 5 Spatial relationships between SDI-1 and SPI-1 (a, left) and between SDI-1 and SPI-12 (b, right)

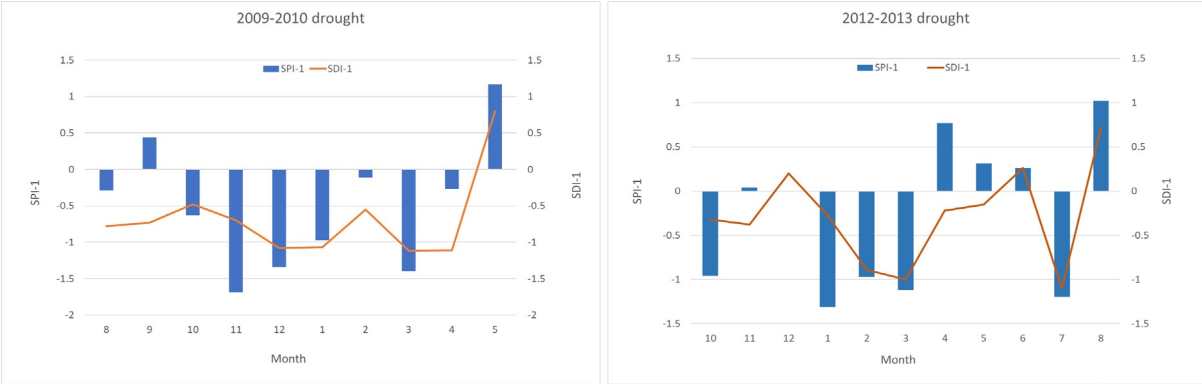

Figure 6 Relationships between SDI-1 and SPI-1 in Hatea catchment for historic drought events

In conclusion, the combined SPI and SDI is an effective practice for hydrological drought detection, the commencement and magnitude of a drought event, with reference to a flow gauge. This is proved for the investigated flow gauges.

Recommendations

For robust assessment of the impacts of meteorological drought on hydrological drought for Northland, the followings are recommended for further studies:

1. to include a wider range of catchment in terms of catchments characteristics and activities;
2. to compute catchment areal rainfall instead of using only single-point data at rain gauges;
3. to verify the SPI-SDI relationships for drought magnitude using more historical drought events;
4. to establish the relationship between meteorological and hydrological drought duration based on SPI and SDI indices; and
5. to integrate results with evapotranspiration, soil moisture, groundwater and remote sensing-based indices.

Selected references

Loon, A. F. V. (2015). Hydrological drought explained *WIREs Water, 2*, 359-392.

McKee, T. B., Doesken, N. J., & Kleist, J. (1993, 17-22 January 1993). *The relationship of drought frequency and duration to time scales.* Paper presented at the 8th Conference on Applied Climatology, Anaheim, California.

Nalbantis, I., & Tsakiris, G. (2009). Assessment of hydrological drought revisited. *Water Resour Manage, 23*, 881-897.

Tokarczyk, T. (2013). Classification of low flow and hydrological drought for a river basin. *Acta Geophysica, 61*(2), 404-421.

Wilhite, D. A., & Glantz, M. H. (1985). Understanding: the drought phenomenon: the role of definitions. *Water International, 10*(3), 111-120.

WMO. (2012) Standardised Precipitation Index - User Guide. In Svoboda M., Hayes M., & W. D. (Series Ed.). *WMO-No. 1090*. Geneva.

Ye Zhu, Wen Wang, Vijay P. Singh, & Liu, Y. (2016). Combined use of metorological drought indices at multi-scales for improving hydrological drought detection. *Science of the Total Environment, 571*, 1058-1068.

Northland Regional Council

P 0800 002 004

E info@nrc.govt.nz

W www.nrc.govt.nz

Northland
REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau