Insights on use of deep soil nitrogen tests from long-term moisture probe data in Victorian low and high rainfall crops

Ben Jones [1] and Dale Boyd[2]

[1] Centre for Sustainable Agribusiness, Marcus Oldham College, 145 Pigdons Road, Waurn Ponds, VIC 3216, Email: jones@marcusoldham.vic.edu.au

[2] Department of Jobs, Precincts and Regions, Cnr Annesley St and Ogilvie Ave, Echuca, VIC 3564, Email: dale.boyd@agriculture.vic.gov.au

Abstract

Deep (0-60 cm) soil nitrogen tests are widely used in lower (<500 mm annual) rainfall environments, and are also being used in high (>500 mm) rainfall environments to estimate nitrogen budgets. Leaching below 60 cm may be a greater issue for interpretation than is currently acknowledged. We inferred leaching and crop water use from an 8-9 year time series of moisture probe data from crops at Victorian low and high rainfall sites.

Leaching below 60 cm was rare during the typical soil sampling period (February-April) except with sandy soil at high rainfall. At high rainfall sites, leaching events were much more common after April, and to a greater depth. Water use from 70 cm began around August at most sites. Water use to (and presumably beyond) the 100cm depth was often observed after September.

Nitrogen budgets in high rainfall environments should account for nitrogen that has been leached below 60 cm, and potentially extracted below 100 cm later in crop growth.

Keywords

leaching, soil water, root depth, crop water use, fertilizer

Introduction

Soil testing to 60 cm to measure mineral nitrogen (N) has become a standard for crop agronomists in low rainfall (<500 mm annual) areas (Unkovich, et al., 2020), but interpretation of test values may need to change in high rainfall (>500 mm annual) areas. Some of the low rainfall rationale follows: Spring-type cereal roots have typically reached this depth before early stem elongation (Kirkegard & Lilley, 2007), beyond which the yield response to N decreases. Evapotranspiration is likely to offset lower rainfalls over this period, and N leaching is less likely. Soil below 60 cm is in turn less likely to be a significant reservoir of nutrients. In many seasons it may be feasible to ignore leaching, and make simple N budgets from the soil test, fertilizer N, and an estimate of N mineralization. There is likely to be a diminishing marginal return to testing deeper, between increased cost and minor improvement in information. This is especially so if the N response is less likely.

Cropping decision methods in higher rainfall areas have initially been adapted from lower rainfall areas, but are being improved to suit high rainfall cropping (McCaskill, et al., 2016). Despite this, the 60 cm 'deep' soil N test was still a reference point quoted at cropping field days in southern Victoria and irrigated regions in 2020 (personal observation). While 60 cm may remain useful in high rainfall areas as an easily sampled, industry-accepted depth, it may be necessary to change the way test values are interpreted, particularly in N budgets. Many of the factors that support the low rainfall rationale (previous paragraph) are likely to change with a longer growing season and higher rainfall.

Victoria is fortunate to have a publicly available 10 year record of soil moisture probe data at low and high rainfall cropping sites. Moisture probe data is less rigorous than lysimeter data but more available. It also has the potential to be a good control on modeled soil water data, which is important given that models are often used to derive long-term management strategies. This study aimed to use the data to illustrate the relative extent of leaching and water (and by inference nutrient) uptake below 60 cm in higher, compared to low rainfall environments.

Methods

Moisture probes

The study used capacitance probes installed as part of Agriculture Victoria's long-term Soil Moisture Monitoring project (https://extensionaus.com.au/soilmoisturemonitoring/). Three soil moisture probes from cropping sites with long and reasonably complete data records were chosen in low rainfall and high rainfall environments (Table 1). Most crops sown were cereals or canola, apart from at Lake Bolac which transitioned to perennial pasture after canola in 2015.

Table 1. Location, annual rainfall and soil type of capacitance probe sites used in the study. Headings are hyperlinked to the webpage for each probe site.

Site	Birchip	Ouyen	Werrimull	Hamilton	Lake Bolac	Sale
Latitude, Longitude	-35.98, 142.92	-35.07, 142.32	-34.39, 141.60	-37.74, 142.03	-37.71, 142.84	-38.37, 146.99
Annual rainfall (GSR) mm	374 (256)	329 (212)	270 (172)	641 (448)	536 (352)	559 (322)
Soil description	Clay loam	Light sandy clay loam	Fine sand	Clay	Clay loam	Sand over clay

The probes collect data at 10 cm intervals between 30 and 100 cm, and report at hourly intervals. Rain was summed for each calendar day, and the midnight moisture content taken to represent each day. Daily data was aggregated by integer day of year into five day periods to simplify analysis, giving 73 periods in most years. Periods without complete data were excluded from the analysis.

Probe data is a relative number (range 0 to 100). An upper and lower limit (notional plant available water; field capacity and wilting point) was estimated for each sensor (layer). Five day period data was filtered by stability (ie not after rain) and time of year (May through November: not too dry). After inspection, abs (change over period) < 0.2 was used as the stability criteria. The minimum and maximum of filtered values was taken as the lower (scaled to 0) and upper limit (scaled to 1).

Soil temperature may confound probe water content measurements. If temperature compensation was inadequate, it should appear as annual drying or wetting patterns, with less effect at depth. This was not observed, and any effect should not confound leaching events at the scale of one to several five day periods. Moisture content and change from period to period were presented visually for all years at all sites and are available on request.

Leaching

After inspecting change in soil moisture data, an arbitrary criterion for a leaching event was set as: any period with an increase in relative moisture content of > 5 %, in at least one layer. Each event was characterized by determining the shallowest and deepest layers with a 5 % relative increase, and then averaging the relative moisture content change between those layers, inclusive.

Drying

An arbitrary criterion for drying of soil at 70 cm (ie deeper than 60 cm), most likely due to root water use and not drainage after leaching, was set as: any five day period with decrease in relative moisture content of 2.5 % or more, after mid-year, and not immediately following a leaching event.

Results

Leaching events

Leaching events at low rainfall sites tend to be less frequent, especially deeper than 60 cm (left of Figure 1a). Events at high rainfall sites (right of Figure 1a) are more frequent, and often deeper than 60 cm in winter and spring months. The Werrimull and Sale sites are closest in frequency (both sandy soil), but events at Sale are more likely to be deep.

Leaching events tend to be bigger compared to the layer PAWC at low rainfall sites (Figure 1b-d), and biggest in the 100 cm layer at all sites, suggesting flow beyond 100 cm when these events occur. The timing of leaching deeper than 60 cm is quite random at low rainfall sites, but more likely in months 5-7 at Hamilton, 6-9 at Lake Bolac (both straddling winter), and throughout the first 9 months of the year at Sale.

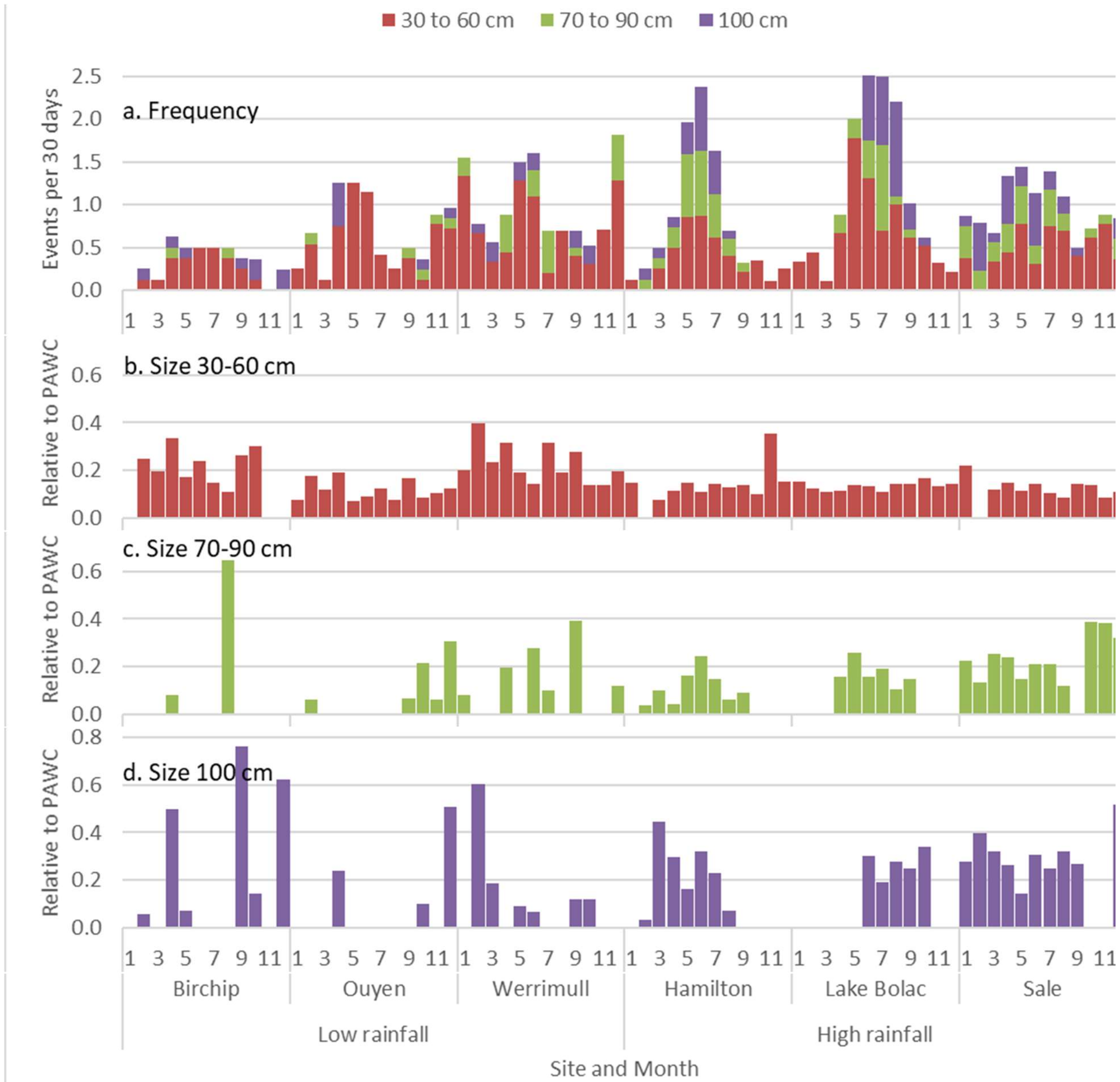

Figure 1. Average frequency (a) and size (b-d for different depths) of potential five day leaching events at low and high rainfall sites. Data is organised by 30 day 'month' within the year, across all available data 2010 – 2020 (criteria as per methods). Events are grouped by maximum depth of leaching.

Drying

Drying at 100 cm was evident at all high rainfall sites from September-October on in most years (not shown), with complete drying to 100 cm suggesting continued water use below the probe depth. At low rainfall sites patterns were similar, but with some potential lateral flow effects. Dates for the earliest drying events at 70 cm were fairly consistent around mid July-September (Figure 2), apart from Birchip. Several events there (detected as per methods) were unrelated to crops. Dates of remaining drying events (2016, 2019, 2020) are from mid September-October. There was no strong drying effect in some seasons because there was little stored moisture to use (eg. Birchip 2013, 2014).

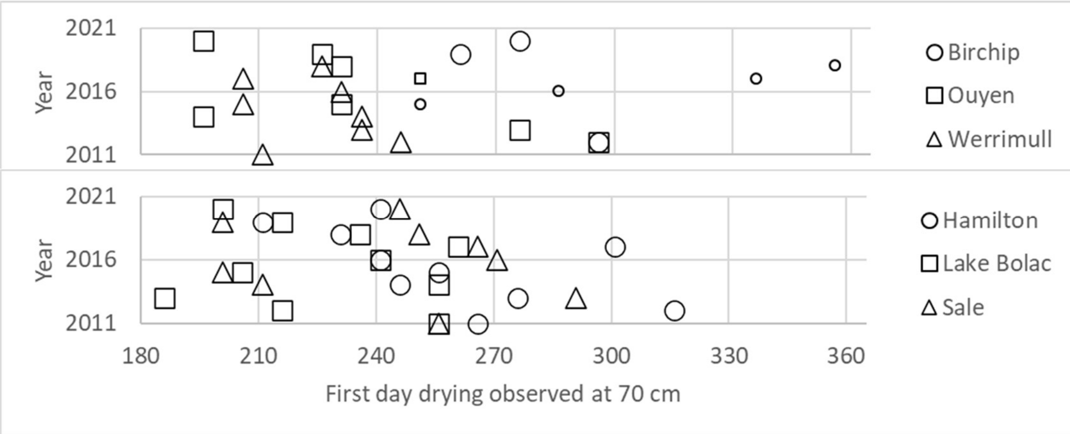

Figure 2. Day of year drying first observed (first day of five day period). Sites are separated by low (top) and high (bottom panel) rainfall. Small symbols are used for drying events unlikely to be related to onset of water use by crops: after probe installation, rain at harvest in years where the subsoil didn't wet up, and artificial watering events.

Discussion and Recommendations

The differences between low and high rainfall, and between soils, highlight some considerations when using 0-60 cm soil samples in a soil nitrogen budget. Nitrogen to 60 cm estimated at sowing from a pre-sowing sample was likely to be unaffected by leaching below 60 cm at both high and low rainfall, apart from in sandy soils where leaching to depth was more common before May.

Over winter, leaching to 100 cm and probably deeper was common with high rainfall, regardless of soil texture. In environments with frequent leaching, net nitrogen supply to the crop over winter is unlikely to relate to 0-60 cm nitrogen at sowing, or total mineralisation, a good portion of which may end up below 100 cm. Nitrogen budgets constructed in high rainfall years using only 0-60 cm pre-sowing nitrogen and without estimates of leaching loss and available nitrogen at depth are potentially misleading. The effect will be lessened with medium maturity varieties typical at low rainfall sites, and increased with the earlier sowing and later maturity used to maximise yield with high rainfall.

At all sites, consistent drying likely related to crop water use could be observed in the 70 cm layer between July and September, proceeding to the maximum measured depth by September-October. Water and nutrient uptake below 100 cm is occurring at a time when crop growth relevant to yield and quality is affected by nitrogen, especially with high rainfall. It may be impractical to soil sample to these depths in commercial crops, but agronomic decision making should take account of nutrient potentially stored and/or leached below this depth.

References

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