How to use

PRECISION AG MAP LAYERS

to think about frost differently

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Frosts strike across southern and eastern agricultural regions nearly every season, with most damage caused in early spring during flowering. Frost is one of the biggest environmental and ultimately financial, issues grain growers are faced with, given there are no genetic strategies to mitigate the effects of frost, and very few cost-effective options for insurance.

Actual occurrence of frost is determined by location and landscape factors as well as climate. The rate of cooling and final temperature of the plant canopy is determined in part by the balance between thermal radiation emitted to space and radiation absorbed from the soil. Local topography is also important, as cold air tends to run down slopes and drainage lines and will pool in flats and basins. Barriers such as tree or fence lines can impede flow and allow cold air to accumulate higher in the landscape. The severity of the frost and hence the extent of the subsequent damage is therefore variable across the landscape (Biddulph, 2016).

What is a frost?

Frost - Radiation frost consists of cold, chilling and freezing damage. Canopy air temperatures ≤0°C

Freezing Temperature – Canopy air temperatures ≤0°C at which freezing of plant tissue may occur, screen (at 1.2m) temperatures ≤2°C.

There is evidence that cold and chilling temperatures that don't drop to the freezing range cause damage to the plant:

Chilling Temperature – Canopy air temperatures less than 5°C and greater than 0°C

Cold Temperature – Canopy air temperatures less than 8°C and greater than 5°C. From this temperature and below pollen viability is reduced (Thakur et al, 2010; Cakrabarti et al., 2011)

Which Precision Ag Layers could we use to make frost management decisions?

There are a variety of precision ag map layers collected and available to the modern grain grower. The wide range of practical uses for map layers is not always realised when making variable crop management decisions. Elevation data for example, is collected and embedded in documentation data from agricultural machinery when recording seeding, spraying or spreading operations. This data is particularly useful when it is recorded using RTK GPS signal, as is it is extremely accurate – 2cm in fact. Elevation data can be processed into a map layer which can then be compared with other layers, such as yield data to look for correlations, such as frost impact on yield.

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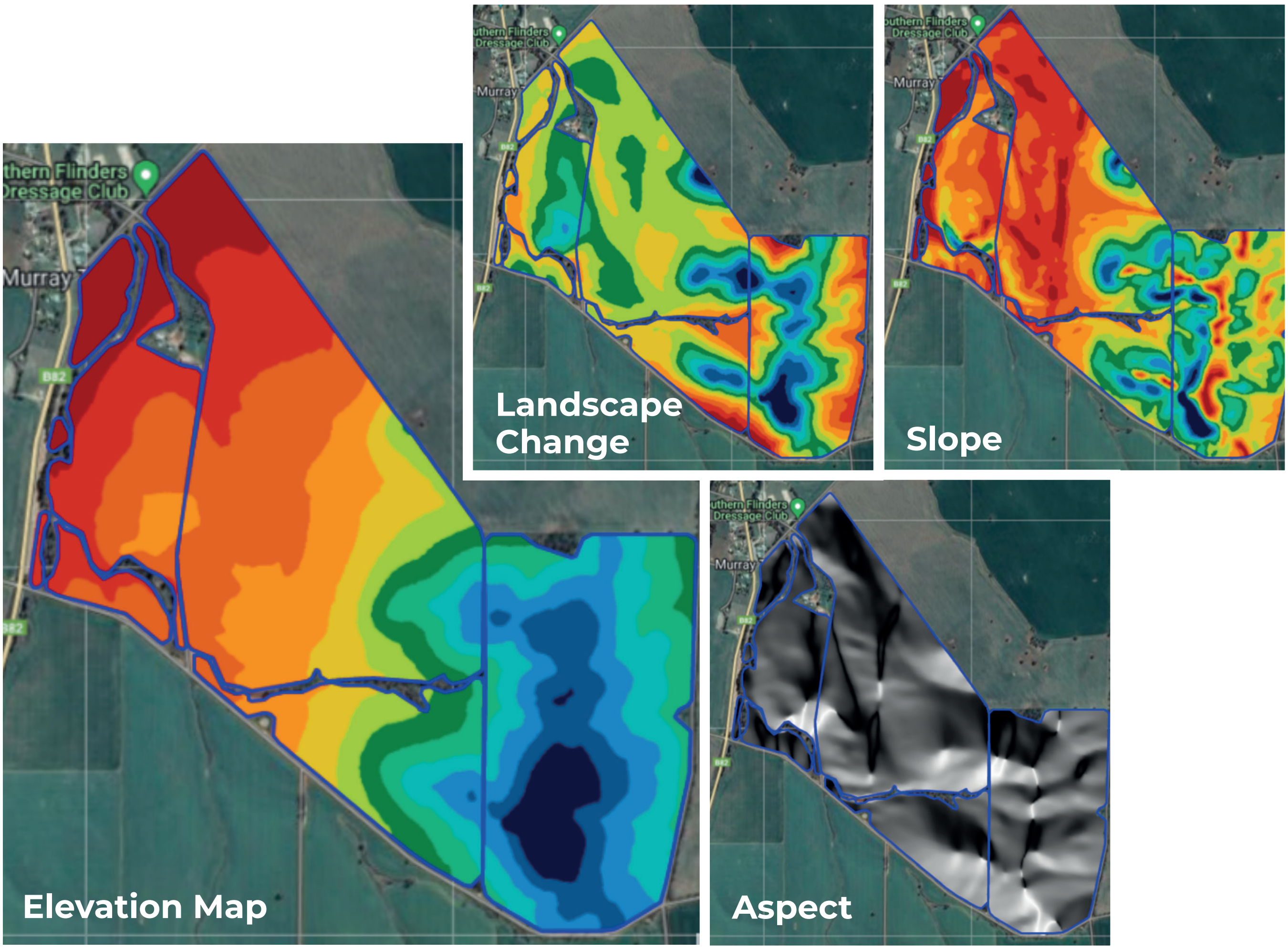
There are other map layers that can be processed as a ‘derivative’ of elevation data, including aspect, slope, and landscape change.

Let’s look at the landscape change map in more detail:

- An ***elevation map*** provides absolute height differences across a field – expressed as a metre above sea level value. Red indicates a lower value, blue indicating a higher value.
- A ***landscape change*** map can give more intricate detail about localised height difference. To explain in basic terms – you could be standing on top of a hill, but still be standing in a localised, minor hollow! The landscape change map picks up this detail, whereas the elevation map does not. Hence the landscape map could provide great value and insight into movement (shedding and pooling) of water and cold air movement. It is expressed as a positive or negative value, once again represented by red as low, and blue as high.



Why investigate these maps further?

- To understand the extent and daily range of temperature variances in differing areas of a field and how much impact minor topographical changes in a field can impact on yield
- To understand how common precision ag layers such as elevation, landscape change and yield data can help farmers plan for, scout for and respond to frost damage using variable or zoned management.

THE DEMONSTRATION SITE

FARM DETAILS

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Owners: Orrock Farming (leased property)

Location: Murraytown, SA

Field Details: 195ha

Average Rainfall: 425-450mm

Crop Rotation: Beans, Canola, Wheat, Wheat, Barley

The purpose of this demonstration was to 'ground truth' a landscape change map as an indicator of the temperature changes (and resulting frost) at different points in the field, and to see how this related to yield variability.

Having a data layer indicating the spatial effects of frost may be very useful when crop scouting or making management decisions before or after a frost event occurs. The process needed to be simple and affordable so that farmers could collect the data and place sensors on their own properties to monitor frost following our process.

Elevation data is commonly recorded by farmers 'in cab' software using precision ag mapping technology, so the data simply had to be downloaded and processed into a map; an inexpensive process.

The demonstration site located at Murraytown in the Southern Flinders Ranges is cropped by Orrock Farming. It is situated in a productive, grain growing region of the Southern Flinders with an average rainfall of 425-450mm.

'There are so many factors about farming I cannot change' said Todd Orrock *'and frost, at this stage, is one of those factors. Collecting quality precision ag data is something that we try to do well, and I am confident that as the years go on, we are learning more about what these maps are telling us. The yield maps, compared with the topographical maps such as the landscape layer help us make quick and calculated decisions about managing frost based on the commodity prices and spring weather conditions each season'.*

A History of Frost Events and Extensive Damage

'Woolfords' paddock is 195ha of highly undulating loamy clay with calcareous outcrops on rises, with 50m elevation gain from the low-lying frost prone areas, up to the ridges that rarely encounter a frost event. The field has a significant paddock history of frost, confirmed by yield maps, satellite imagery and crop scouting post frost event. The paddock was sown to Spartacus Barley on the 12th of May 2021 into dry soil.

The low-lying areas of the field are affected by frost in September and October to some extent in 80% of seasons, as described by Todd Orrock.

Orrock Farming do not run any livestock, so grazing frosted crops is not an option. Their equipment is not geared for a broad scale hay operation, so the decision to cut for hay needs to be precise, considered, and a last resort option. The business is therefore very interested in tracking and monitoring frost accurately, to plan for and to enable viable management decisions to be made late in the growing season.

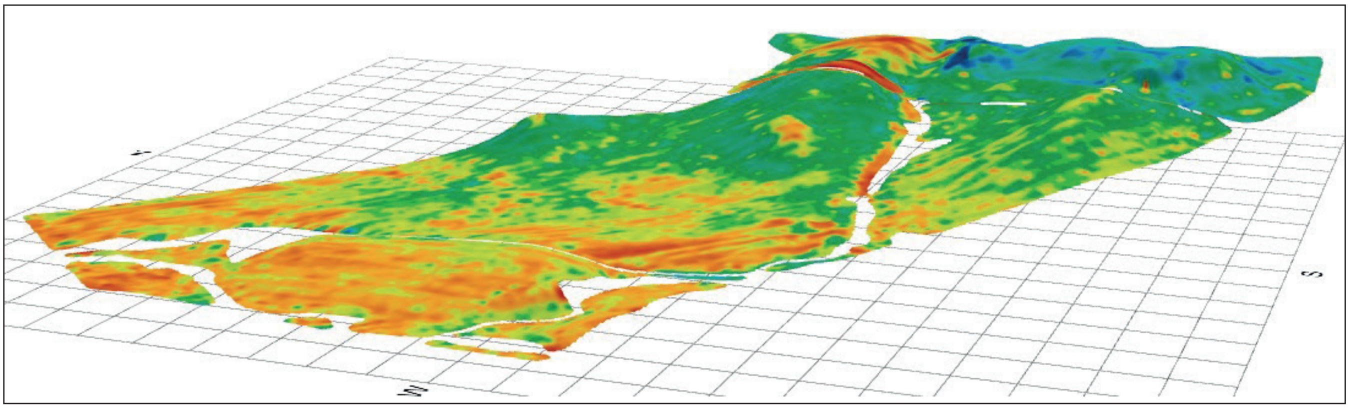


***Figure 1** - Yield affected by frost in 2016 (shown in orange). The higher elevation on the top of the ridge (RHS) side is largely unaffected by frost.*

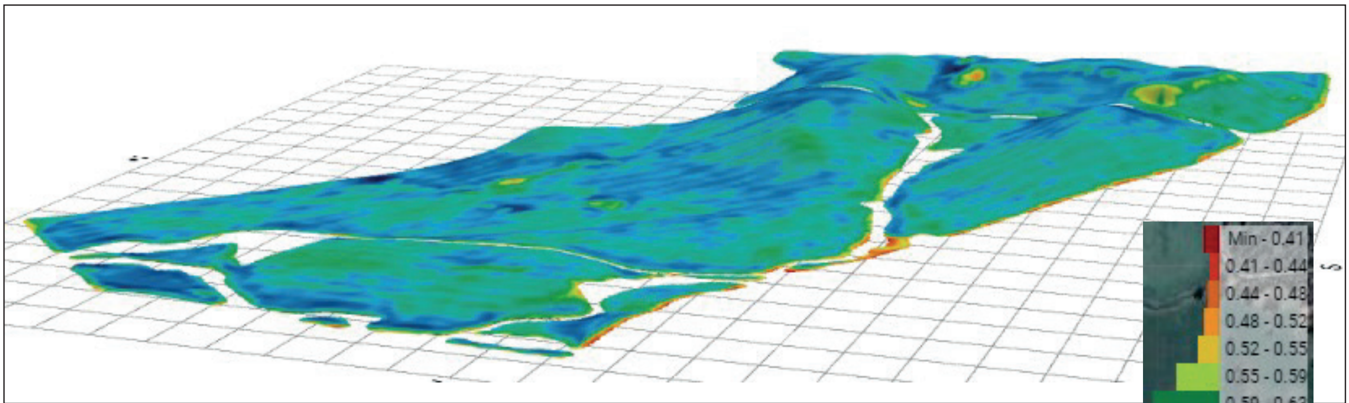


***Figure 2** - SVI Satellite image from September 2016, before the frost event. The biomass in the field is relatively even and tracking towards an even and solid barley yield. SVI (Satamap Vegetation Index, or 'NDVI') image from the 2nd Sept 2016 – The variation (CV%) in biomass is 13%. The Barley Yield variation (CV%) at the end of the season was 24%, due to the impact of late season frost*

The above figures show the severity and variability of an extreme, late season frost event in Woolfords paddock in 2016. Figure 2 shows that the barley biomass was tracking relatively evenly after solid winter and spring rainfall. After a severe frost event on October the 26th, the crop was left with a massive yield penalty. Figure 1, a yield map, shows the yield penalty with losses up to 2.87 t/ha.

What we did...

To look at the variability of frost impact in the different landscape zones, ten iButton temperature sensors were placed in strategic locations throughout the field. By viewing the landscape change map as a background layer in the PCT AgCloud software program, the sensor sites were selected. Some were placed in 'negative' zones (red), meaning a localised depression, some were placed in a 'positive' value zone, a localised rise or ridge. Some were placed in neutral areas, where the terrain is relatively even and flat. The aim was to have sensors in varying degrees of landscape change to test the accuracy of the map as an indicator of cold air movement, hence frost risk.

The sensors are designed for outdoor use and were set to log every 20 minutes and the data needed to be downloaded every 30 days. The sensors were mounted at 1.1m height, an industry standard. When downloaded, the data was available in raw form as a CSV spreadsheet and a temperature line graph.

With predicted frost impact zones established, and temperature data across these zones being recorded, the impact of frost on the crop was noted by visual assessments by the grower and the agronomist, and at each sensor download event by the project manager. Photographs of the crop at each site were taken by the project manager, and the end of the trial, grain and plant samples were collected for further assessment.

Yield mapping with the Intelliview mapping system on the New Holland CR9.90 harvester gave a paddock scale indication of the frost damage across the field.

Figure 3 - *The iButton Sensors placed through-out the field and a description of the terrain at each site in the table.*

1	Low lying, localised depression
2	Low lying, along a creek
3	Mid Slope, flat neutral landscape
4	Side of mild slope
5	Mid slope, slight hollow
6	In centre of a mild depression
7	Top of ridge
8	Top of ridge
9	Side of steep slope, gully
10	Side of steep slope

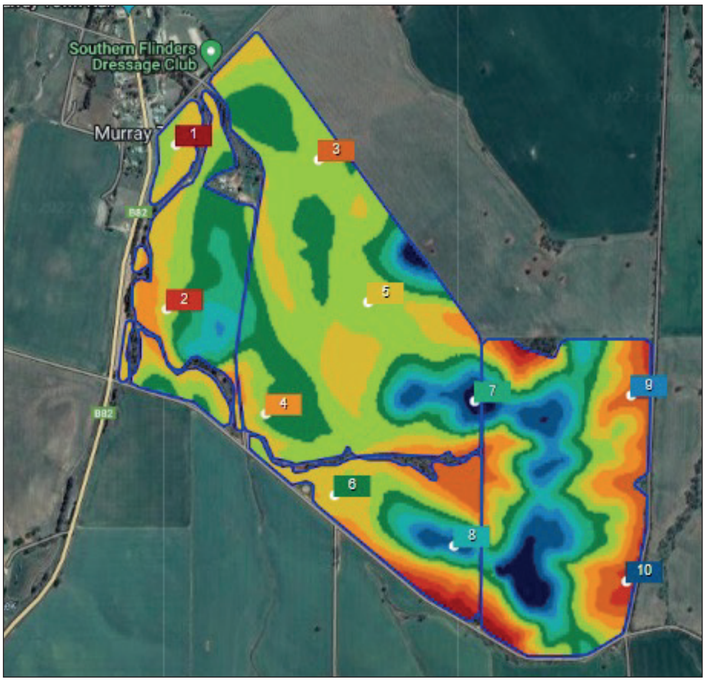


Figure 4 *- The iButton Sensor sites. These were selected in PCT AgCloud using the Landscape Change map as a background layer then exported as KMZ geo-referenced points to scout to the locations and install the sensors in the field.*

The Results

The variation in frost affect across the field...

The paddock was harvested on the 10th December 2021 and averaged 3.8t/ha barley yield. The yield map (processed) captured values from 2.02t/ha through to 6.63t/ha. The Coefficient of Variation is 17% - indicating significant variability and a suitable candidate for variable or zoned management. Looking at the placement of the sensors on top of the yield map, sensors #1, #2, #3 and #4 (in low lying zones) appear to have low yield values at 2.5t/ha, compared to the average of 3.8t/ha. Given the assessments throughout the season and the fact these are rich and fertile soil types, preliminary assumptions are that these low-lying sensors have captured low temperatures and lower yield values due to frost. Low yields at sensors #7 and #8 can be explained by shallow and eroded soil types, this is typical for this area of the field. Sensor #9's location has yielded well as expected (area, although low lying, tends to drain cool air well and the historical yield maps rarely show damage at this site). Sensor #10 was affected by crop chemical damage, so this low yielding result can be ignored as far as frost is concerned.

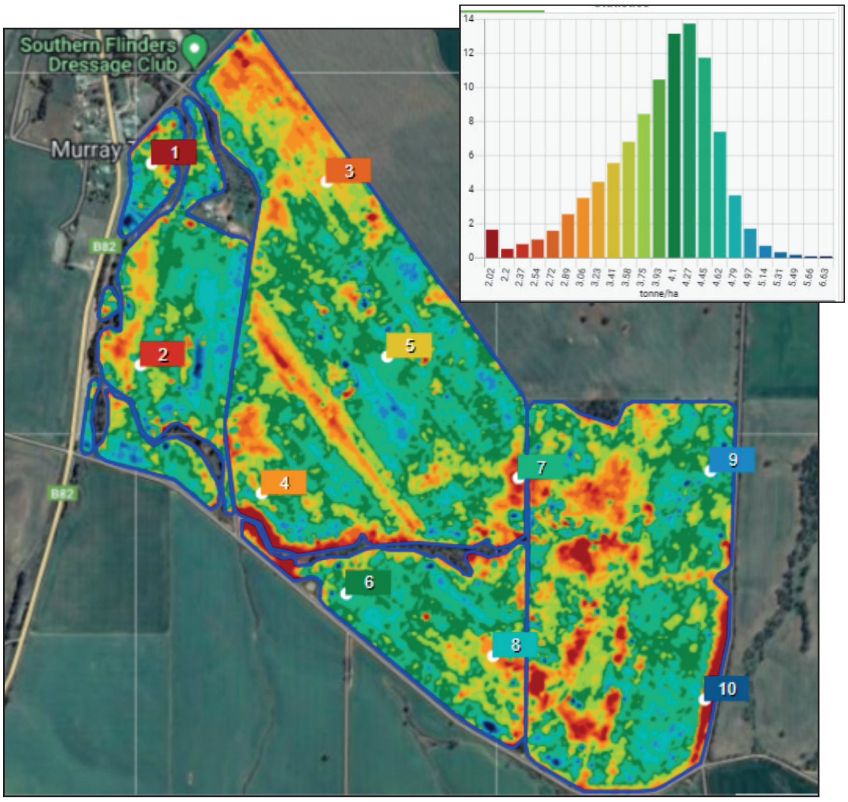


***Figure 5 -** The 2021 Barley yield map with the sensor sites placed over the top. The low yielding areas on the eastern side of the field where the '#7' Sensor and '#8' Sensor are located can be explained by soil type – this is a shallow limestone ridge. On the west side of the field there is evidence of a yield penalty (due to frost) where #1 and #2 sensors are located.*

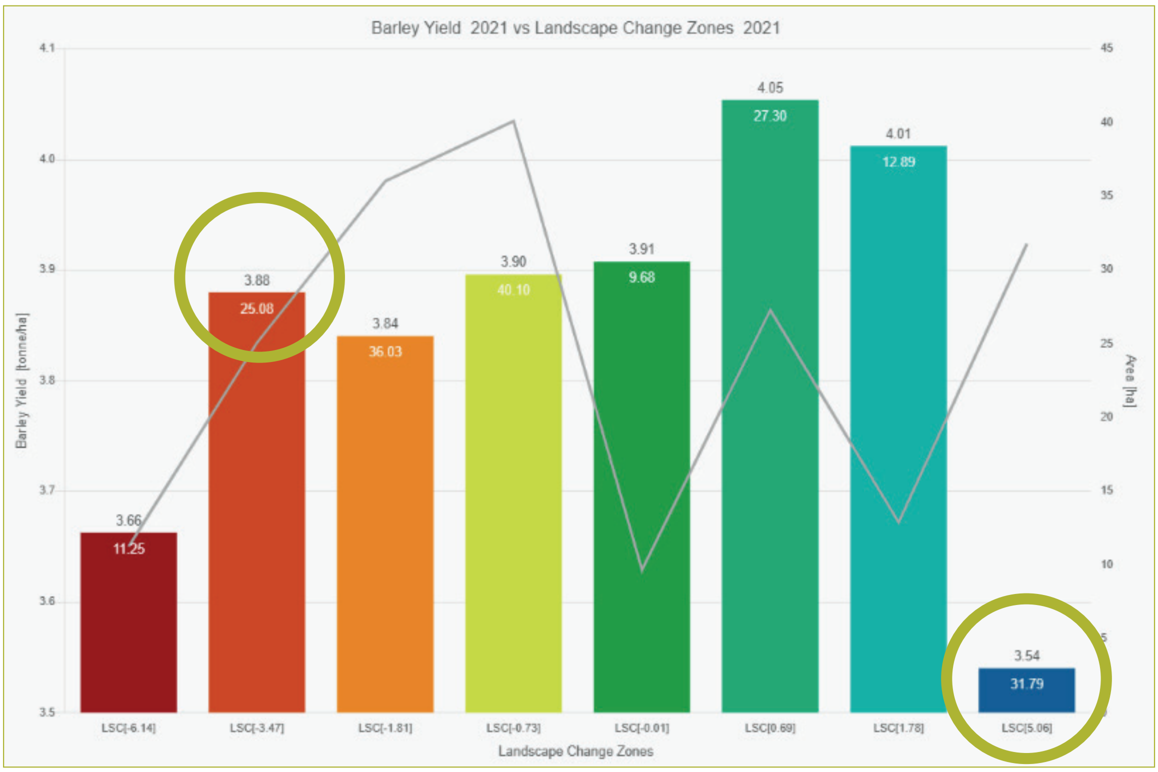


***Figure 6 -** A comparison of each Landscape change zone x 2021 Barley Yield. There is a direct correlation - the more positive the value (blue zone) on the landscape change map, the higher the yield. There are a couple of outliers. The orange column circled may be attributed to low lying areas of the field which are not affected by frost. We can assume that these zones drain cool air effectively. The small blue zone circled is just (3ha) and is simply an elevated zone that yielded poorly. This is the peak of the limestone ridge, a well elevated, but eroded soil zone that is known to yield poorly.*

‘#1’ Sensor – Localized depression

(Negative or RED/ORANGE Zone)

The ‘#1 sensor’, located in a low lying, frost prone area of the field. This site had signs of significant crop damage to the barley heads after the October frost event upon visual assessment.

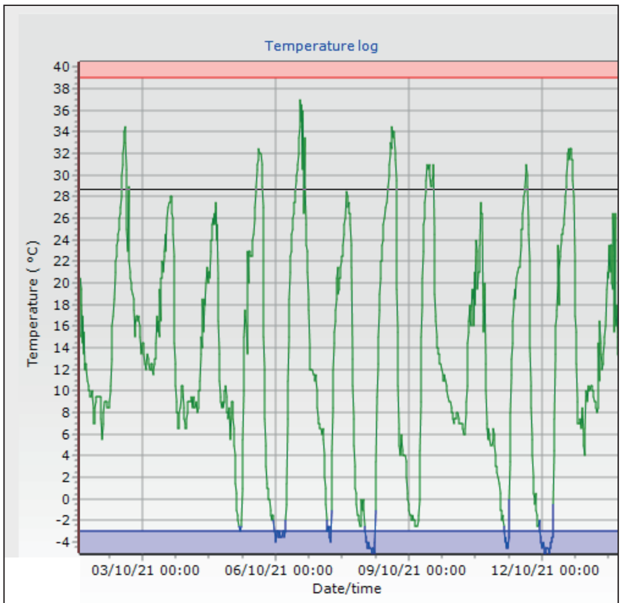
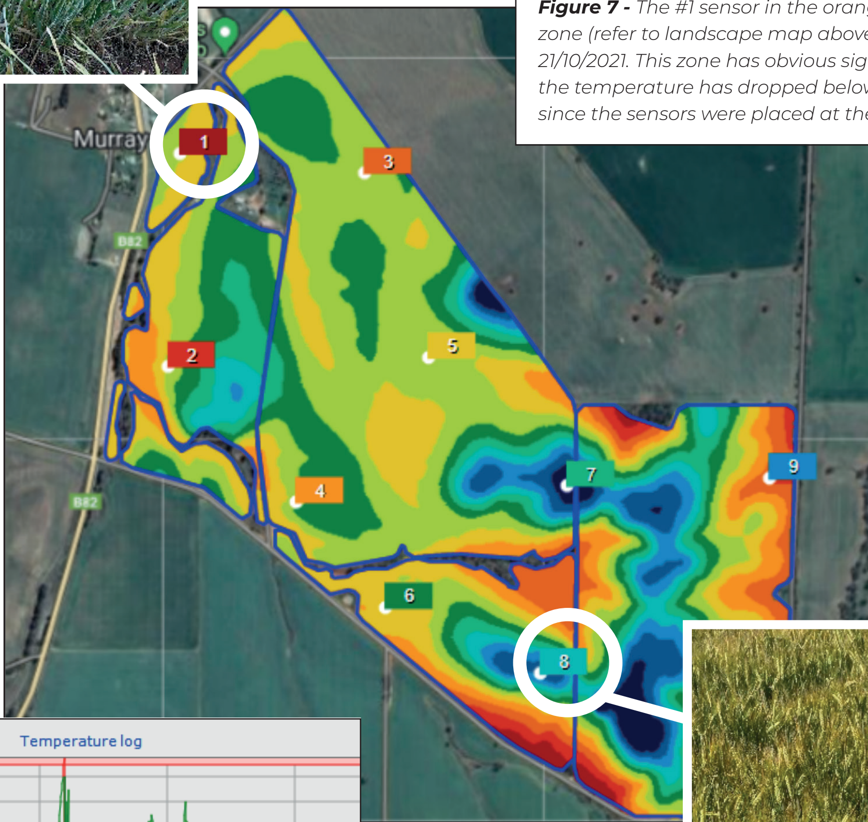


Figure 7 - The #1 sensor in the orange landscape change zone (refer to landscape map above) from 24/9/2021 to 21/10/2021. This zone has obvious signs of frost damage, and the temperature has dropped below zero on several evenings since the sensors were placed at the site in July.



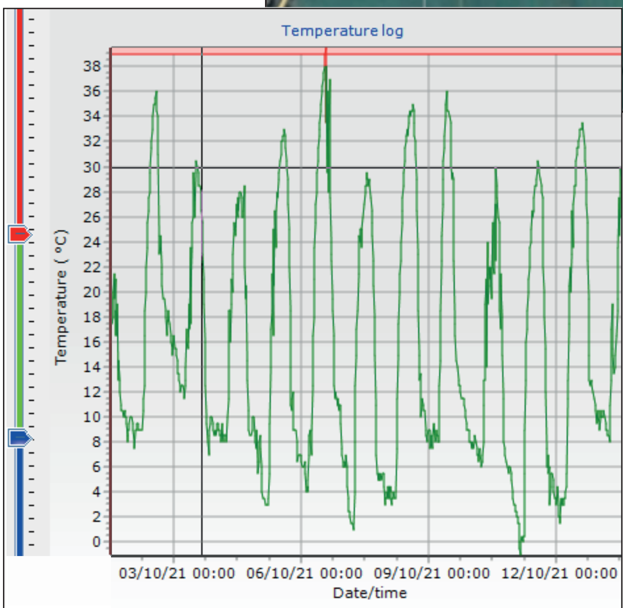


Figure 8 - #8 sensor in the blue zone (refer to landscape change map above) from 24/9/2021 to 21/10/2021. This zone has no visible signs of frost and the low temperatures have been far less extreme

‘#8’ Sensor – Top of Ridge

(Positive or BLUE Zone)

‘#8’, located on a limestone rise, highly elevated area (blue zone on Landscape Change Map). This site had no signs of frost damage upon inspection. This sensor recorded just a handful of incidences where the temperature dipped to zero. The ridge is a low-risk frost zone due to it’s location, where cold air is very unlikely to pool.

Frost Frequency and Severity

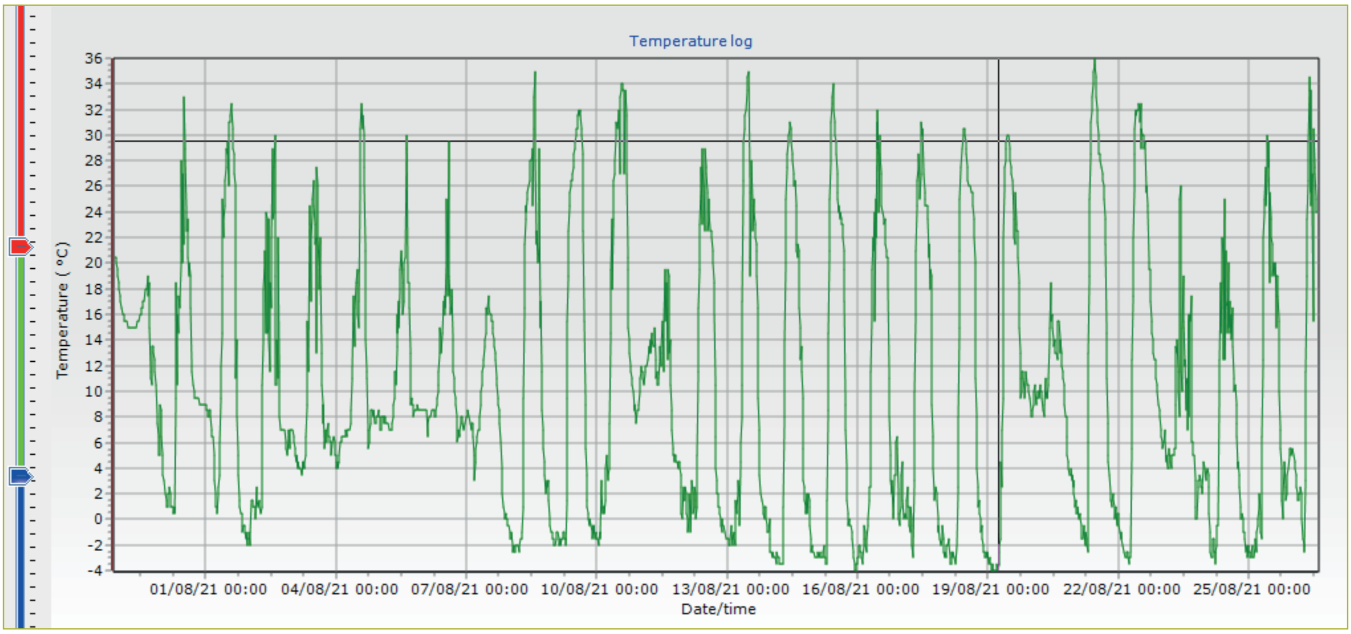
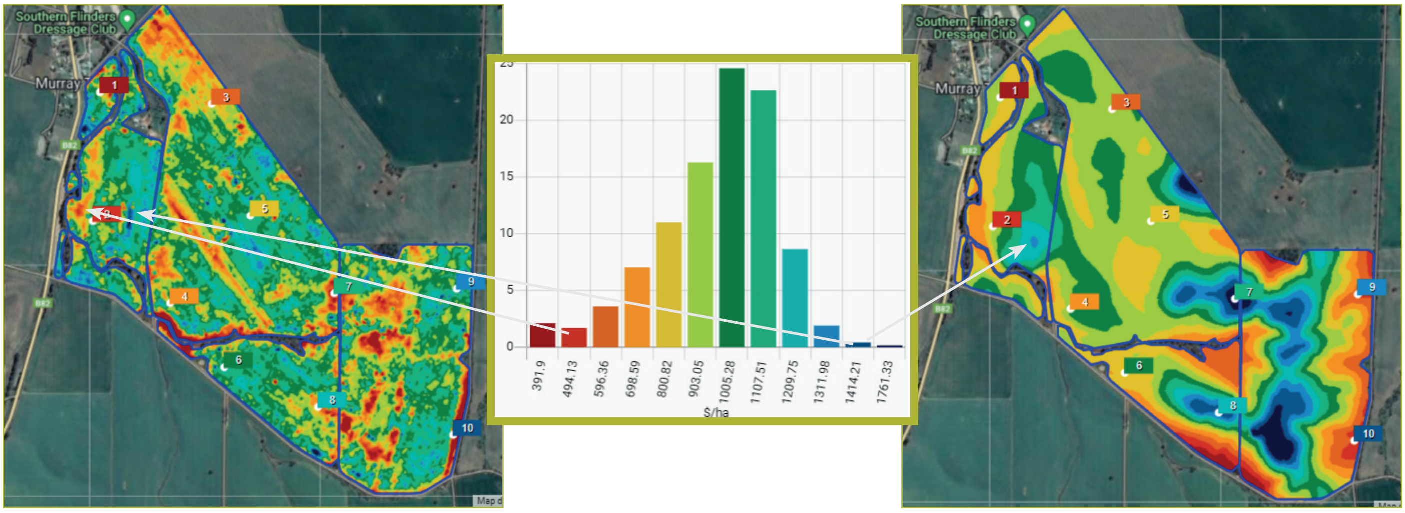


Figure 9 - *An example of the typical frost frequency in July, August and September for the low-lying sensors. The red line is at 0°C. In this graph, the sensor recorded 17 frost events in a 30-day period.*

The sheer quantity of frost events was a shock to the grower and a surprise when analysing the results. The temperature dipped below zero degrees up to 17 times in the months of August, September and October whilst the iButton sensors were present in the field at sensors #1, #2 and #4. A testament to the resilience of our cereal crops!



In terms of economics, the profit map above suggests that last year the option of carrying the crop through to harvest, and not cutting for hay was a profitable (and the simplest option). The field averaged a profit of $903/ha. There were zones where this peaked to $1761/ha and some zones, as indicated on the graph above, that were frost effected/or poor soil types resulting in these areas dipping to $391/ha profit, but even still, they were profitable. This is important to note, as when a profitability maps have been generated for Orrock Farming in previous seasons, frost affected zones in yield maps can incur losses of up to -$300/ha.

WHY WAS HARVESTING THE BEST OPTION IN 2021?

- High grain prices and low hay prices
- Ease of coordination to simply harvest rather than call in hay contractors
- Even though frost damage was evident throughout the season, it was not severe or widespread enough to warrant a variable management operation, unlike past seasons

Now that we have established that the Landscape Change map is useful layer for predetermining the frost risk in Woolfords paddock, the plan will be to simplify it into management zones, which Orrock Farming could be used to 'snap into action' if frost strikes in future seasons.

'HOW TO' - Steps to establish management and monitoring zones for frost on your own farm

If you are interested in using precision ag data to monitor frost and create management zone maps for your own fields, these maps could be a template for management practices such as:

- Selecting frost tolerant varieties to grow in the frost prone zones
- Rolling high risk zones in preparation for hay cutting
- Having the zones ready for frost assessment, making the crop scouting process quicker
- Grazing or partially grazing zones of frost affected crops
- Refencing the most prone zones to manage them entirely differently year in, year out, eg fencing off separately as a new field

What steps should I take to collect the information I need about my own fields?

Collect 'as applied' data from the seeder, or other slow and consistent moving paddock vehicle using RTK GPS. This data needs to be processed to obtain the Landscape Change map layer. This may involve the assistance of a Precision Ag Consultant.

Compare the Landscape Change layer with layers such as yield maps and imagery from seasons with known frost events to look for correlations.

Use the Lanscape Change Map to strategically select sites for frost sensors. It is best to select positive and negative extremities (red and blue zones). If using multiple sensors, place the majority of the sensors in the historically frost prone areas.

Download and compare the data from the frost sensors, paying particular attention to suspected frost incidence, and how these locations performed in the yield map.

If appropriate, split the field up into frost management zones based on the risk severity. These zones can be used for a variety of management decisions throughout the season.

Creating my frost management zones

If you have a field with enough frost risk variability to warrant splitting the field into management zones, there are number of ways to do this. It may involve the assistance of a precision ag consultant to help with the map creation.

The Landscape Change map, for example could be simplified down into three simple zones based on their susceptibility to frost. Here is what we created for 'Woolfords' paddock. We split the map zones at the -5m, -1m and +4m intervals which produced a reasonable and representative looking zone map. A few small depressions were moved from the red zone to the yellow zone, (area circled below). Despite the fact this is a low-lying area, it doesn't ever seem to cop a yield penalty so must drain cool air well.

A landscape change frost management zone map

	High Frost Risk
	Moderate to Low Frost Risk
	Low to Very Low Frost Risk

Figure 10 - *The Landscape Change map was compared with yield maps from several seasons to and then simplified into three management zones in PCT AgCloud.*

Conclusion

For some growers, that are logistically set up for hay operation, the decision to cut a frost affected crop can be simple. However, on many occasions like for Orrock Farming, who are very much geared towards a grain harvest operation, hay or grazing is not the simple answer. The most powerful tools that growers can have in their PA toolbox - are spatial map layers to explain the yield limiting factors in their fields. Information gathered from their own farms, doing 'your own science', is the best way to understand the factors driving productive capacity in different areas of the field. Precision data such as the the Landscape Change layer, coupled with information gathered from the iButton sensors goes a long way to spatially capturing the most frost prone zones and their area, so when frost does strike, scouting and decisions can be quickly made, with the ultimate goal of salvaging profit.

References

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