Application of simple climate analyses in assessing risks – examples for Northern Australia

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This document demonstrates a set of analyses in Australian CliMate which are suited to preliminary risk assessments for existing or proposed agricultural enterprises. The aim is that these tools are transparent and easy to use, and they allow practical experts in a discipline to apply semi-quantitative risk assessments using long term weather data.
We suggest you quickly scan this document and look for an issue or analysis that suits your specialist area. We are exploring methods to bring expert knowledge together with simple analyses to capture the essence of riskiness for each location. This may lead to an exploration of management options for risk reduction e.g. which planting window has the lowest risk?

Simple climate risk assessment can explore:

1. System fit into the climate/weather: water balance (P, E, T, RO, DD)
2. Timing and system status for key operations: preparation, planting, productive growth, harvest using climate variables: rainfall, soil water, temperature (hot/cold), heat sum.

In order to structure this risk analysis, we can consider two broad groups of assessment: s**trategic issues** which generally have time scales over seasons and can consider systems issues; and **tactical issues** which focus on the here and now and guide day to day decisions.

Strategic analyses

In planning an enterprise and modifications, long term data fits into strategic risk analyses through exploration of weather patterns and probabilities of events – an analysis of the climate. Such analyses can range from simple visual interpretation of patterns to qualitative exploration of risk using expert witness models[1]. Analyses available to explore strategic issues include:

- How's the Past? - weather pattern visualisation;
- How often? -probability of a weather event in a time window e.g. planting rain, growing season rain;
- How hot-cold? - heat and cold stress analysis;
- Yield potential? -yield potential all years – simple WUE rules;
- SWApp – water balance analysis using simple green/dead cover
- What trend? - variability vs. trend;

Example applications are provided in order to stimulate your imagination on how to apply an analysis that might capture and enrich your understanding of risk management.

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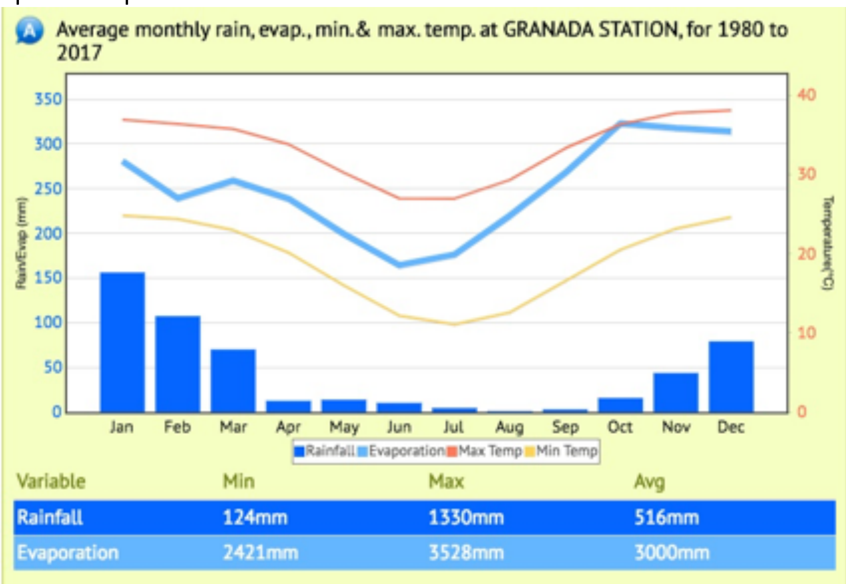
[1] *An expert witness model is extracted/elucidated by working with a local expert who can codify experience using a set of queries - the result being a rapidly gained set of semi-quantitative models that can be easily rerun with other experiences and eventually cross checked with real world experience in the future.*

How's the Past?

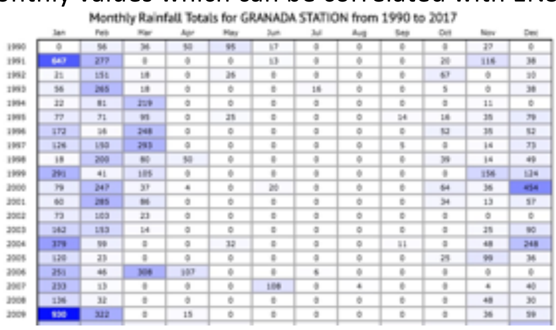
Presents views of monthly and annual rainfall and temperature to quickly explore relationships and patterns.

Climate conditions are presented as:

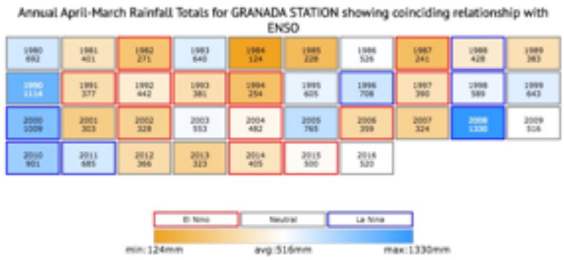
- a histogram of average monthly values for rainfall, minimum and maximum temperature and evaporation potential



- a "mud map" of monthly values which can be correlated with ENSO conditions



- a "mud map" of annual values colour codes with ENSO conditions



Where does this fit into strategic analysis

This long term view (climate) shows and opens up questions such as:

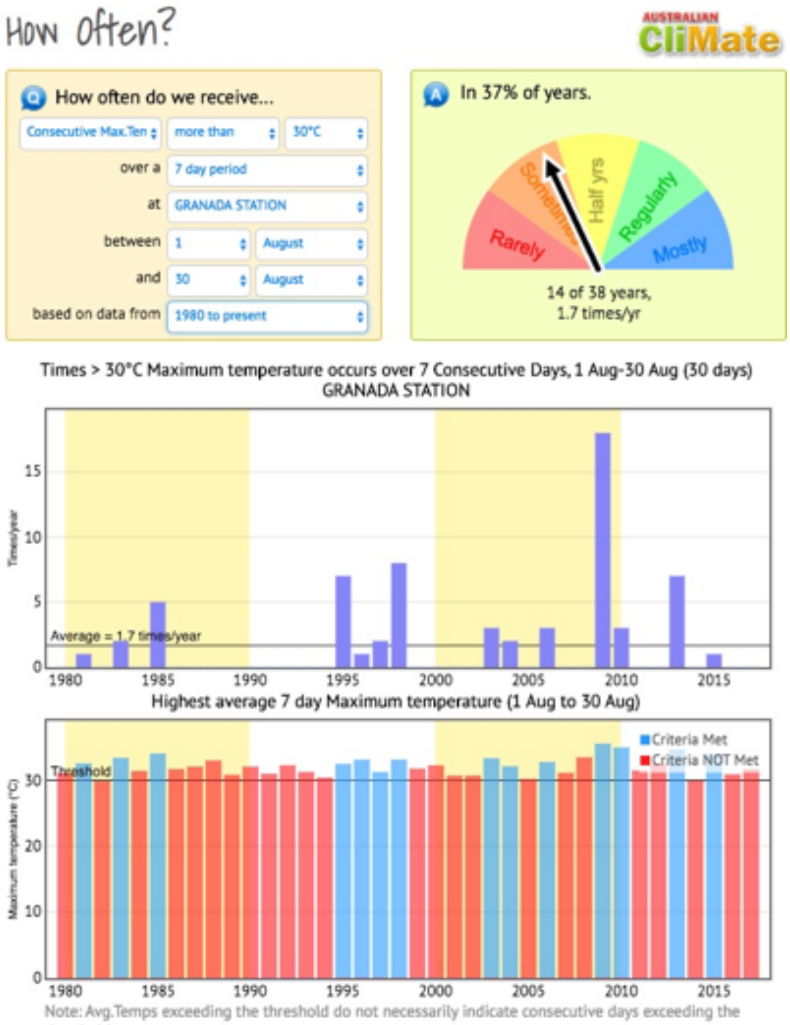
- Annual and monthly rainfall and evaporation potential –what months does rain exceed evaporation?
- How often are there exceptions to the smooth monthly graphs?
- What are the wettest and driest months?
- The "grid maps" allow for a rapid visual assessment of annual and monthly weather variables.

How Often?

Calculates probabilities of weather events (rainfall, maximum and minimum temperatures and solar radiation) in a specified window of time.

Results are presented as:

- a fire chart showing the percentage of years and average number of times each year the event occurred.
- occurrences each year and
- maximum occurrence each year

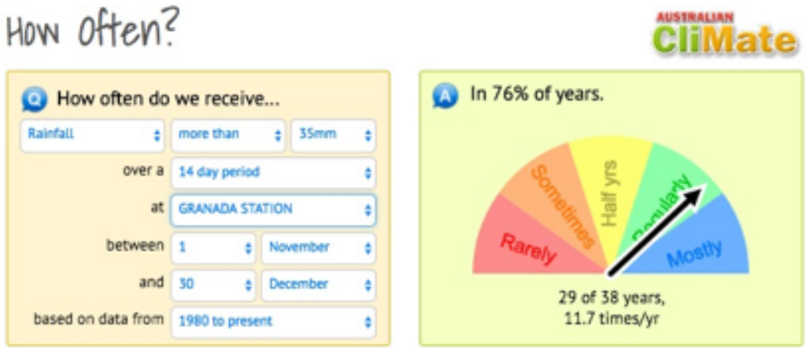


Where this analysis fit into decision making

Howoften? provides probabilities of future events to better inform and manage risk. For example, incidence of frost, heat stress, planting rain or extreme rainfall.
It allows the decision-maker to answer questions such as:

- What is the change of a sowing event based on amount of rainfall over 5 days?
- How often is a heat sum achieved in a growing season?
- What is the probability of temperature being below or above a critical level for germination or flowering?
- How often will I get enough rain to fill my soil type?
- What are the chances of wet weather during harvest?

For example, 35mm of rain over 14 days occurs in 76% of years between Nov and Dec with 11 events/year i.e. a reasonable chance. Probabilities in September –October is 13%!



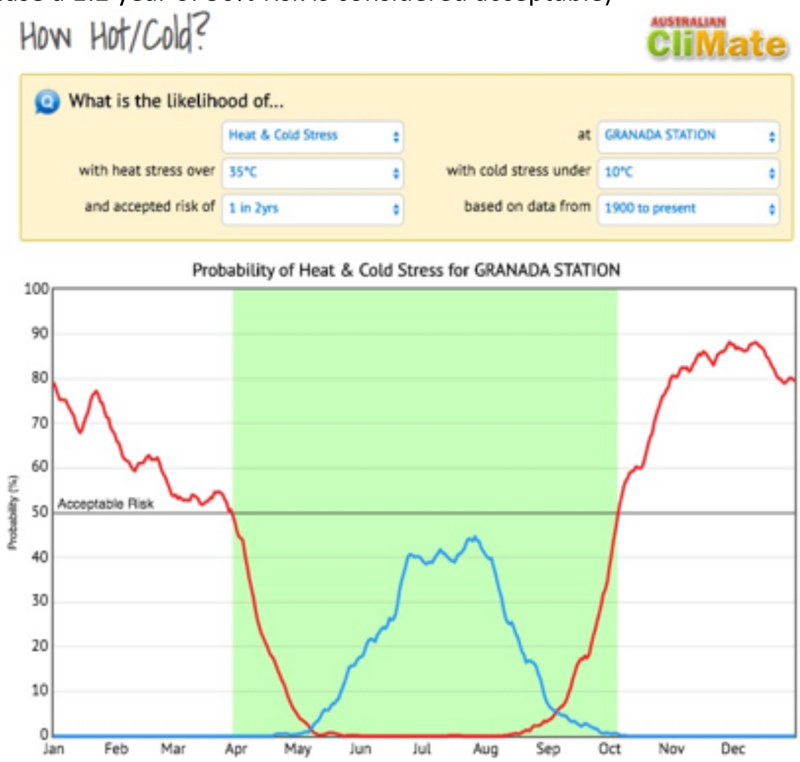
How Hot/Cold?

How hot/cold? provides a rapid assessment of heat and cold stress risks through the year. Crops and pastures have optimum temperature ranges where they perform best. A minimum might be where growth stops or the plant is susceptible to frost (<2°C) while the maximum temperature will be determined by plant species.

How hot/cold? calculates the frequency of temperature thresholds for each day of the year. A probability of occurrence or risk can be specified, identifying periods when heat and cold stress are below a chosen risk.

Temperature stresses are presented as:

- a graph showing a probability (%) of heat and/or cold stress each day of the year
- green bands represent when either temperature stresses are below the specified risk level (in this case a 1:2 year of 50% risk is considered acceptable)



Where does a measure of hot and cold stress fit into decision making?

When planning a new crop, pasture, variety or location for suitability, this analysis quickly assesses risks associated with temperature extremes. For example:

- what is frost risk around flowering?;
- when is the best time for crop or pasture establishment to avoid heat <u>and</u> frost stress?

For example, the period between April and October has <50% chance of receiving both heat (>35^{o}C) and cold (<10^{o}C) stress (see above)

Potential Yield?

Yield in dryland environments is determined by water supply (starting soil water + in-seasons rain). As a strategic analysis, Potential Yield? provides a first cut estimate of average productivity and variability.

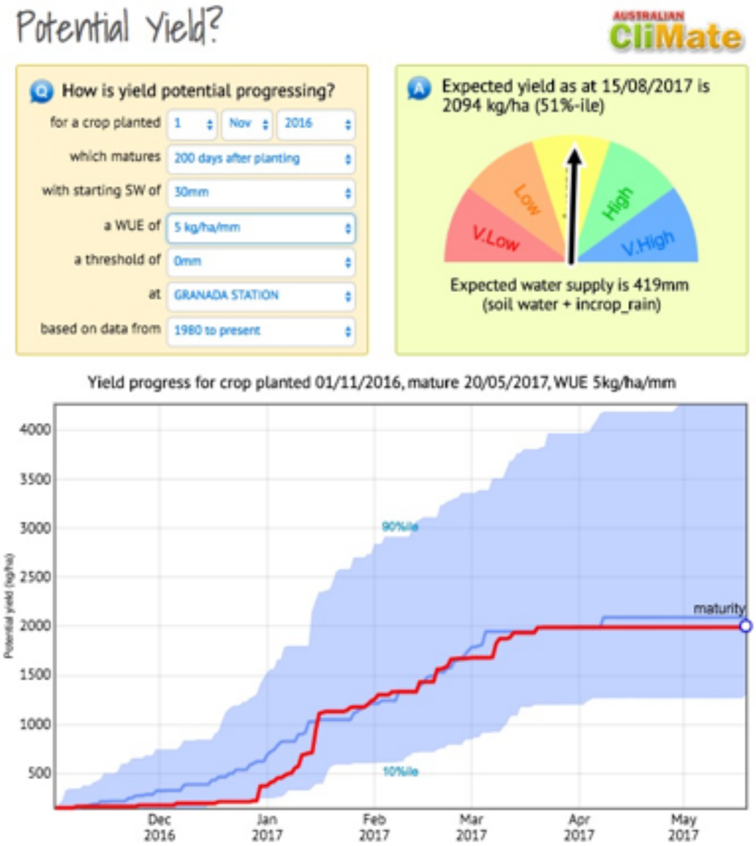
Yield is estimated as: **= [starting soil water + in-season rainfall - threshold water] * WUE** (kg/ha)

Where:

- **Threshold water** is subtracted from the above and represents water lost as evaporation or water needed before grain accumulates; and
- **WUE** (water use efficiency) (kg/ha/mm) represents how water is converted to grain, lint or dry matter.

Yield estimates are presented as:

- a fire chart showing expected yield for the current season; and
- a graph showing yield projections and plumes showing the spread of yield (10-90-%ile).



Where does an estimate of yield potential fit into decision making?

Potential yield has two main applications: tracking the current season and reviewing long term productivity.

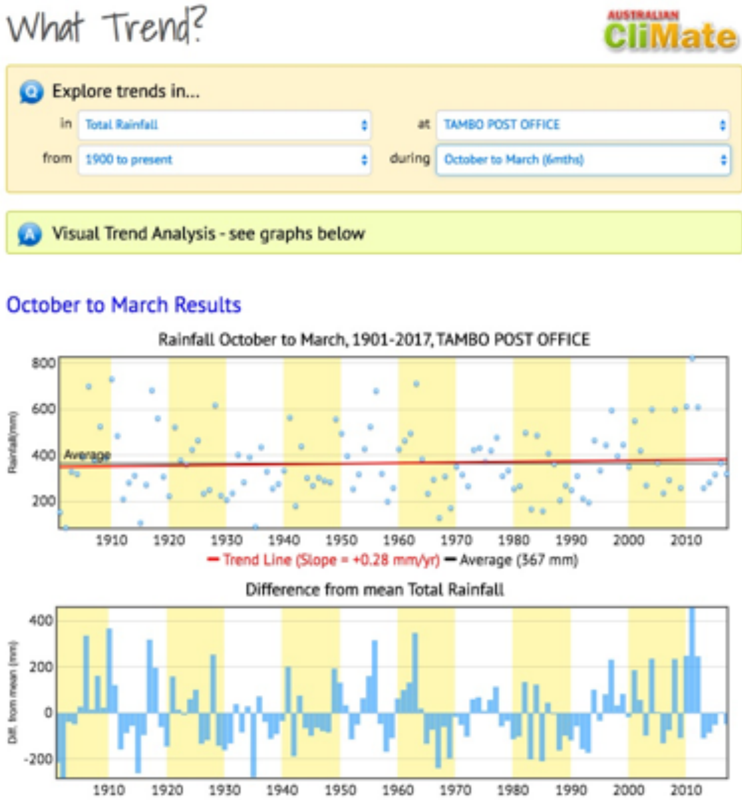
As a strategic tool, the above ***example*** shows that for a pasture species whose growing season is November-March, using a water sue efficiency value of 5kg/ha/mm that average production expected is ~2000 kg/ha but this ranges from 1200 to 4200 kg/ha for 10%ile and 90%ile years respectively.

What Trend?

With much public discussion relating to climate change, Trend? facilitates exploration of trends and variability in annual rainfall, temperature and radiation and incidences of specified values in a time window. The purpose of What Trend? is to allow individuals to better understand trends at a range of time frames and put trends in the context of annual variability.

Trend are presented as:

- A scatter graph with average and line of best fit (and slope);
- differences from the mean; and
- cumulative differences (known as a residual mass curve).



Where does this trend analysis fit into decision making?

Trend? is an exploratory and educational analysis to allow exploration of trends (if they are apparent) in relation to seasonal and annual variability for a location.

Tactical analyses

In applying day to day management decisions, recent past and long term climate data can guide risk reduction through improved understanding of *current system status* (rainfall, soil water stored, heat sum for the season, drought status) and probability of short term futures. Such analyses can be based on simple visual interpretation of patterns through to quantitative analysis of risk using simple *expert models*[2]. Analyses available to explore tactical issues include:

- How wet? N? -soil water and nitrate accumulation in current season;

[2] *An expert witness model is extracted/elucidated by working with a local expert who can codify experience using a set of queries - the result being a rapidly gained set of semi-quantitative models that*

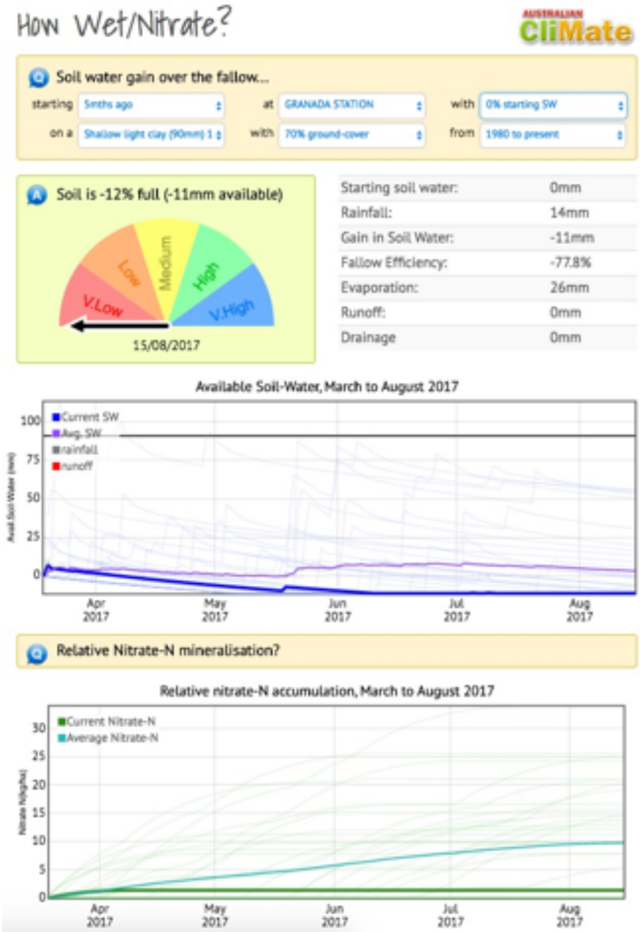
- SoilWaterApp – tracking soil water in fallow and crops for dryland and irrigated conditions (iOS App only)
- Season's progress? -current season in relation to past;
- How likely? - seasonal forecasts and reliability;
- How's El Nino? -current ENSO status from the Australian Bureau of Meteorology;
- Yield potential? -yield progress and expectations for the current season;
- Drought? –warning and status

How Wet? Nitrate?

Estimates soil water and nitrate gains over a fallow. Soil water, evaporation, runoff and drainage are estimated on a daily basis (water balance). Nitrate mineralisation (from organic carbon) is based on the duration the surface soil is moist, temperature and soil organic carbon.

Soil water and nitrate gains are presented as:

- a fire chart showing (% and mm) of Plant Available Water;
- a table of water balance components; and
- graphs showing gain in soil water and nitrate relative to average and all years.

- 

Where does soil water and nitrate gains fit into decision making?

Starting soil water and nitrate set the scene for a season. Both soil water and nitrate supply crops and pastures for later in the season.

Tactical questions that can be asked of this analysis include:

- How effective was the pre-wet season in storing water for a new pasture sowing? Do I have enough water to reduce establishment risk?
- How does soil moisture and nitrate N accumulation over the fallow compare to previous years? [I have a good feel for past years and inputs, but not so sure about this year's start]

In the ***example above***, the period since the 2016-17 has not resulted in any accumulation of soil water and nitrate accumulation is also well below average. While this period is traditionally not effective in water accumulation, the lines above the median show many seasons do accumulate significant soil water – it is these years, when identified, that provide improved opportunities to establish water sensitive improved pasture species.

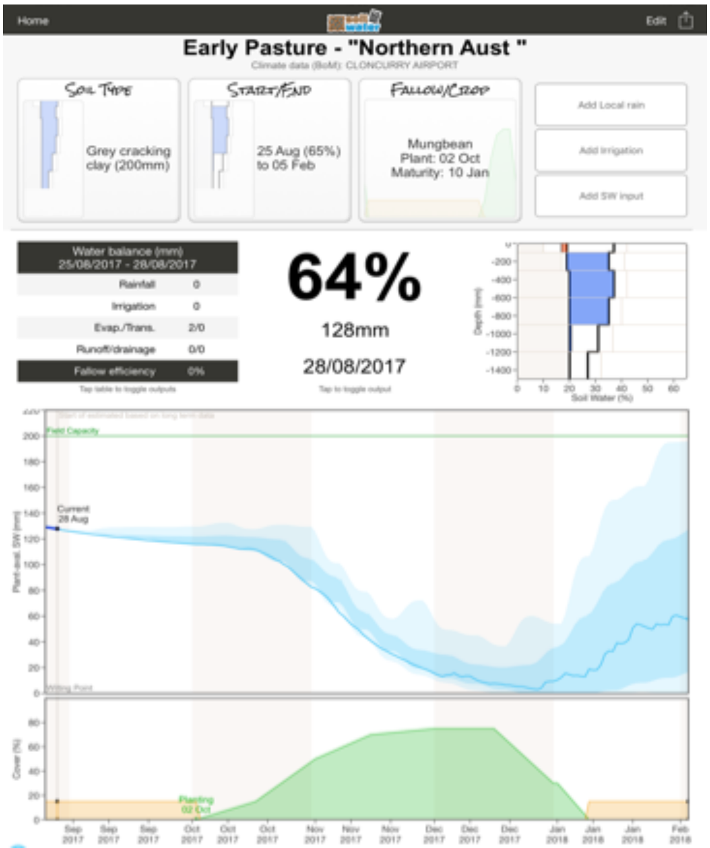
SoilWaterApp (SWApp), an iOS App

Soil water status is tracked during fallow and crop periods for dryland and irrigated conditions. Impacts of weather, soil type and agronomy can be quickly compared while local rainfall can be used to customise estimates for each paddock. SWApp, developed by the GRDC for the grain industry, is applicable to a wide range of crops and pastures.
SWApp supports good agronomy by:

- tracking soil water leading to critical operations (wetting up);
- tracking soil moisture for each crop and paddock using current seasons' rainfall and irrigation;
- estimating water use for the coming season; and
- tracking irrigation requirements and forecast needs

Soil water estimates are presented as:

- a summary of soil water to date, water balance and soil profile water; and
- a graph showing current soil water and distribution for all years (60 and 90%ile plumes) and dead and green cover.



Where does an estimate of soil water fit into decision making?

Apart from irrigation, stored soil water is the only water supply to carry crops and pastures between rainfall events. Successful crop and pasture establishment is generally very dependent on a reserve of soil water to ensure root growth and plant establishment, even in high rainfall areas as rainfall is erratic and unpredictable.

Tactical issues guided by soil water status include:

- Effectiveness of pre-wet season in storing water for a new pasture sowing? Do I have enough water to reduce establishment risk?
- How does soil moisture and nitrate N accumulation over the fallow compare to previous years?

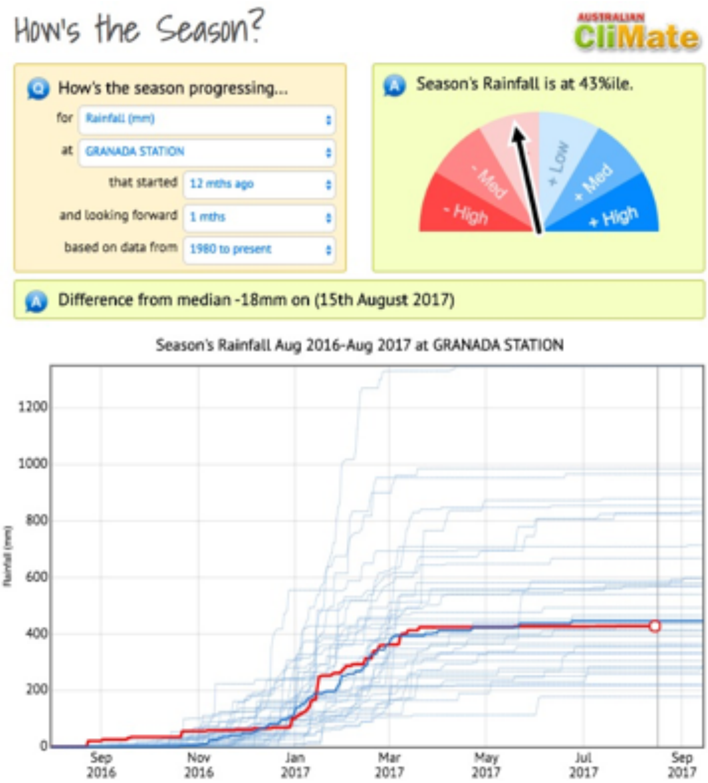
This ***example*** shows soil water for a crop or pasture sown in early October with soil water nearly exhausted by December. This soil was 64% full (128mm available) at the end of August, indicating the necessity of having reasonable stored water to minimise risk for successful establishment.

How's the Season?

Explore the current seasons': rainfall, temperature, radiation and heat sums in relation to previous years. The aim is to put the current season in perspective without bias – it is human nature to put more emphasis on the recent past (good and bad) whereas good decision making should be based on unbiased risk assessment.

Results are presented as:

- a fire chart, with a percentile rank and difference from median
- a graph showing the current season, the median and all years. Each year can be highlighted by hovering over each line.



Where this analysis fit into decision making

- In diagnosis of the current season as it progresses; and

- Setting production expectations

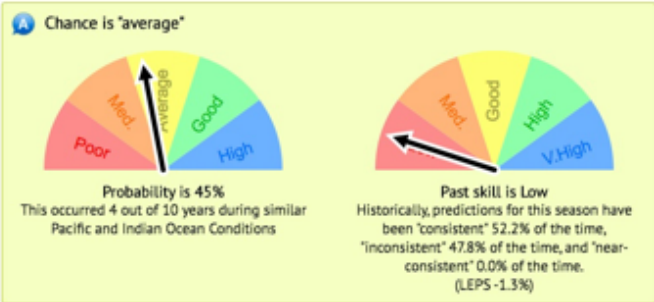
The ***example above*** shows that the last 12 months has been close to the average, tracking the long term median closely. The spread of lines shows how variable each season has been, (and will be!).

How Likely?

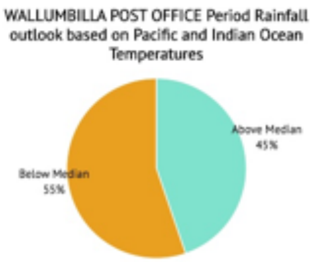
How Likely? provides a probabilistic seasonal rainfall and temperature forecast for 3 to 6 month forward with an assessment of forecast skill. The current forecast is based on correlations between seasonal weather and sea surface temperature and El Niño Southern Oscillation index values. POAMA/Access S forecasts to be added when available.

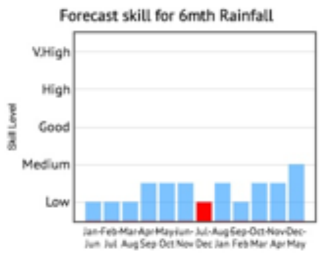
Seasonal forecasts are presented as:

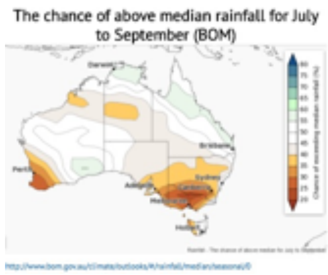
- A fire charts showing the probability of rainfall or temperatures exceeding the median (50%ile), tercile 1 (33%ile) or tercile 2 (66%ile) values;
- A fire chart showing past skill

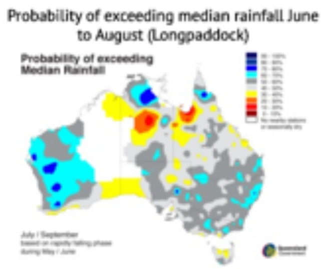


- pie chart showing probabilities and a histogram showing skill for each month and maps from the Bureau of Meteorology and Longpaddock.
  Links to the BoM and Longpaddock are at the bottom of each map









Where do seasonal forecasts fit into decision making?

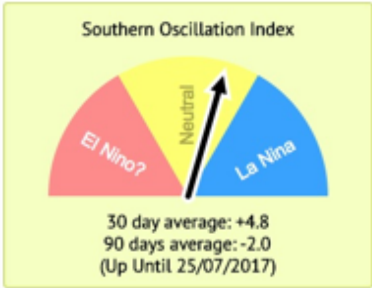
Production risk is dominated by uncertainty in the coming season. A reliable forecast can play a big part in most agricultural inputs, but at this stage, all forecasts have variable skill. Nevertheless, How likely? provides several views of forecasts which can form part of operational management

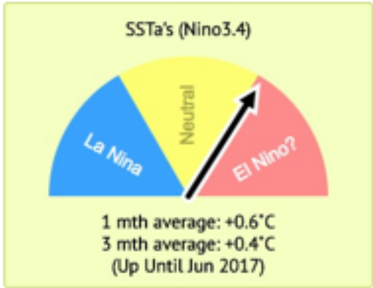
How's El Nino?

The status of El Nino Southern Oscillation index (ENSO) can provide useful indicators of whether an El Niño or La Niña exists. This analysis is a look-up of analyses from the Bureau of Meteorology. ENSO status is based on key atmospheric and oceanic indicators.

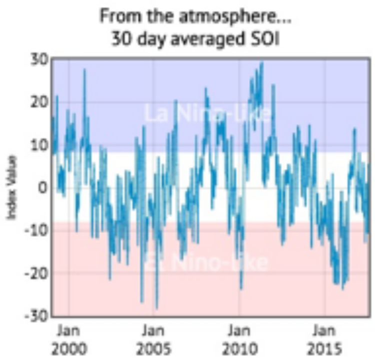
El Nino and Sea surface temperature conditions are presented as:

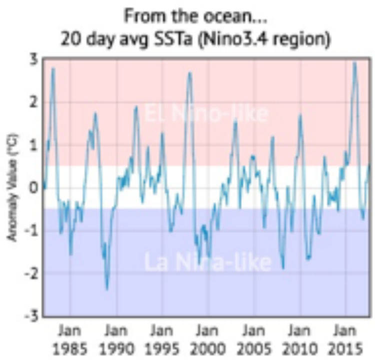
- fire charts showing current SOI status and





- time series of SOI and SST values
-





Where does ENSO status fit into decision making?

ENSO patterns provide a view of El Niño, La Niña and Neutral ENSO conditions. Given the slow movement atmospheric (SOI) and ocean (sea surface temperature) indicators may inform us about weather in the coming months.

Potential Yield?

Yield in water limited environments is determined by soil water at planting plus in-crop rain. This analysis gives a progressive update of yield expectation based on rainfall-to-date and average rainfall looking forward to maturity. Yield is estimated as:

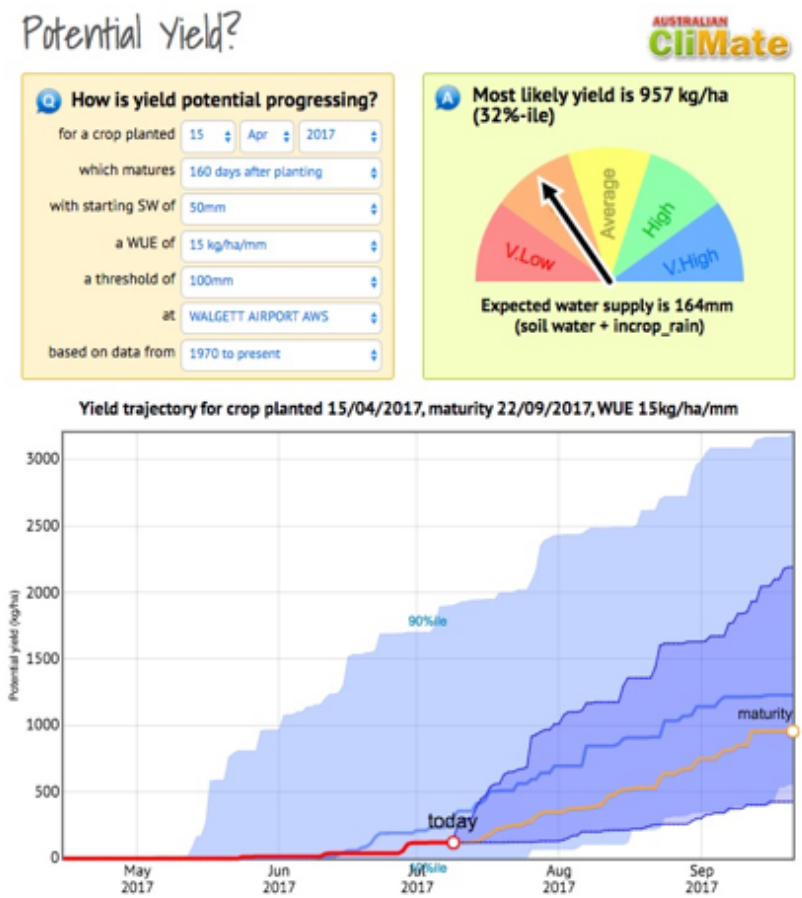
= [starting soil water + in-crop rainfall - threshold water] * WUE (kg/ha)

Where:

- **Starting soil water** (mm) is soil water at planting;
- **In-crop rainfall** is actual rainfall (mm) from planting to the current date + expected rainfall until maturity;
- **Threshold water** is subtracted from the above and represents water lost as evaporation or water needed before grain accumulates; and
- **WUE** (water use efficiency) (kg/ha/mm) represents how water is converted to grain, lint or forage.

Yield estimates are presented as:

- a fire chart, expected yield, a percentile ranking and expected water supply; and
- a time series showing yield expectation to date, projected yield based on average in-season rain, and plumes (all years and this year) showing the spread (10-90-%ile) of likely yield.



Where does an estimate of yield potential fit into decision making?

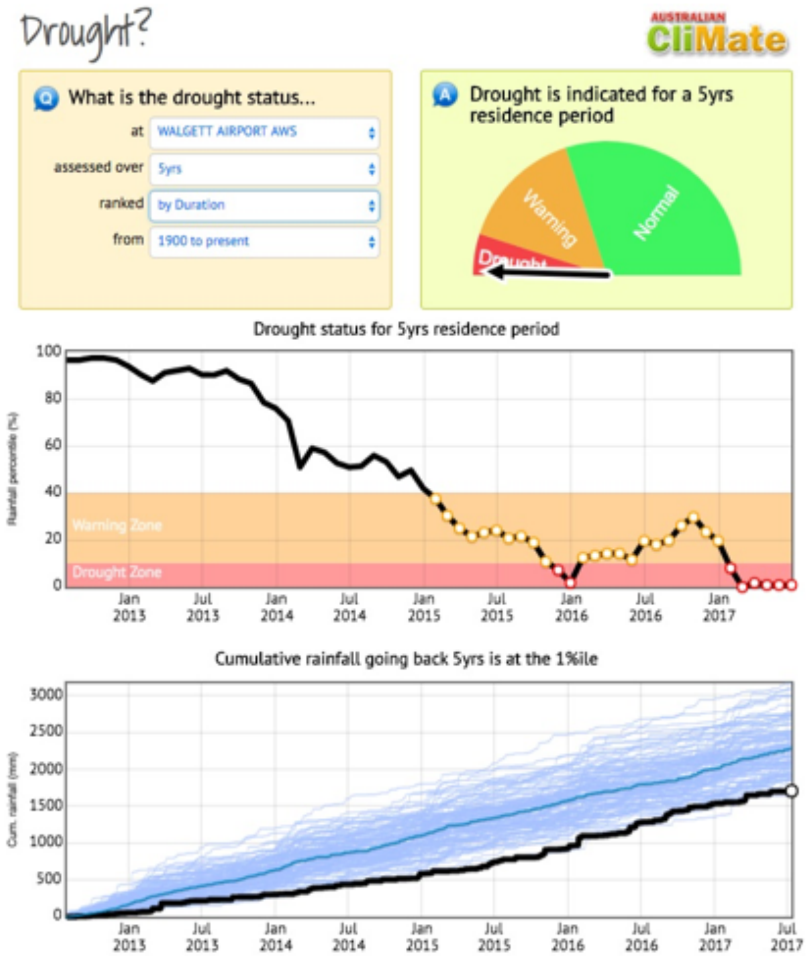
Potential yield has two main applications: tracking the current season and reviewing the season after harvest to benchmark the crops performance.
Have an object basis for estimating yield potential is used to adjust inputs and later in the season, marketing decisions. An above average expectation indicates that inputs such as fertiliser or disease management require more attention for the yield to be achieved, and conversely, reduce inputs when expectations are lower than average, as show above.

Drought?

Drought? tracks drought status (no drought, warning or drought) using the Rainfall Percentile Method. Drought conditions are indicated when rainfall for a specified duration (6 months to 5 years) is <10% of the long term value. The duration or "residence time" is dependent on the situation being considered e.g. a "drought" can manifest in a short time when a system has little buffering, while systems such as large water reservoirs, designed to supply water over a series of years will have a longer residence time of 2-5 years. Droughts can be categorised by duration (months), depth (%ile) and ENSO conditions.

Drought status is presented as:

- a fire chart showing drought status, a time series of drought status for the residence period selected and a simple cumulative rainfall for the residence period showing rainfall percentile. The starting point of the graph is determined by rainfall in the previous "residence period.



- a table showing previous drought statistics and ENSO status with the current drought marked yellow. Previous droughts can be ranked according to depth, duration or depth and duration

Historical Droughts (1900 to 2017) at WALGETT AIRPORT AWS for a 5yrs residence time.
Sorted by Duration showing El Ninos and La Ninas

Rank	Drought Period	Drought Length	Drought Depth	Drought Integral	Warning Start	Warning Length	Warning ENSO State	Drought ENSO State	Actual Revovery Rainfall
1	Dec 1945 to Feb 1948	27mths	0%ile	206%mth	Nov 1945	1mth	Neutral	Neutral	1097mm
2	Mar 2005 to Apr 2007	26mths	0%ile	170%mth	Dec 2004	3mths	El Nino	El Nino	801mm
3	May 1941 to Jun 1942	14mths	2.7%ile	75%mth	Jan 1941	4mths	El Nino	El Nino	386mm
4	Jun 1944 to Jul 1945	14mths	1.8%ile	67%mth	Sep 1942	21mths	Neutral	Neutral	404mm
5	Jan 1969 to Oct 1969	10mths	4.5%ile	27%mth	May 1968	8mths	Neutral	Neutral	416mm
6	Jul 1940 to Dec 1940	6mths	4.5%ile	19%mth	Feb 1940	5mths	Neutral	El Nino	111mm
7	Jan 2017 to Jun 2017	6mths	0%ile	48%mth	Jan 2016	12mths	El Nino	Neutral	174mm
8	Jan 1916 to Jun 1916	6mths	0.9%ile	37%mth	Dec 1915	1mth	Neutral	Neutral	248mm
9	Jul 2004 to Nov 2004	5mths	2.7%ile	23%mth	Nov 2002	20mths	El Nino	Neutral	130mm
10	Aug 1915 to Nov 1915	4mths	7.2%ile	6%mth	May 1915	3mths	El Nino	La Nina	57mm

Where does drought status fit into decision making?

Drought? provides an objective assessment of rainfall deficit for the "residence period" using one of the Bureau of Meteorology's >4,000 rainfall stations? Drought? can provide land managers and industry with an alert of approaching drought and a measure of duration and depth of drought.

Appendices

CliMate Flier

Australian CliMate *(v2)*

Assessing risk in Australia is part of most decisions we make on a farm. A new version of the Australian Climate App (www.climateapp.net.au) has ten analyses which add value to Australia's network of ~8000 climate stations available from SILO using the Bureau of Meteorology's weather observation network.
Each analysis supports an aspect of risk analysis including current season progress, forecasts, rainfall and soil water updates, drought and variability/trend analysis. Analyses include:

- How often? -probability of a weather event in a time window e.g. planting rain;
- How wet? N? -soil water and nitrate accumulation in current season
- How hot-cold? - heat and cold stress analysis;
- How's the Past? - weather pattern visualisation;
- What trend? -visual assessment of variability and trend; *
- How likely? -probability and reliability of seasonal forecasts;
- How's El Nino? -current ENSO status from the Australian Bureau of Meteorology;
- Season's progress? -current season in relation to past;
- Yield potential? -yield potential for the current season; *
- Drought? –status for specified residence period. *

WWW version *(v2)* www.climateapp.net.au
or go to the **App Store for v1**. New iOS and Android versions due later in 2017.

SWApp flier

SoilWaterApp

*Soil water status can be tracked during fallow and crops for dryland and irrigated paddocks using the new **SoilWater App** (SWApp). Impacts of weather, soil type, stubble cover and agronomy (dates, crops) can be quickly compared while local rainfall can be used to customise estimates for each paddock. SWApp compliments soil sensors and weather stations. SWApp, developed by the GRDC, is applicable to a wide range of crops.*

SWApp supports good agronomy by:

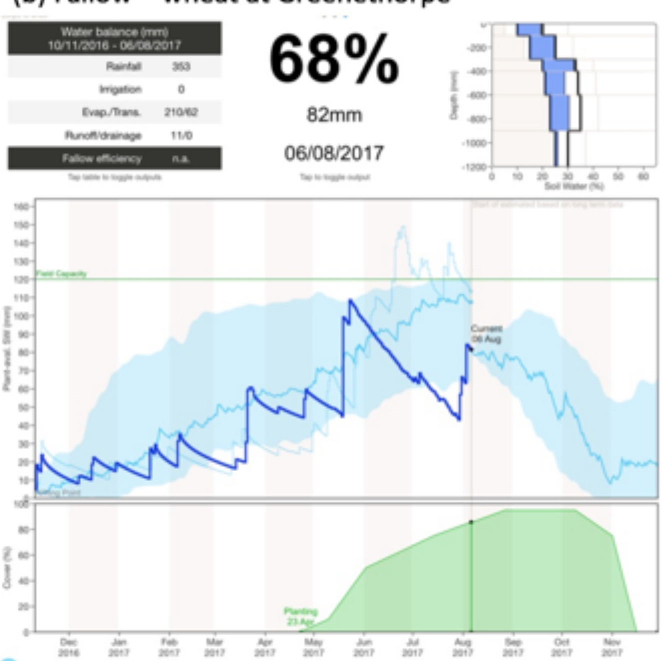
- tracking soil water in the fallow (wetting up);
- estimating water use for the coming crop; and
- tracking soil moisture for each crop and paddock using current seasons' rainfall and irrigation.

Applying SWApp

Two applications of SWApp below show: (a) - water storage over a fallow since Nov. at St George when little of the rainfall was stored (1%) and the soil water is well below average; and (b) – after a fallow, in the middle of a wheat crop.

(a) Fallow at St George

(b) Fallow – wheat at Greenethorpe



Once a paddock is configured by selecting: location; soil type; crop and fallow conditions, an update of soil water is as simple as opening the App and selecting the paddock. SWApp automatically updates rainfall from Silo. Analyses can be easily shared and any entered data is securing backed up.

SWApp is available in the App Store for iOS devices (iPhone, iPad).
Visit www.soilwaterapp.net.au for more information