

Long Paddock: climate risk and grazing information for Australian rangelands and grazing communities

G. Stone^{A,B}, R. Dalla Pozza^A, J. Carter^A and G. McKeon^A

^AQueensland Government, Environment and Science, GPO Box 2454, Brisbane, Qld 4001, Australia.

^BCorresponding author. Email: Grant.Stone@qld.gov.au

Abstract. The Queensland Government's Long Paddock website has been redeveloped on Amazon Web Services cloud computing platform, to provide Australian rangelands and grazing communities (i.e. rural landholders, managers, pastoralists (graziers), researchers, advisors, students, consultants and extension providers) with easier access to seasonal climate and pasture condition information. The website provides free, tailored information and services to support management decisions to maximise productivity, while maintaining the natural resource base. For example, historical rainfall and pasture analyses (i.e. maps, posters and data) have been developed to assist in communicating the risk of multi-year droughts that are a feature of Queensland's highly variable climate.

Additional keywords: carrying capacity, climate, decision support tools, extension, grazing.

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Introduction

The Long Paddock website <https://www.longpaddock.qld.gov.au/> (accessed 31 January 2019) is a Queensland Government initiative that has served Australian rangelands scientists and land managers since December 1995. Long Paddock receives over 17 000 visits per month (2017 monthly average) with over 146 000 return users (i.e. >2 visits within 2 years – Google analytics count). Long Paddock was developed to provide relevant and tailored information to Queensland and Australian rural landholders, managers, pastoralists (graziers), researchers, advisors, students, consultants and extension providers, enabling them to incorporate climate-related risk into their decision-making.

The origin of the Long Paddock name comes from the Australian vernacular, where the national stock route network is informally referred to as the 'long paddock' given its geographic extent – 'the longest paddock in the world'. In times of severe drought, some graziers take to droving to keep their livestock supplied with feed, moving long distances along stock routes, sometimes across state boundaries. 'Going on the long paddock' is an Australian way of mitigating drought risk; likewise, using the Long Paddock website can assist in reducing drought impacts through delivery of historical, current and forecast information on rainfall and pasture production products for Australia's rangelands in general and Queensland's grazing lands in particular.

Historically, multi-year periods of dry ('drought') and wet ('floods') have had major impacts on rangeland enterprises, driving processes of land degradation and exacerbating financial and social hardship (McKeon *et al.* 2004). Past governments have recognised the need for community support through

documentation in Royal Commissions and direct financial assistance (e.g. Daly 1994). It has been recognised (e.g. Allan *et al.* 1996) that global climate systems have variability in key climate drivers such as sea surface temperatures and atmospheric pressure at time scales that have had major effects on regional rainfall, agricultural production (i.e. grain, fibre, beef), livestock carrying capacity and human systems (e.g. communities). Global phenomena such as El Niño Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO) have strong effects on year-to-year rainfall variability (Stone *et al.* 1996; Power *et al.* 1999; Henley *et al.* 2015).

Not surprisingly, many regional computer-based systems have been developed to monitor and forecast climate variability (e.g. Henry *et al.* 2007). Internationally, other countries also host drought-focussed websites, for example the 'Drought Mitigation Center' (University of Nebraska, <http://drought.unl.edu/>, accessed 31 January 2019) and the 'African drought and flood monitor' (Princeton University, <https://iciwarm.info/abc/>, accessed 31 January 2019). These sites also include specific education, planning and monitoring sections; however, it is beyond the scope of this paper to review global climate web-based information.

Long Paddock information products and application

Long Paddock uses climate databases of Australia-wide historical and real-time climatic variables (SILO – Scientific Information for Land Owners; <https://silo.longpaddock.qld.gov.au/>; Jeffrey *et al.* 2001; Beesley *et al.* 2009) to describe current climatic impacts. These climatic data are also used as input to a simulation model (i.e. AussieGRASS; Carter *et al.* 2000) of soil water balance and pasture growth/biomass to provide additional relevant indicators of

environmental variables. The AussieGRASS model has been parameterised for 185 pasture communities across Australia, using calibrated visual estimates of pasture biomass (Hassett *et al.* 2006) and extensive sets of remotely-sensed green and surface cover. Thus the historical climate data along with simulated variables, provide an objective approach to rank current conditions relative to the 128 years of historical records.

Rainfall in many regions of Australia is strongly influenced by the ENSO phenomenon, which provides a basis for seasonal climate outlooks (Stone *et al.* 1996). Using historical analogue years, AussieGRASS allows these outlooks to be extended to other important environmental variables (e.g. pasture growth, ground cover, runoff and fire risk). In this way, the Long Paddock website provides information, which is incorporated into risk management tools (described below) to assess current conditions and assist planning with future business decisions.

As with other global and regional systems, the Long Paddock website includes the following functional features for Queensland and Australian users:

- (1) Concentrating on regional and rangeland areas and specific features of livestock systems (e.g. pasture productivity).
- (2) Providing timely information with monthly updates through an interactive web-based portal.
- (3) Providing historical records and simulations back to 1890, allowing objective ranking of current conditions relative to past variability.
- (4) Interpreting ENSO-based forecasts to address the major (i.e. 60% of years) source of current and future (3–12 month) rainfall variability.
- (5) Providing maps of historical assessment of El Niño and La Niña (i.e. ENSO) impacts on annual rainfall (April–March) across Australia.
- (6) Providing maps of historical rainfall at longer timescales (5–13 years) concentrating on historical periods across Queensland's rangelands.
- (7) Providing maps of Queensland drought declared regions and lists of revocations.
- (8) Providing remotely-sensed data and imagery across Queensland's rangelands since 1987.
- (9) Providing multi-variable customised property-based reports for land management decision-making.
- (10) Supporting extension to users through workshops, videos, webinars, training, producer conferences, as well as government and industry briefings.
- (11) Monitoring usage to determine relevant needs, quality control and demonstration of government support of community needs.
- (12) Providing Australia-wide climate change projections data for 2030 and 2050 in 'ready-to-use' formats suitable for input to biophysical models.
- (13) Providing a scientific basis for users to understand climate variability and change; and hence develop better risk management approaches (e.g. Cobon *et al.* 2009).

Rainfall variability – awareness of extended wet and dry periods

The Long Paddock website focuses on Queensland's highly variable climate and the impacts that it has on running a

successful and sustainable grazing enterprise. Rainfall distribution (spatially and temporally) is of vital importance for Australian rangeland ecosystems and pastoral enterprises with respect to their function and productivity (McKeon *et al.* 2004). Long Paddock provides a range of products and services to present climate variability (listed above), such as the well-known A1-sized 'Australia's variable rainfall' poster, which shows a 128-year history (to date; 1890–2018) of Australia's highly variable climate as a collage of 128 maps expressed as percentiles (Fig. 1). Each map displays annual rainfall (April–March – to avoid splitting the northern Australian wet season), 'relative to history' (e.g. McKeon *et al.* 2004) on a 5 × 5-km pixel grid, nationally. The poster indicates the major drivers of rainfall variability in Australia: (a) with years classified as El Niño or La Niña; (b) a time series of the Southern Oscillation Index (SOI); (c) the time series of the IPO. These time series enable users to visually inspect the correlation between historical rainfall variability and climate drivers (e.g. Crimp and Day 2003; Helman and Tomlinson 2018). Since 1997, several thousand of these maps have found their way onto office walls, into graziers' homes and as part of university curricula.

A further analysis of 'Australia's variable rainfall' poster has summarised the rainfall data into a new poster showing 18 well known 'Extended wet and dry periods for Queensland' (Fig. 2). These alternating periods range from 5 to 13 years include the iconic 'Federation' (1896–1903) and more recent 'Millennium' (2001–2007) droughts, which have had dramatic impacts on Queensland's rangelands. The classification of the periods was derived from historical analysis of 'drought' and 'recovery' periods over the history of Queensland's agricultural industries (Daly 1994) and other regions of Australia's rangelands (e.g. Gibbs and Maher 1967; Condon 2002; McKeon *et al.* 2004; Stone 2004).

Historical commentaries (social, climate and economic) have been included on the poster for each period, to build a comprehensive picture of the past – a summary of the impacts of multi-year rainfall variability on Queensland's agricultural industries and environment. In addition, the time series of the SOI and IPO allows a visual representation of the multi-year behaviour of climate drivers and rainfall (e.g. Crimp and Day 2003). For Queensland's grazing lands (Day and McKeon 2018), the difference in rainfall between adjacent periods is shown. This component of multi-year variability has had major impacts on varying 'expectations' of livestock carrying capacities in contrast to actual 'safe' carrying capacities (McKeon *et al.* 2004).

This new poster is an eye-catching, enlightening and powerful discussion tool to help improve climate variability awareness. For example, the extended periods of low- and well below average rainfall demonstrate the risks associated with property or infrastructure investment at these times, whereas extended wetter periods were likely to be more beneficial from a resource and primary production perspective (e.g. Cobon *et al.* 2009). Further analysis will be undertaken to determine if there are identifiable patterns within the climate system (e.g. ocean circulation, ENSO, IPO combinations) that might signal the change from wet to a dry period, or the converse (e.g. Henley *et al.* 2015). Given the current drought conditions, which commenced in 2012 (<https://www.longpaddock.qld.gov.au/drought/archive/>, accessed 31 January 2019), it is not surprising that there has been strong demand for both posters.

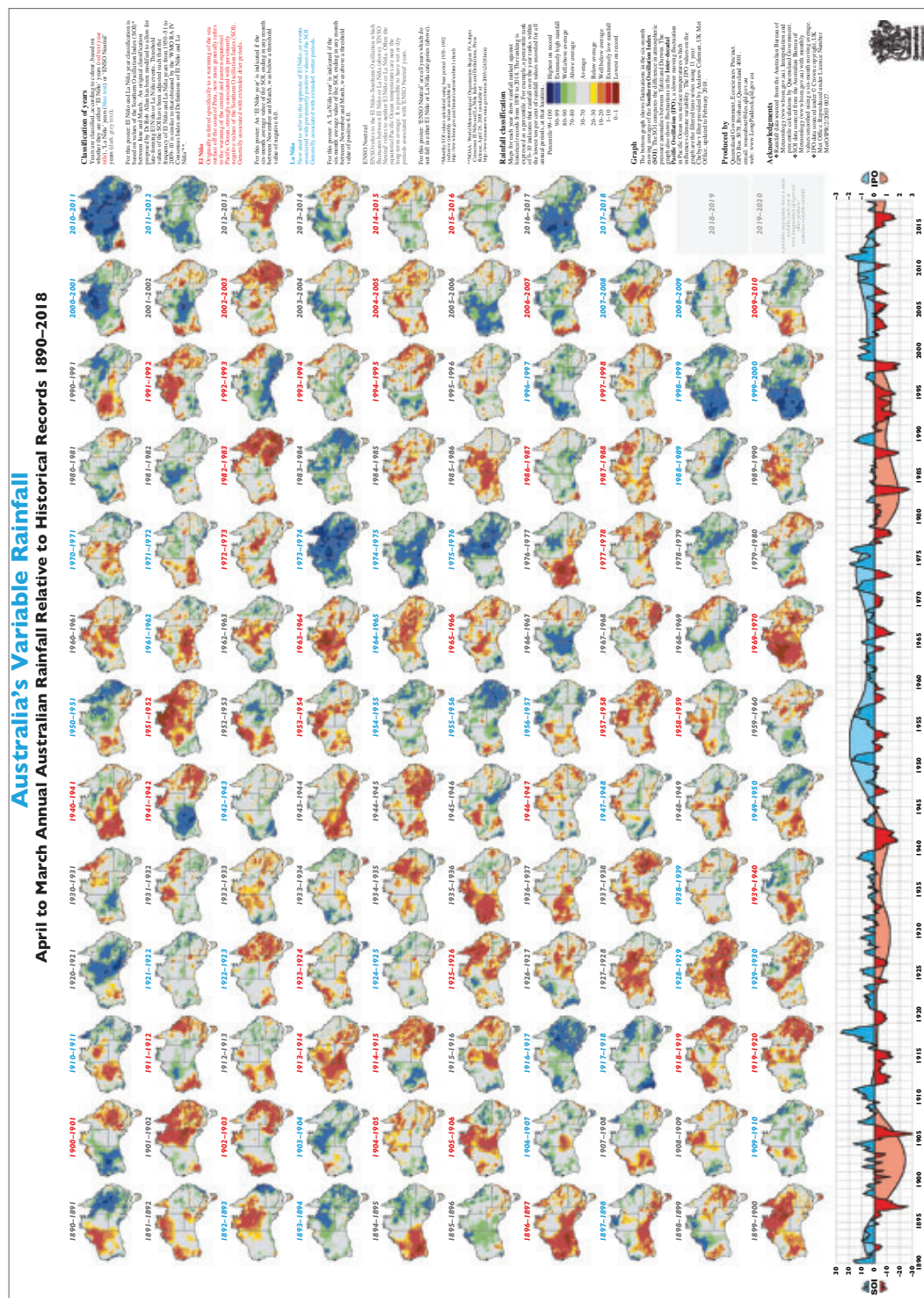


Fig. 1. The A1-sized ‘Australia’s variable rainfall’ poster shows a 128-year history (to date; 1890–2018) of Australia’s highly variable climate as a collage of maps (<https://www.longpaddock.qld.gov.au/rainfall-poster/>).

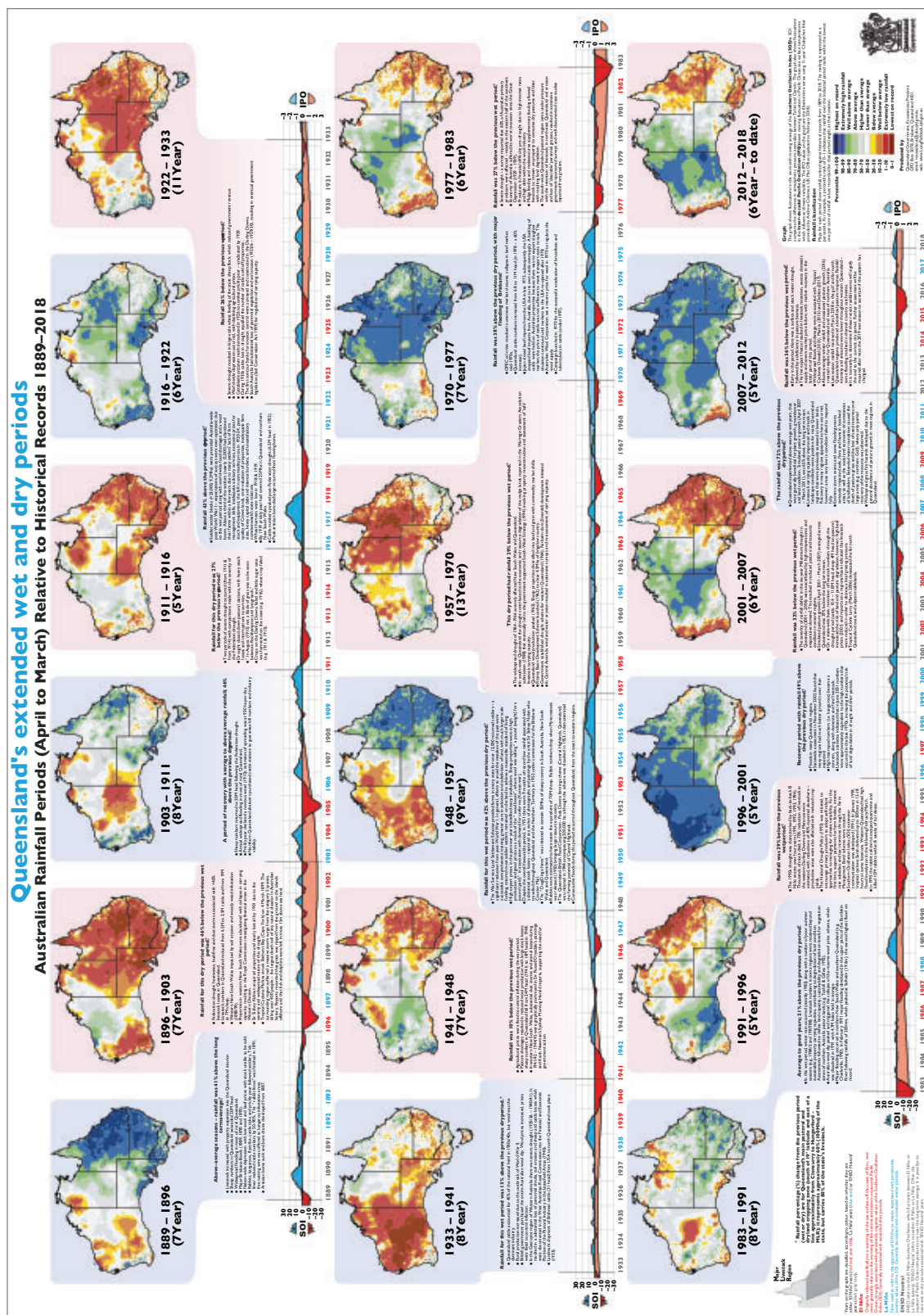


Fig. 2. The 'Extended wet and dry periods for Queensland' poster was summarised from 128 years of rainfall data contained in the 'Australia's variable rainfall' poster to produce a new poster, showing 18 wet and dry periods that relate the impacts of multi-year rainfall variability on Queensland's agricultural industries and environment (<https://www.longpaddock.qld.gov.au/rainfall-poster/>).

Along with the 'Australia's variable rainfall' poster and the 'Extended wet and dry periods for Queensland' poster, two more posters have now been created. First, the 'Australia's modelled pasture growth' poster has been developed to match the 'Australia's Variable rainfall' poster maps 'year for year', where modelled pasture growth generated by the AussieGRASS model allows the user to get the best interpretation of annual primary production (i.e. pasture growth, not just rainfall) relative to historical modelled output. Second, another version of the 'Australia's variable rainfall' poster has been created that includes past tropical cyclone tracks and names. The presence/absence of the cyclones, in combination with ENSO year-types and annual rainfall outcomes communicates that cyclones may not consistently contribute sufficient rainfall or pasture production (spatially and temporally) to provide beneficial drought relief. In addition, land managers operating enterprises in subcoastal regions (e.g. north Queensland hinterland) often identify with tropical cyclones as the major events in climate history (more so than droughts) that impact adversely on their primary production (e.g. destruction of crops and infrastructure such as fencing).

In a 2-year period, more than 11 000 of these four poster types have been distributed across Australia. A stand-alone 'Rainfall Posters' web page has now been created on the Long Paddock home page, so that users can navigate to it using the 'Rainfall Posters' tab. Digital versions of the posters and annual update patches will continue to be available at this page; hard copy posters can be obtained by email requests (via

longpaddock@qldgov.au; Australia only). Another feature recently developed is the innovative Rainfall poster 'Map App' visualisation, which is also available on the Long Paddock 'Rainfall Posters' web page (Fig. 3). The 'Map App' allows the user to view each wet and dry period as a 'carousel' and easily switch between rainfall or pasture growth modes. Individual annual rainfall and pasture growth years of interest can also be viewed simultaneously for assessment. The 'Map App' is mobile and tablet friendly, hence the user can view the visualisation on portable devices immediately if internet services are available. The webinar entitled 'Our rainfall and pasture growth – comparing current seasons with the past' relates the main points of the rainfall poster series for the user (<https://www.longpaddock.qld.gov.au/about/webinars/>, accessed 31 January 2019).

Land management decision support tools

The Long Paddock website provides a range of management decision support tools at regional (i.e. AussieGRASS) and property (i.e. FORAGE) scales. AussieGRASS (<https://www.longpaddock.qld.gov.au/aussiegrass/about/>, accessed 31 January 2019) is a tool to simulate key biophysical processes associated with the condition of the natural resource base at regional scales (e.g. local government areas or bioregions – nationally). AussieGRASS products include data and maps on a 5×5 -km spatial resolution. Multiple biophysical variables (e.g. rainfall, pasture growth, pasture biomass, runoff, curing) are

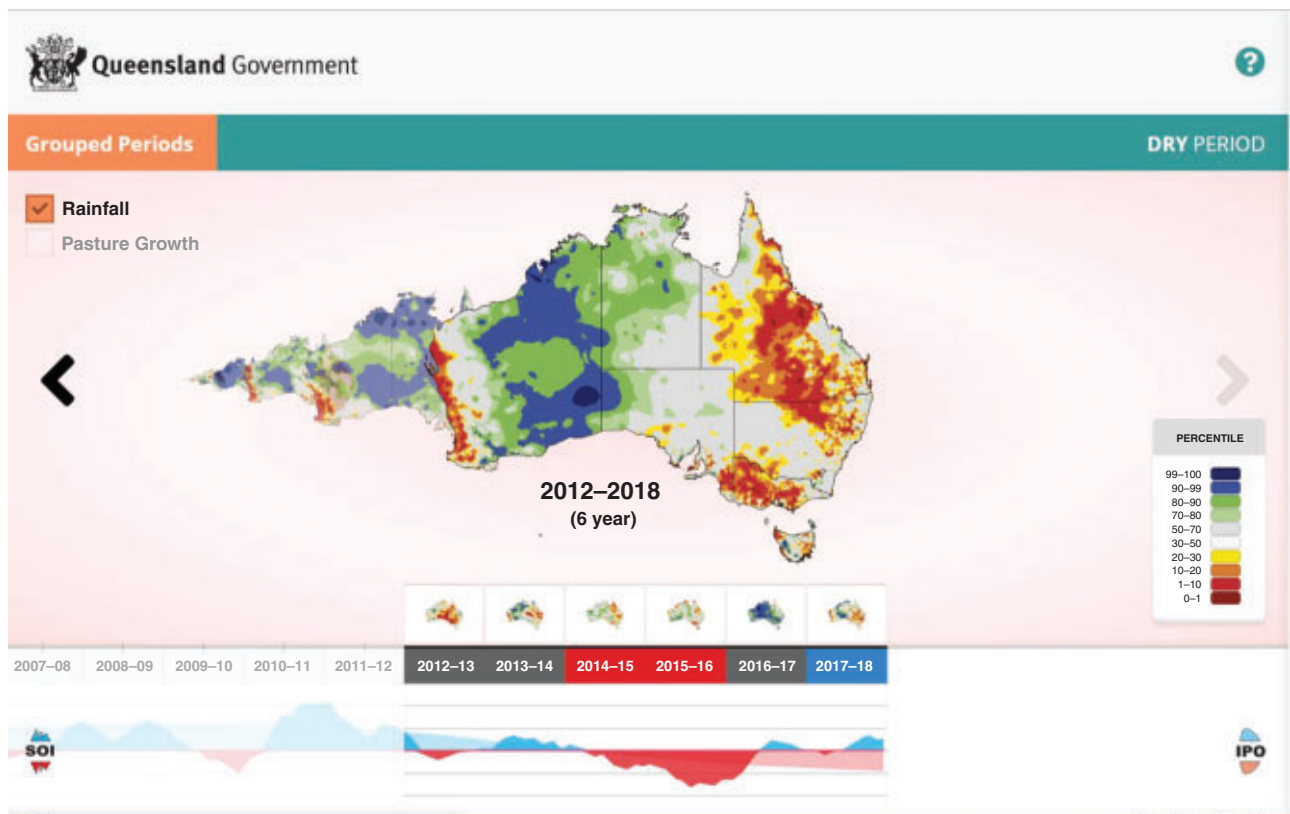


Fig. 3. The Rainfall poster 'Map App' visualisation, available at the Long Paddock 'Rainfall Posters' (<https://www.longpaddock.qld.gov.au/rainfall-poster/>).

offered as absolute, relative and forecast products (from 1 to 36 months), with 105 new maps generated each month. Several of these products were previously provided on a subscription basis, however, a Queensland government open data policy makes the AussieGRASS products fully accessible to all users; regular data downloads can be automated using public domain software such as *wget* (<https://www.gnu.org/software/wget/>, accessed 31 January 2019).

The FORAGE reporting system (<https://www.longpaddock.qld.gov.au/forage/about/>, accessed 31 January 2019) provides climate, pasture, ground cover and land type reports for individual properties (Queensland only), through 12 reports (currently) that are emailed to the user. The user only needs to specify: the property of interest on a map interface; the report(s) of choice; and the email address to have the PDF reports emailed to their inbox. At the time of writing (December 2018), over 33 000 FORAGE reports have been requested from greater than 2600 users (since 2011), covering more than 35% of the Queensland rural property area. There are currently over 1500 reports requested each month – with ~30% accessed by government agencies, 5% by Natural Resource Management catchment groups, and the balance (~65%) assumed requested by land managers, consultants, property valuers and rural agents. Long Paddock website webinars entitled ‘FORAGE – free property information to assist with grazing land management decisions’ describe the available FORAGE reports, along with reports in development as Parts 1 and 2 (<https://www.longpaddock.qld.gov.au/about/webinars/>).

Both AussieGRASS and FORAGE systems require climate data, which is supplied by SILO: an enhanced database containing Australian climate data from ‘1889 to yesterday’. Data are provided in several ready-to-use formats, suitable for research and climate applications. The SILO database is also undergoing an upgrade and will be available on Amazon Web Services (AWS) (<https://aws.amazon.com/08/07/2018>, accessed 31 January 2019) cloud computing platform (anticipated late-2018) to provide an enhanced user interface. As part of the upgrade, direct access will be offered to Australian climate data users, but SILO access from Long Paddock and the supply of climate data to all current Long Paddock applications will continue unchanged.

Australian applications

The Long Paddock information system concentrates on Queensland’s grazing lands. Nevertheless, other rangeland regions of Australia share the same issues of managing for high climate variability (e.g. McKeon *et al.* 2004) and the need for current and forecast information (Carter *et al.* 2000).

The collegiate nature of Australian rangeland science and support community along with the economy of scale of computing systems have led to the development of the Australia-wide products such as maps of historical rainfall variability (Carter *et al.* 2000). The regular updated climatic databases from Bureau of Meteorology, which include data collected before Federation (i.e. 1900), provide the basis for the Australia-wide approach.

In terms of relevance for other Australian rangeland communities, a key feature of Long Paddock is the regional ownership, responsibility and delivery to the local community. Thus other Australian states have developed their own targeted

products and where appropriate, Long Paddock products or products derived from Long Paddock data are used (e.g. New South Wales, <https://www.dpi.nsw.gov.au/climate-and-emergencies/droughthub/information-and-resources/seasonal-conditions/reports>, accessed 31 January 2019; and Northern Territory <https://dpiir.nt.gov.au/primary-industry/primary-industry-publications/northern-territory-pastoral-feed-outlook>, accessed 31 January 2019).

Climate change data and information

Climate change impacts on grazing lands have been summarised in several papers (e.g. Cobon *et al.* 2009; McKeon *et al.* 2009). Long paddock provides a climate change information service designed for a range of users (<https://www.longpaddock.qld.gov.au/climate-adaptation/>, accessed 31 January 2019). Modellers can access ready to use, Australia-wide, formatted climate data using the Consistent Climate Scenarios system. This system provides several statistical downscaling methods via a scenario basis that adjust SILO data to some future time on a Global Climate Model (GCM). Over 1 million files have been served to customers since the system’s inception. A recent addition to the climate change information available is the 10-km dynamically downscaled and bias-corrected data from a subset of the IPCC Fifth Assessment Report (AR5) GCM models for Queensland.

Educational and industry/regional planning assistance for climate change is provided through the Climate Change Risk Management Matrix process and work books (e.g. impacts, adaptation, and vulnerability analysis). Climate change information for a location or property can be accessed with the FORAGE Climate Change Projection report (see FORAGE webpage). Regional scale views and summaries of climate change risk in Queensland can be viewed at the Climate Adaptation page, whereas the new ‘climate change dashboard’ can assist regional users’ understanding of future climate change.

Recent Long Paddock redevelopment

There have been significant advances in web technology since Long Paddock was launched 23 years ago. Here we provide a brief summary of our current updates to highlight (for other developers) the need for flexibility and adaptability to benefit from rapidly changing technologies and scientific knowledge. The Long Paddock website has been redeveloped and refreshed in a modern AWS cloud computing environment (February 2018) – a secure, high availability, scalable system, with a reduced requirement for systems administration. This new framework also allows for easier integration of new products in the future. Additionally, the new website has improved functionality, making it easier for users to access information.

Following departmental precedence, a decision was made to move the older in-house system run by a different government department to an alternative cloud-based platform. AWS was chosen from the other cloud providers, as it suited our needs and was already being used to redevelop the SILO system. A major advantage of the new system is that AWS provides a ‘scalable service’, where computing processor resources are directed as required (i.e. when demand increases – more processors are brought online). AWS also provides almost unlimited storage

with multiple redundant backups, as well as software tools to support a modern web environment.

In preparation for the upgrade, Long Paddock users were surveyed about their experience. Overall, there was strong satisfaction rating for the website (90%), though, users commented that it would be beneficial to make graph and map presentations more interactive. Many Long Paddock users (77%) stated the reason for accessing the website was to view Southern Oscillation Index values (SOI) – due to the availability of the 30-day, 90-day, monthly SOI values and corresponding data files. Over a third of respondents (39%) accessed meteorological data (e.g. SILO climate data), whereas other popular site locations included the Seasonal Climate Outlooks (40%), rainfall and pasture data and maps (21%), drought information (13%) and property management reports (5%).

These results, in combination with those from a survey of the grazing industry's needs, prompted the redevelopment of the Long Paddock website. The focus is on improving the communication of complex scientific information in a way that users can more easily understand and use more effectively for decision-making. The webinar entitled 'The Long Paddock website: what's new and it's all free!' gives the user an introduction to the enhanced Long Paddock website (<https://www.longpaddock.qld.gov.au/about/webinars/>, accessed 31 January 2019).

Long Paddock benefit assessment

Long Paddock has been providing information to the Queensland government and Australian rangelands community of researchers, consultants and pastoralists and so on since 1995. Over the 23-year period, climate and pasture information has been used to objectively rank current conditions of rainfall, simulated pasture growth/biomass (and other key modelled outputs, e.g. runoff) relative to the historical record. This information has been used in submissions to government for the use of public monies in drought assistance. As detailed above, the Long Paddock information system is used predominantly by Australian individuals with a wide range of needs (farmers, graziers, agribusiness, education and government). The dominant data type of interest is the SOI which provides a basis for evaluating probabilities of future (i.e. seasonal) rainfall and future planning of management and business decisions. Thus, the products of the Long Paddock information system have become 'embedded' in a wide range of planning and decision-making activities that include knowledge of historical, current and future climatic variability.

A formal economic evaluation of the benefits of AussieGRASS was conducted in 2005 from the perspective of a research and funding agency Land, Water and Wool, Australia (B. J. White, pers. comm.); this evaluation investigated its value for supporting regional applications for drought funding under exceptional circumstances. The report also drew attention to the potential benefits to individual graziers of using AussieGRASS information in grazing management decisions. Although it was not possible at that time to survey and assess individual grazier's decision-making, recent surveys of the use of climate forecasts (e.g. Marshall *et al.* 2011) and simulation studies (e.g. Ash *et al.* 2000; Syktus *et al.* 2003) indicated there are significant benefits in terms of financial and environmental variables.

The high number of visitors to Long Paddock (and return visitors), along with the increasing number of FORAGE reports being requested (as detailed above), indicates a rising demand for Long Paddock products, including individual property-based information integrating climate data, remotely-sensed imagery, climate forecasts and climate-based risk management decisions. Our experience with the Long Paddock information system suggests that this type of approach to the dissemination of climate and pasture information has relevance to other global rangeland regions and communities.

The future for the Long Paddock website

Long Paddock has been well recognised as a stable, objective reservoir of high-quality climate and land management information for Australian rangelands and grazing communities. The upgrade of the website will better serve multiple stakeholders with easy-to-access, useful and innovative products and information. Through the enhanced Long Paddock website, the Queensland Government is providing easier access to seasonal climate forecasts and related decision support tools for grazing systems to assist producers in preparing for drought, alerting to drought onset and generally, coping with drought. The improvements to Long Paddock will continue. For example, our FORAGE decision support tool portfolio will be enhanced to harness the power of AWS, providing even greater customisation at a property and even paddock-scale level to give Queensland graziers a real advantage, such as making climate-smart decisions related to matching stocking rates to predicted available forage. A greater focus on communicating and interpreting the science for users, with more explanatory videos, interactive maps and enhanced tools will be appearing on Long Paddock in the future.

Conflicts of interest

The authors declare no conflicts of interest.

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