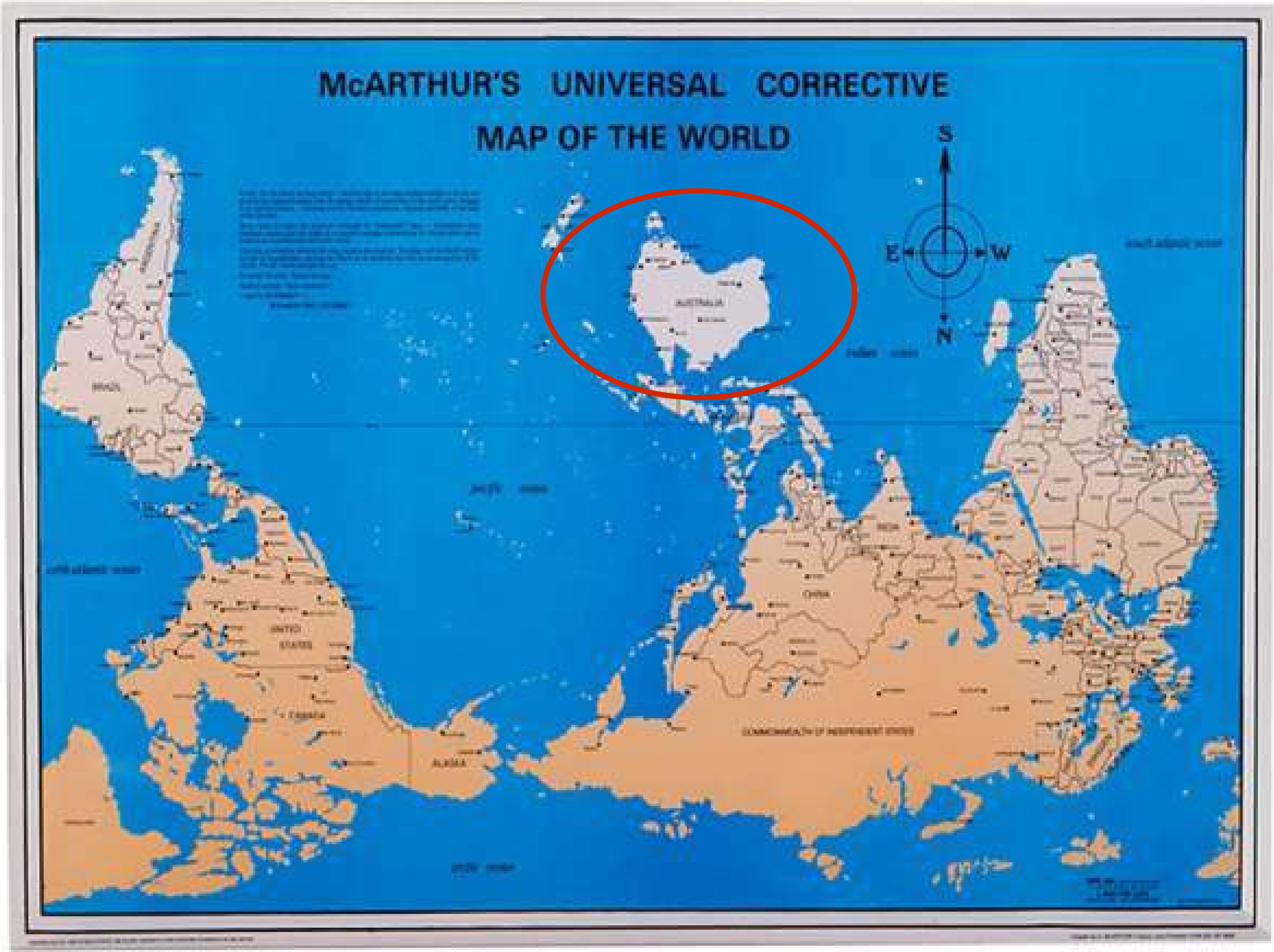
“Agricultural Drought Indices in the Southwest Pacific”

Roger Stone, University of Southern Queensland, Australia.

INTER-REGIONAL WORKSHOP ON AGRICULTURAL DROUGHT INDICES AND EARLY WARNING SYSTEMS FOR DROUGHT Murcia, Spain, 2-4 June 2010.


McARTHUR'S UNIVERSAL CORRECTIVE
MAP OF THE WORLD
S
E
W
N
AUSTRALIA
BRAZIL
INDIA
CHINA
UNITED
STATES
CANADA
ALASKA
COMMONWEALTH OF INDEPENDENT STATES

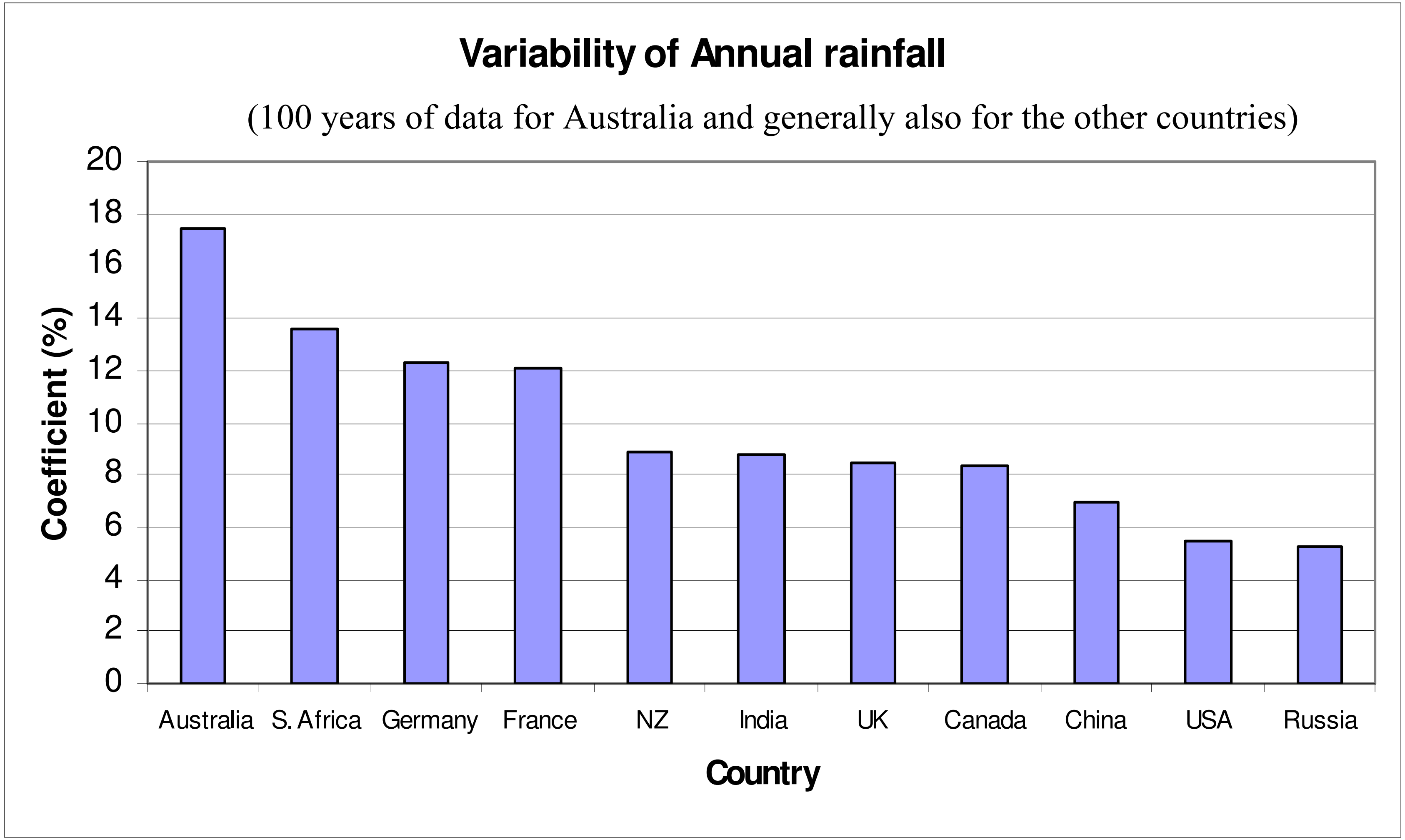
Driven by policy issues:

"In Australia, when drought conditions are so intense and protracted that they may be considered as beyond the bounds of normal risk management practices, an area may be *declared as experiencing drought exceptional circumstances (*DEC)"..

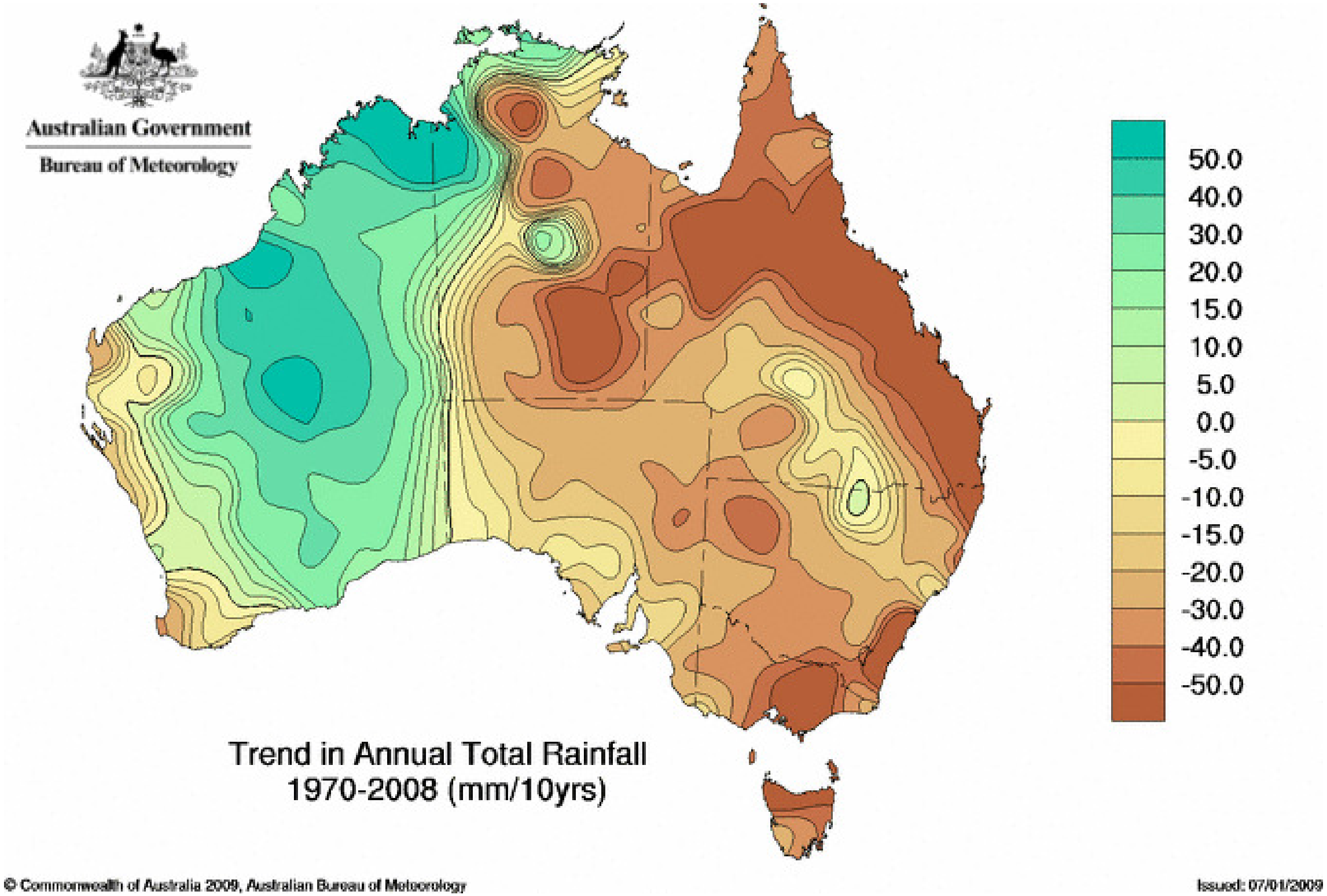
Such events are likely to occur only once in 20-25 years and to be greater than 12 months in duration (White and O'Meagher, 1995; White, 1997).

***Declaration of DEC is based on the assessment of objective scientific information and independent advice presented ('subjective ag-drought indices') to the Rural Adjustment Scheme Advisory Council* (RASAC).**

Australia has very high rainfall variability



(Love, 2005)



And also has long-term shifts in rainfall (mm/decade)

Definitions

1. **meteorological drought - lower than average precipitation for some time period; in some cases air temperature and precipitation anomalies may be combined;**

2. ***agricultural drought - occurs when plant available water, from precipitation and water stored in the soil, falls below that required by a plant community during a critical growth stage. This leads to below average yields in both pastoral and grain-producing regions;***

3. **hydrologic drought - one or a combination of factors such as stream flow, reservoir storage and groundwater; and**

4. **socioeconomic drought - defined in terms of loss from an average or expected return. (It can be measured by both social and economic indicators, of which profit is only one) (McVicar and Jupp, 1998)**

– Australia also has State Drought Policy

"Queensland - a recommendation for a Queensland State Drought Declaration *is made by the Local Drought Committee (LDC) after considering:*

1.A one in ten-to-fifteen year rainfall deficiency over the past twelve months.

***2. Rainfall distributions* (or other extenuating circumstances that relate to agricultural drought) and which may distort an area's total yearly rainfall records should also be considered".**

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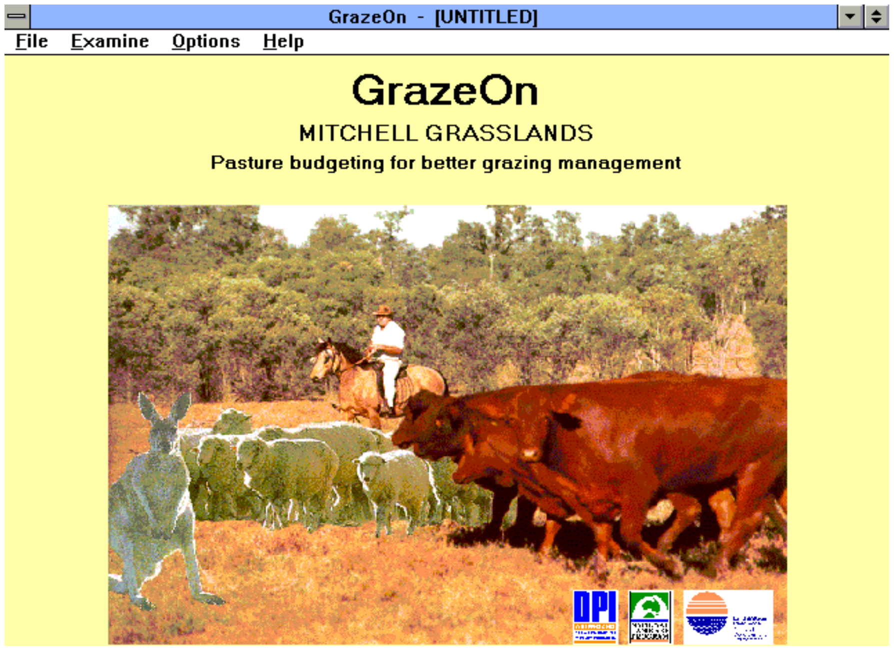
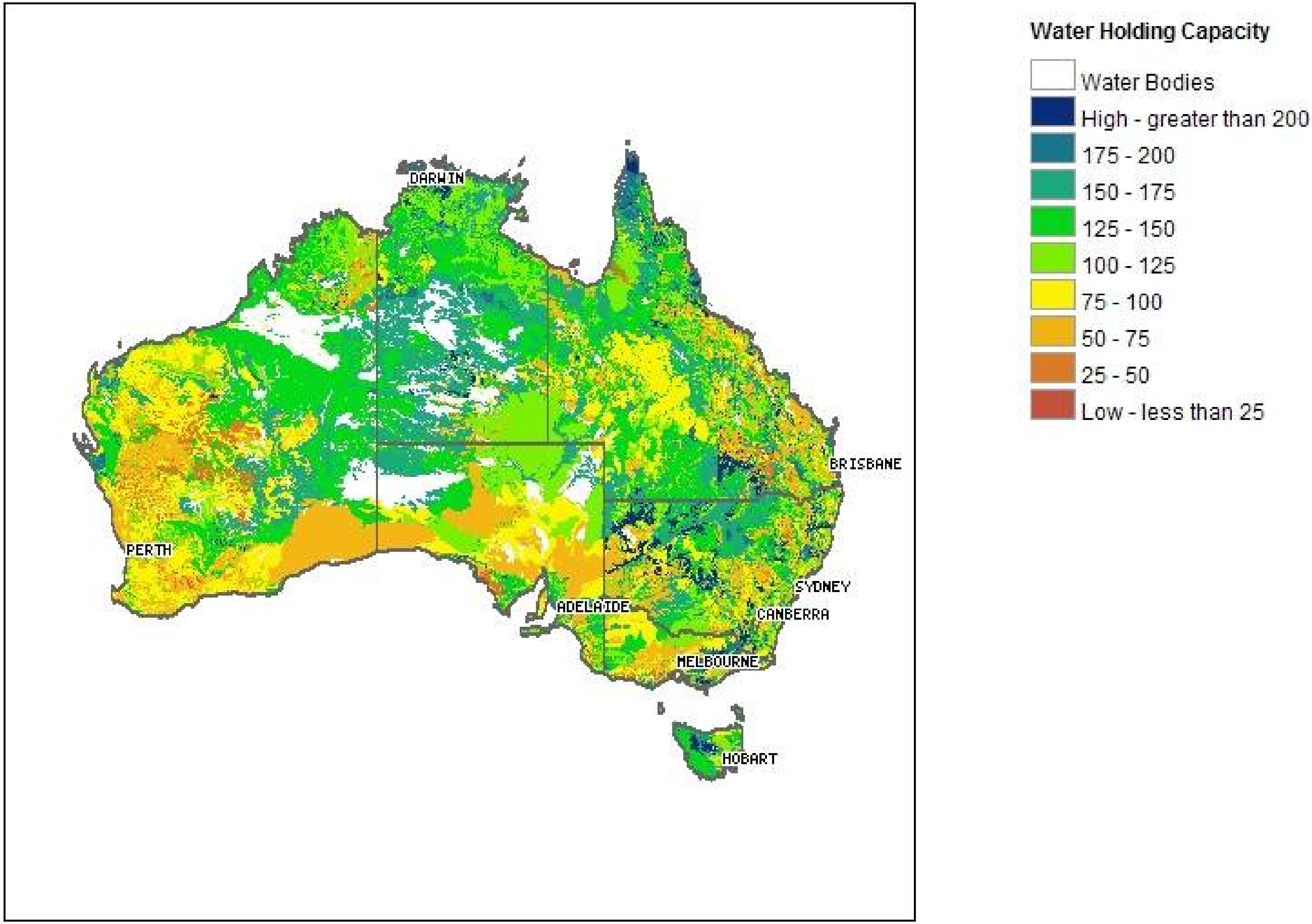


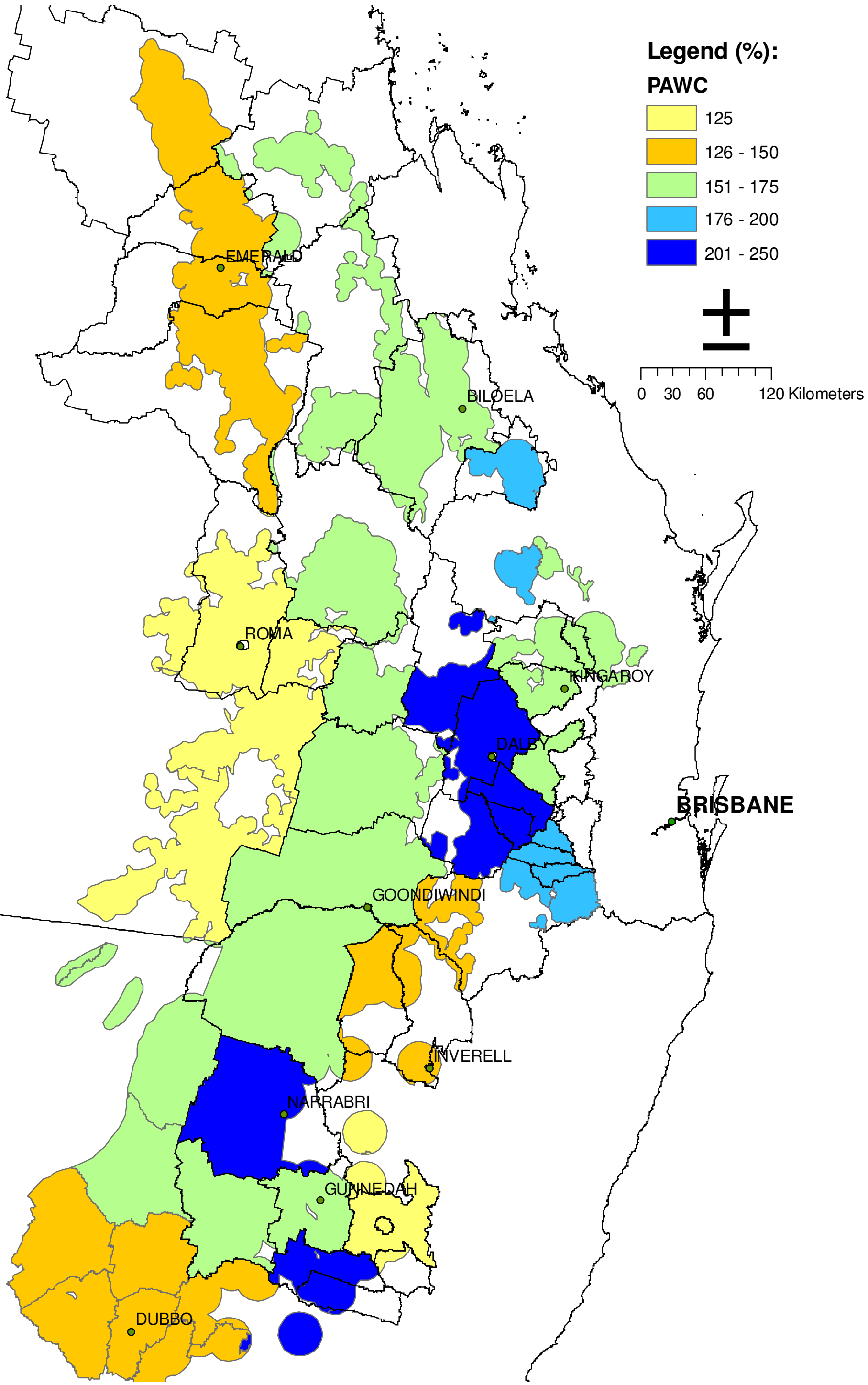
State Local Drought Committees consider a range of more subjective measures that are more closely related to agricultural drought including:

- **Availability of *pasture***
- **Availability of *water***
- ***Condition of stock***
- **The *extent of drought movements* of stock to forced sales or slaughter and to agistment.**
- **Quantity of *fodder* introduced**

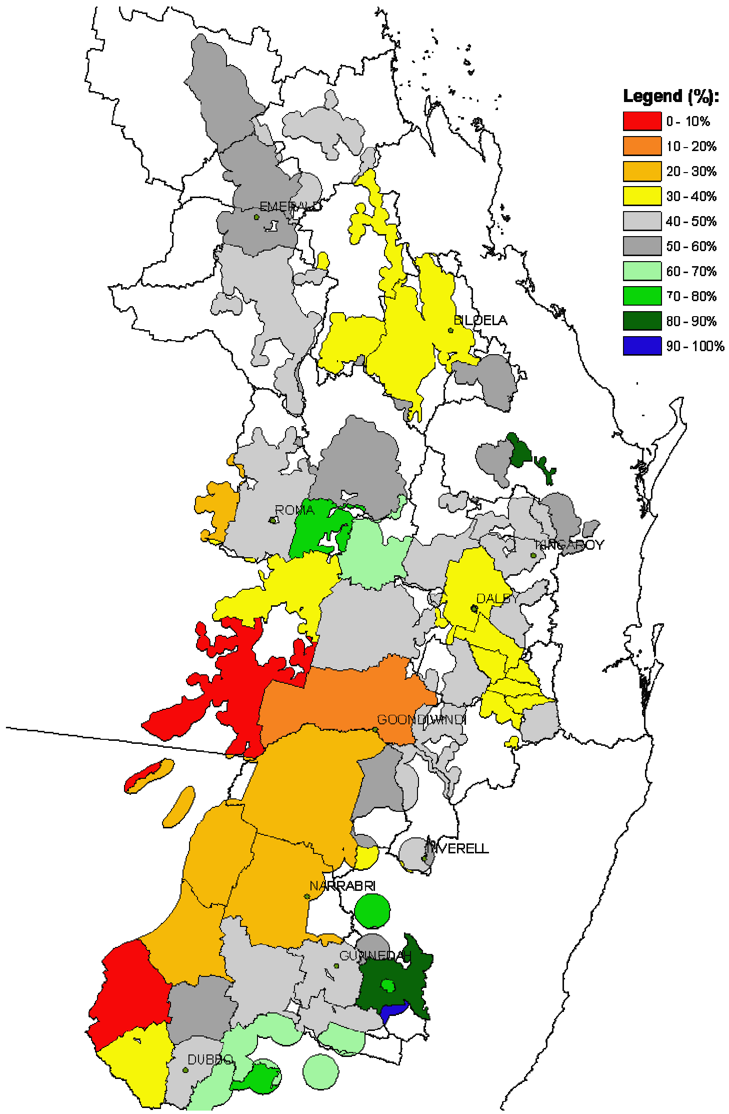


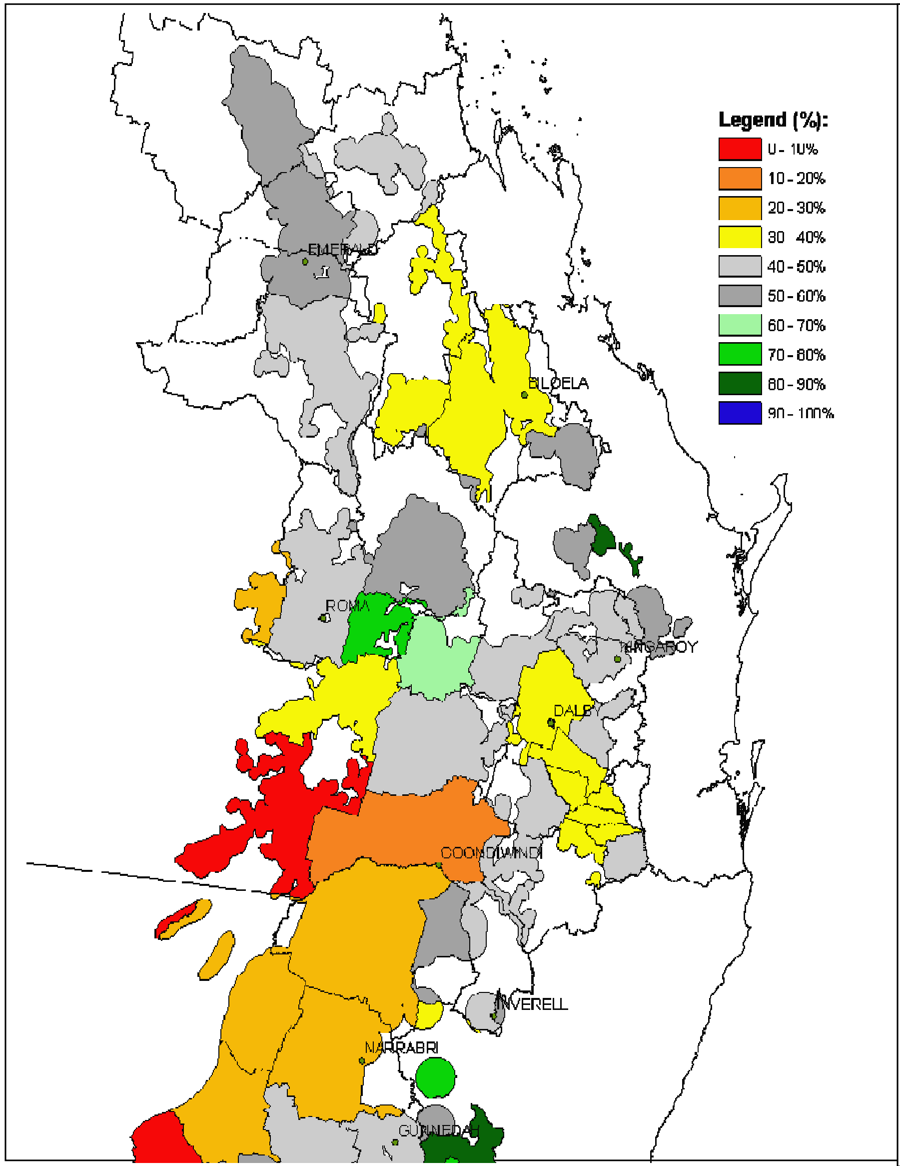
TO ASSIST IN AGRICULTURAL DROUGHT ASSESSMENT – USE OF INDICATORS - KNOWLEDGE OF THE MAJOR WATER-HOLDING CAPACITIES OF SOILS MEASURED IN MM (National Agricultural Monitoring System).

AT THE REGIONAL LEVEL - KNOWLEDGE OF PLANT AVAILABLE WATER HOLDING CAPACITY - (SUMMER CROPPING VALUE FOR SORGHUM CROPPING (Potgieter, 2008).

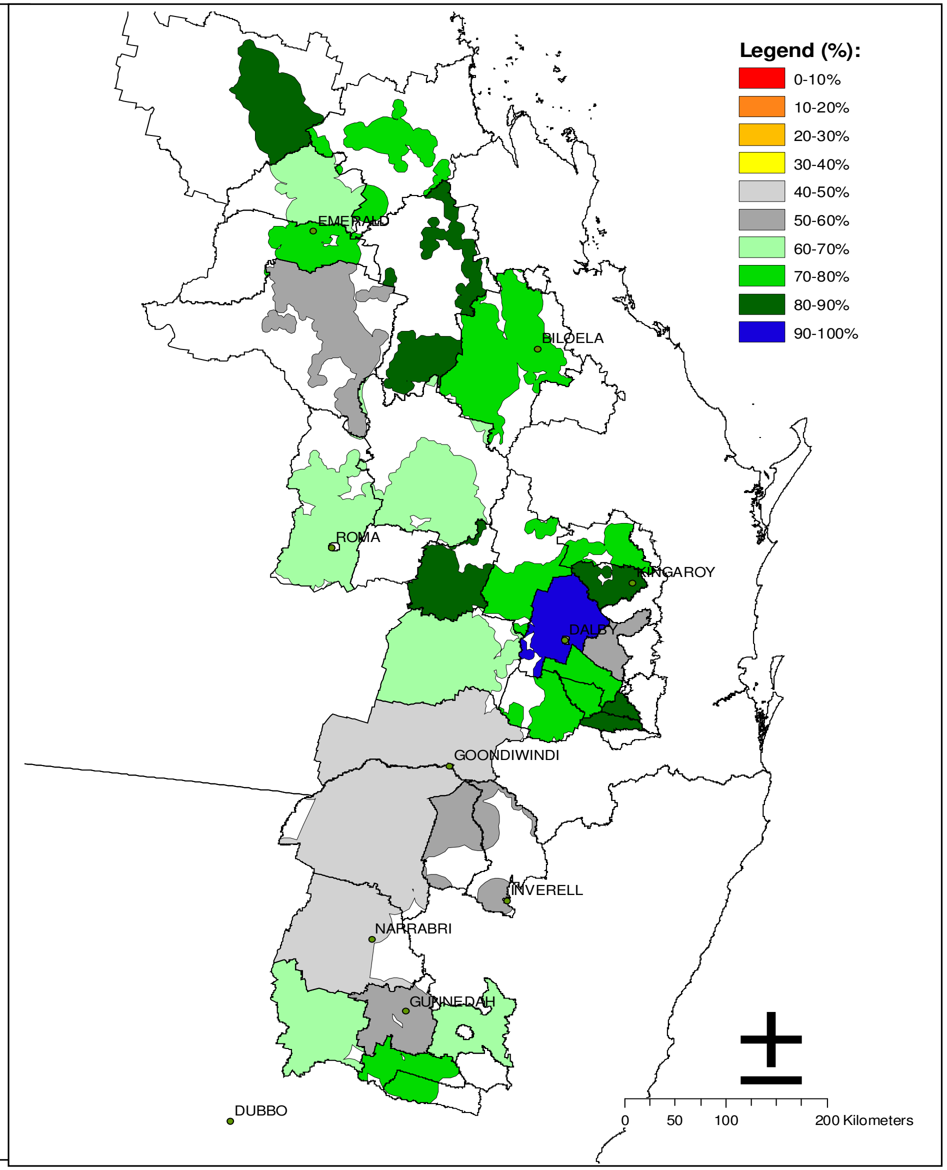


THE VALUE OF KNOWLEDGE OF SOIL MOISTURE LEVELS NOVEMBER, 2007 (Potgieter, 2008)

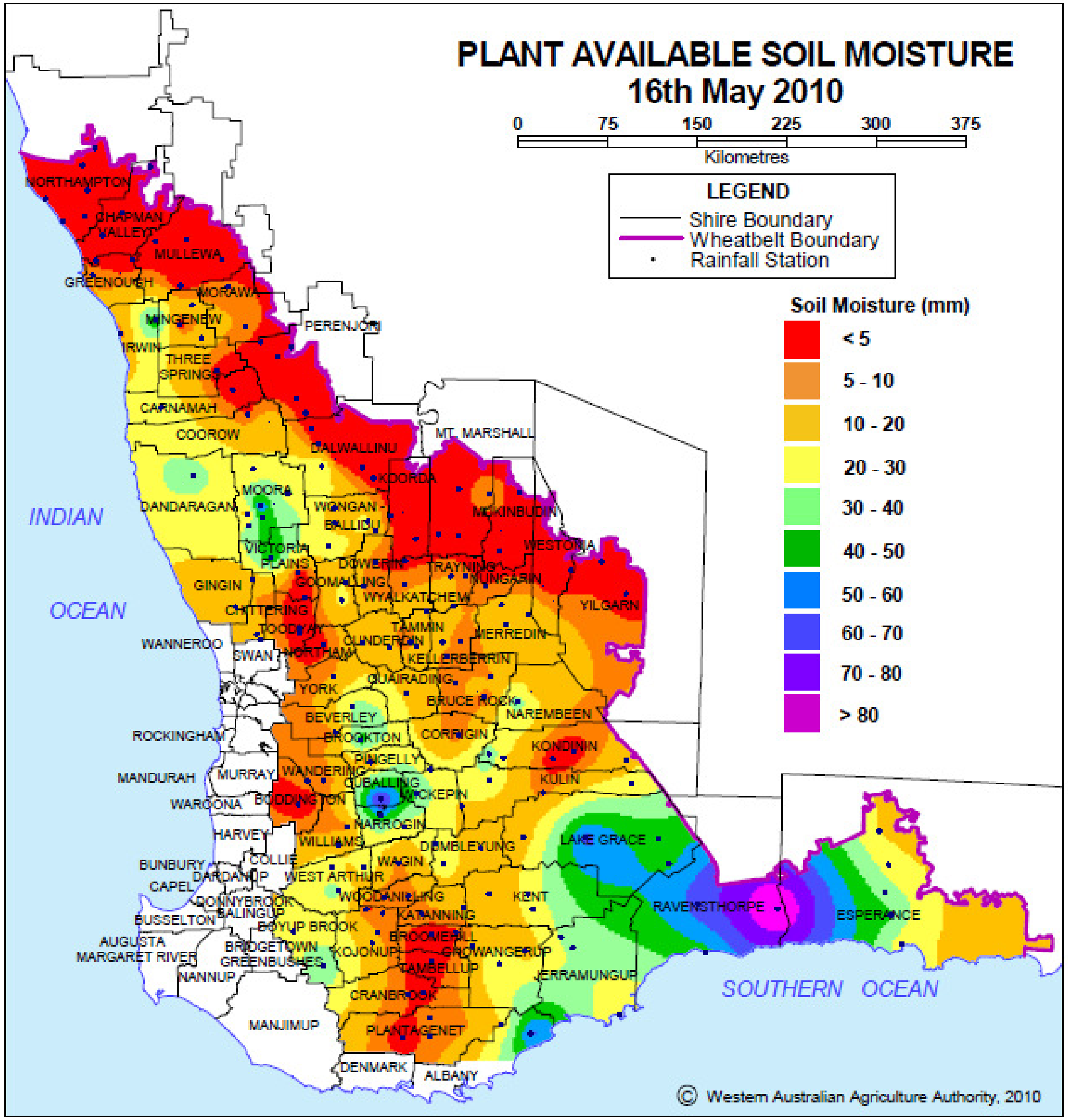




Soil water recharge levels: as at 1st November 2007. Note, the extremely low values (<10 per cent) in some far western shires.



The value of forecasts - forecast of rainfed sorghum yields as at 1st November, 2007 incorporating likely in-crop growing rainfall through the anticipated summer growing season.



Department of Agriculture and Food

Plant available soil moisture maps (April - June)

[Climate Risks and Opportunities Project]

The soil moisture maps are produced from April to June and show *how much water is available to crops in the normal plant rooting zone (ie. 0.5 to 1.5m depth. - plant available soil moisture map).*

It is based on values calculated at 188 real-time rainfall stations using the Stress INdex (STIN) model developed by Dr. David Stephens, Climate Risks and Opportunities Project, Department of Agriculture and Food, Western Australia. The STIN model uses the Ritchie 2-stage fallow evaporation model to calculate accumulated soil moisture

Use of stress models to ascertain crop yields as a function of soil moisture.

•The STIN (STress INdex) model of Stephens *et al. (1989,* 2001) has been developed to monitor and forecast shire, state and national wheat yields *as a function of soil moisture at sowing (sowing date) and the timing and amount of rainfall during the growing season.*

•It is essentially an integration of the CERES-Wheat fallow water balance of Ritchie and Otter (1985) with the FAO (Food and Agriculture Organisation) crop monitoring model of Frére and Popov (1979), *which empirically relates crop yields to accumulated moisture stress.*

•*It has been regularly used in assessing exceptional agricultural droughts (Stephens 1998) in winter-grain cropping regions.*

•*Similar models have been developed in Queensland for wheat (Oz-Wheat, Potgieter et al. 2002) and grain sorghum (Potgieter et al. 2005).*

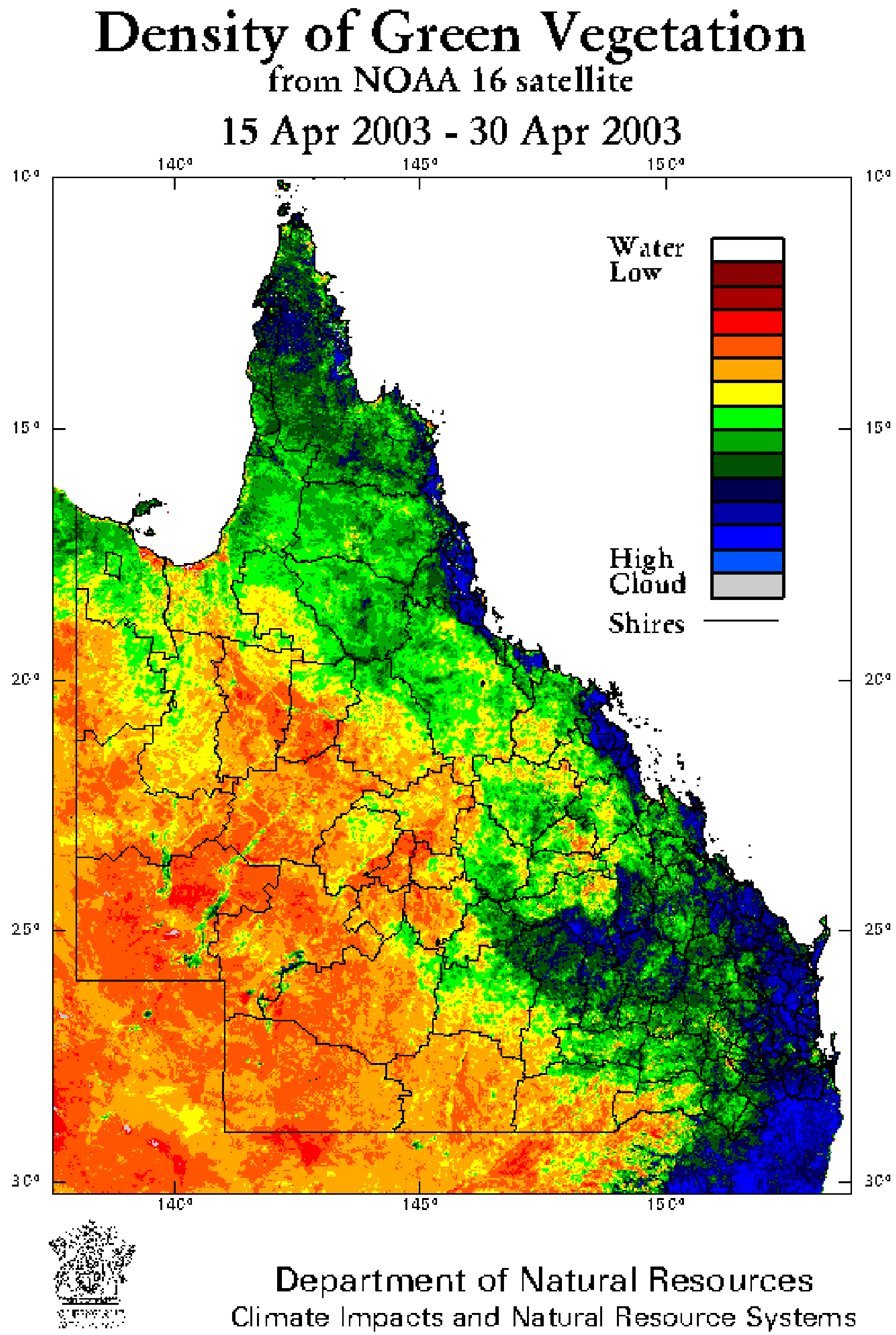
THE VALUE OF REMOTE SENSING IN ASSESSMENT OF AGRICULTURAL DROUGHT IN AUSTRALIA

There are several ways in which remote sensing can assist in mapping and monitoring agronomic conditions of direct relevance to DEC. These include mapping vegetation type and monitoring vegetation condition, moisture availability and soil moisture. This section will be divided into four main sections:

1. Vegetation condition monitoring with reflective remote sensing;
2. Environmental condition: monitoring with thermal remote sensing;
3. Soil moisture: monitoring with microwave remote sensing; and
4. Environmental stress: combining thermal and reflective remote sensing.

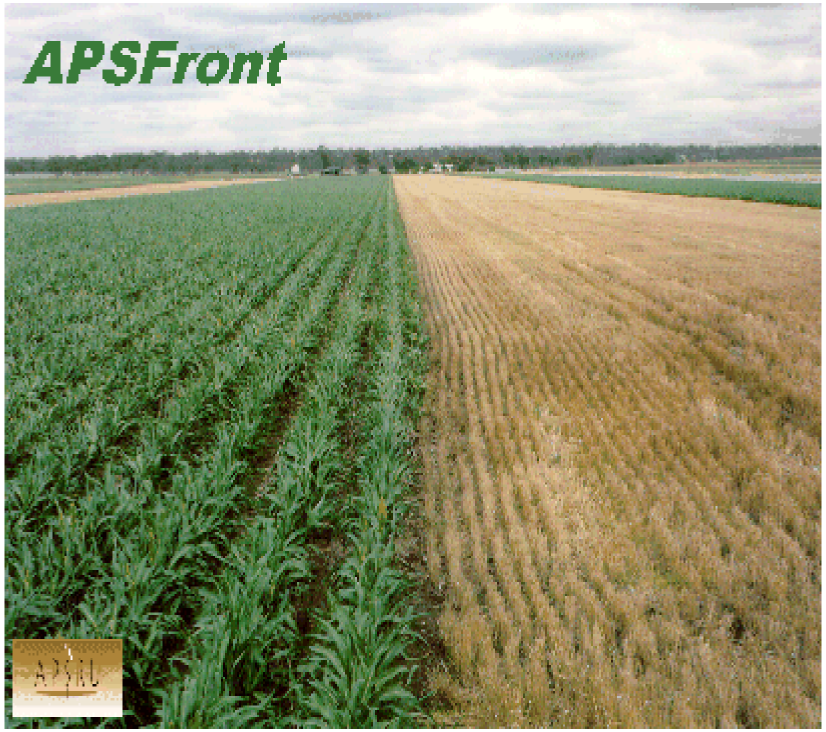
McVicar and Jupp, 1998

EXAMPLE – ASSESSING THE DENSITY OF GREEN VEGETATION



For Agricultural Drought Purposes - The Key Value in the Linking Role of Simulation Modelling

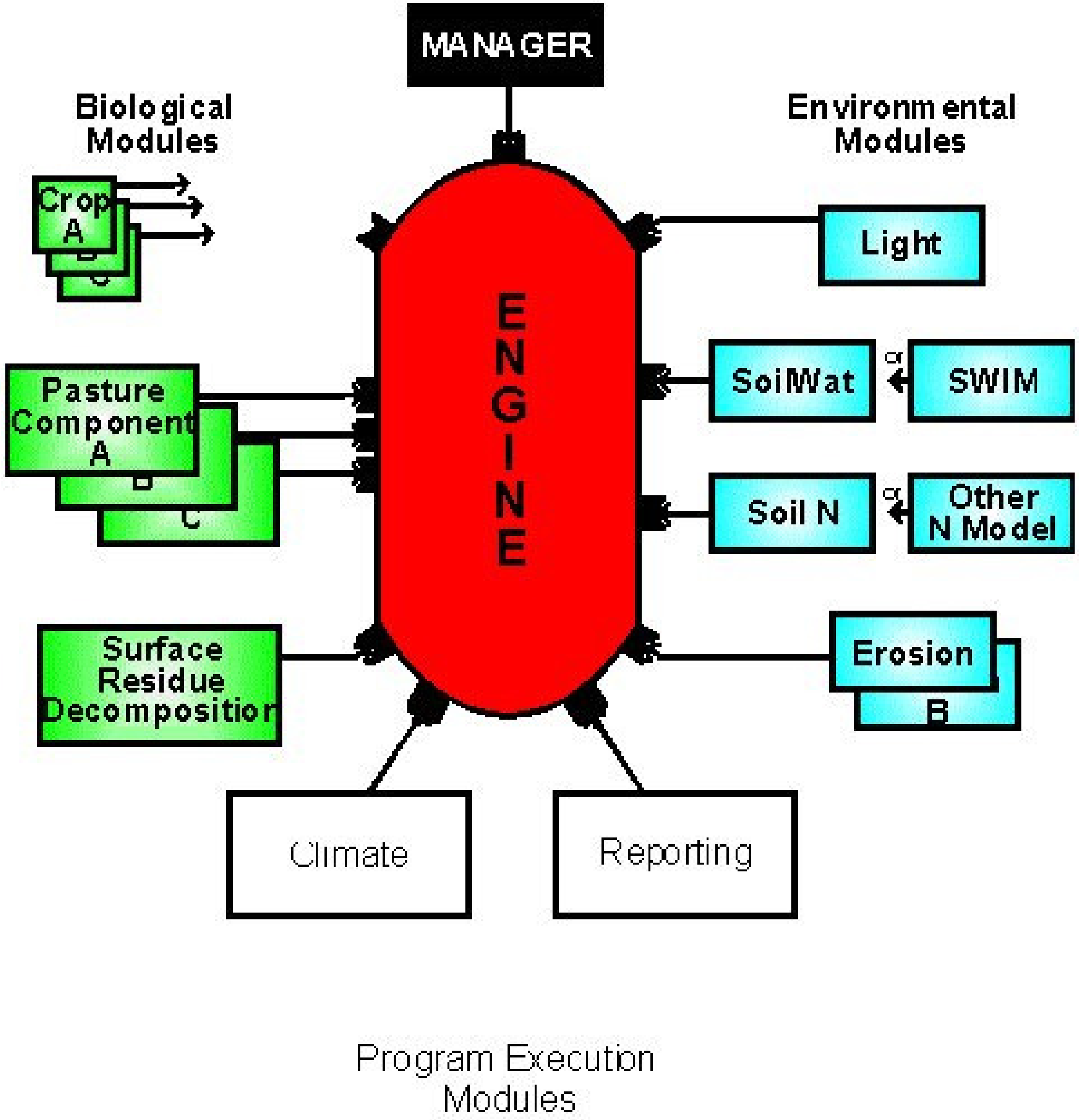
Agricultural Production Systems Simulator (APSIM) simulates



- **Provides historical yield of crops and pastures**
- Assimilates key soil processes (water, N, carbon)
- Assimilated surface residue dynamics & erosion
- Provides a range of management options
- crop rotations + fallowing
- short or long term effects

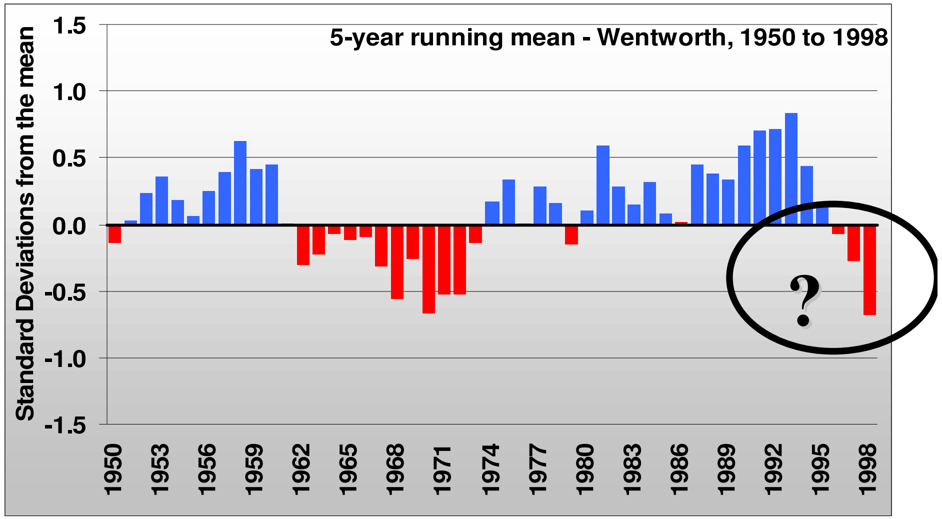
Modular Structure of APSIM

APSIM: precise daily time step model that mathematically reproduces the physical processes taking place in a cropping system

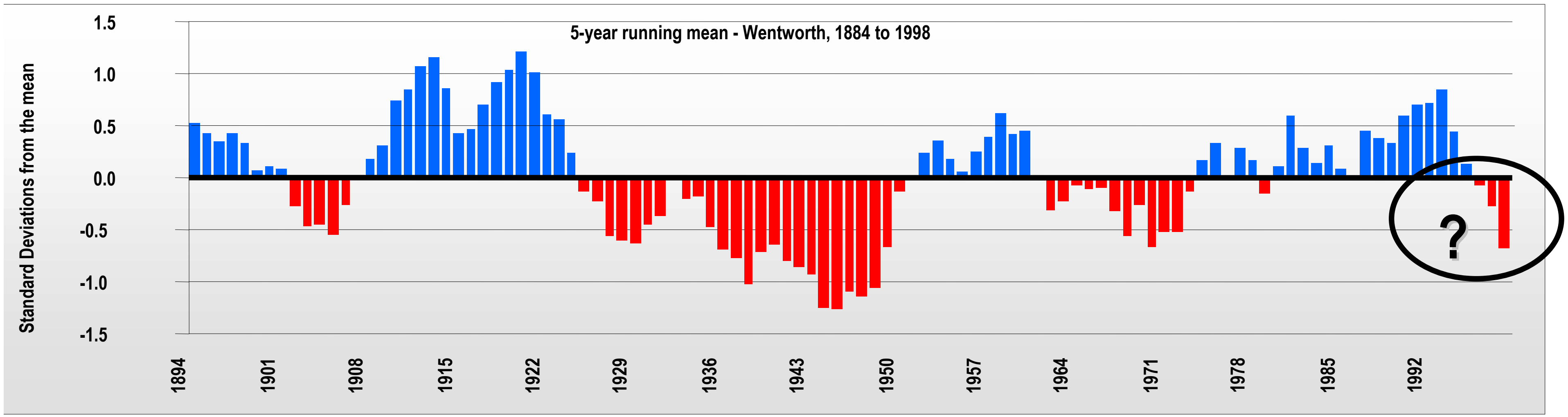


Assessing the potential for exceptional drought assistance - use of simulation models to determine the relevance of recent agricultural droughts in an historical context.

Simulated Wheat Yield 1950+



Simulated Wheat Yield 1890+

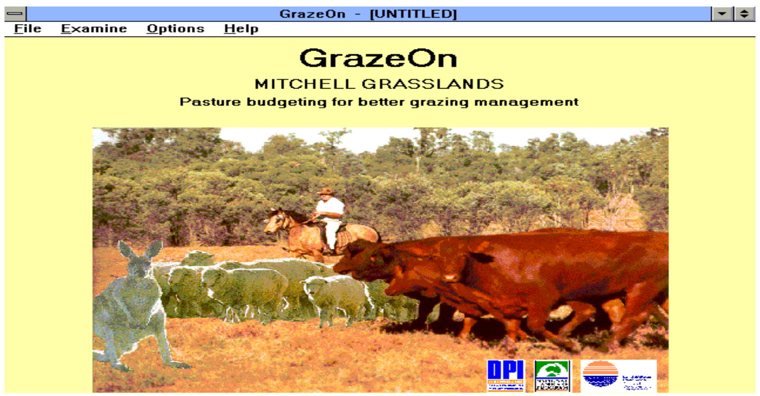


•GRAZPLAN was developed to aid the management of livestock grazing temperate pastures in southern Australia.

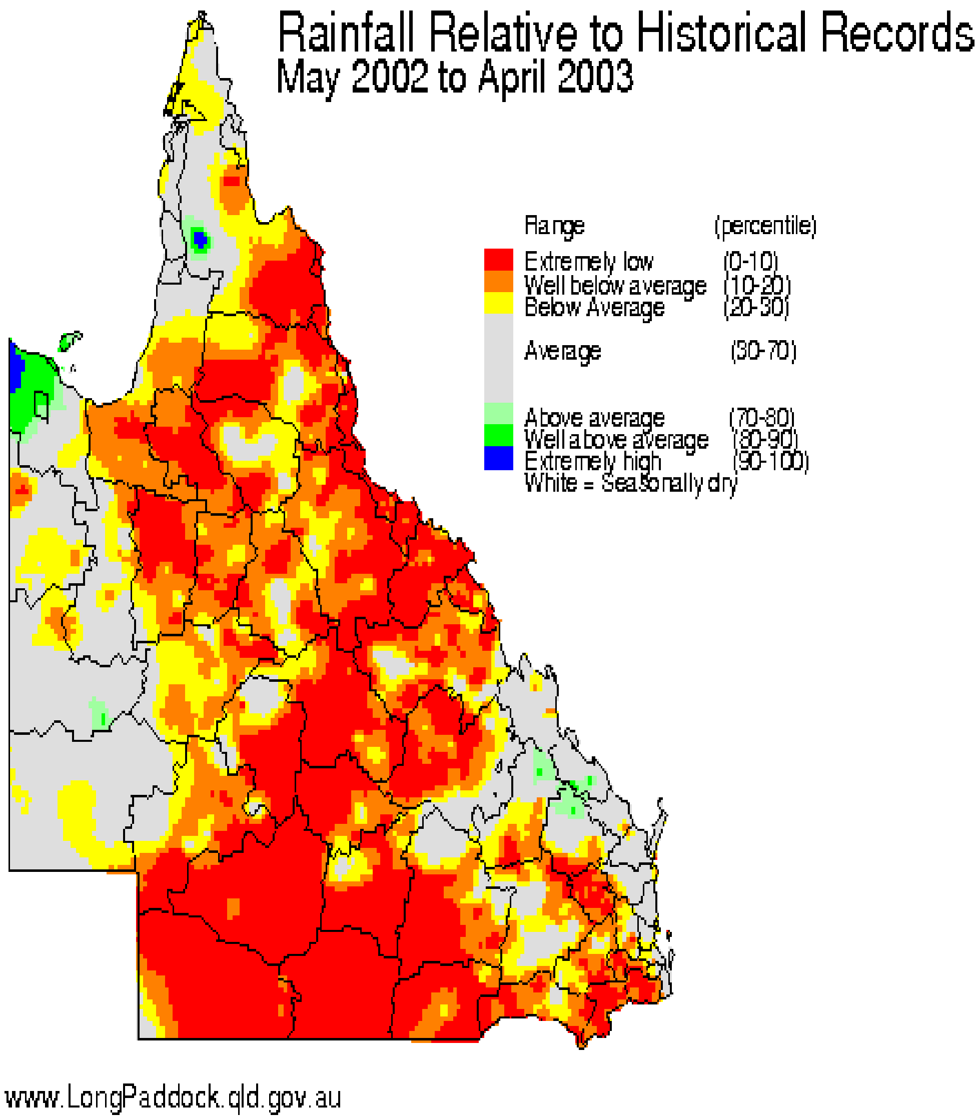
•The GrassGro decision support system (Moore *et al. 1997) predicts* pasture growth and quality in a form suitable for input to GrazFeed (Freer *et al. 1997), which is the* GRAZPLAN animal production model.

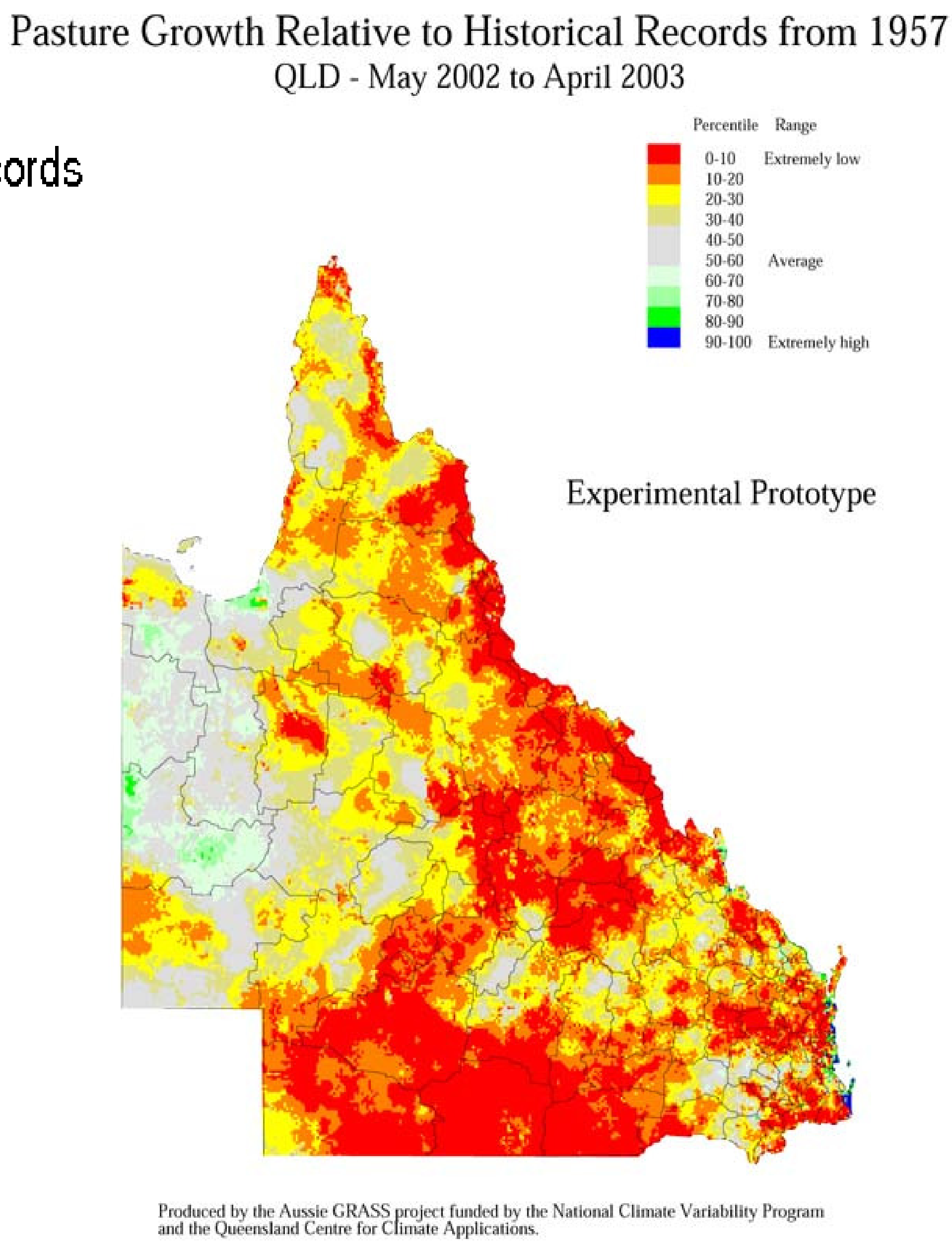
•*Donnelly et al. (1998) used GrassGro to assess and rank droughts at sites near Wellington in the Dubbo Rural Lands Protection Board district of central New South Wales.*

•They were able to estimate pasture production and supplementary feed requirements <u>for the survival of grazing animals</u> in a way that might have practical use in monitoring drought.



The value of pasture growth models in assessment of agricultural drought





Palmer Drought Severity Index (PDSI) (Palmer, 1965)	Water Balance for Droughts – may also have high value for agricultural drought	Widely used internationally. Comparisons between PDSI and soil moisture quite promising - relevance under climate change (Burke and Brown, 2007)	Value in regions with high climatic variability? –
Prescott (ratio) Index (Prescott, 1949).	Periods of plant stress	Simple – includes evaporation losses	Excludes transpiration losses - unsuited for accurately monitoring crops and losses
Hutchinson Drought Severity Index (HDSI)	Progressive index aimed at targeting agricultural droughts.	Uses only rainfall data	Omits rainfall effectiveness and temperature
Plant growth index (McDonald, 1994)	Estimates the duration of the pasture growing season	Intermediate level index	Requires further evaluation.. including across a wider range of agricultural ecosystems

Enhanced Vegetation Index (EVI)(Huete, et al.,. 2002)	**Improved monitoring …less atmospheric influences**	**Remotely sensed MODIS data**	**Limited dataset – launched in 2000 as a scientific rather than operational sensor**
Temperature Condition Index (TCI) (Kogan , 1995)	Rising leaf temperatures with plant moisture stress	Remotely sensed by NOAA AVHRR data	No ability to normalise for variation in daily and seasonal meteorological conditions
Normalised Difference Vegetation Index (NDVI)	**Monitoring vegetation using NOAA/AVHRR data**	**Remotely sensed repeatable and synoptic measurement**	**Current data are best compared with long-term NDVI data set: 'limited to 28 years'**
Soil moisture anomaly (SMA)	Soil moisture index	Highly relevant for vegetative health and agricultural production	Limited observations of soil moisture mean that operationally may not always be practical.

Vegetation Condition Index (VCI) (Kogan, 1990).	**To assess the effect of changing weather on NDVI signals**	**Remotely sensed repeatable and synoptic measurement**	**Emphasis on monitoring 'seasonal dryness' rather than ranking extended droughts**
Monthly VCI (MVCI) (McVicar and Jupp, 1998)	Emphasis on ranking months or seasons across years	A spatial perspective on divergences from the long-term signals	Restricted to comparable months or seasons (eg all Augusts) in the historical records

Normalised difference temperature index (NDTI) (McVicar and Jupp, 2002)	**Insight into the regional soil water balance using data with thermal and reflective capabilities (eg NOAA AVHRR, and MODIS data)**	**Remotely sensed repeatable and synoptic measurement.**	**Current data are best compared with long-term NDTI dataset: 'currently limited to 28 years'.**

THE PDSI and agricultural drought

- **"Despite being developed to provide an estimate of meteorological drought, comparisons between PDSI and soil moisture (Sheffield et al, 2004) suggest that the PDSI might also give useful indication of agricultural drought" (Burke and Brown, 2008).**

(The PDSI was created by Palmer (1965) to provide the 'cumulative departure of moisture supply' from the normal. As suggested by Burke et al (2006) the potential evaporation required as input to the PDSI was calculated using the Penman-Monteith equation instead of the Thornthwaite (1948) equation. Analysis shows that the PDSI has a memory of ~12 months, resulting in the use of this time scale for other indices).

Value in projections of future drought in Australia.

•**The SPI shows little change in in the proportion of land surface in drought in projection of future drought.**

•**However, all other indices, which *include a measure of the atmospheric demand for moisture*, show a significant increase in the proportion of land surface in future drought – with an additional 5%-45% of the global land surface in drought.**

•The Mediterranean, Amazonia, and Southern Africa predominantly have a reduction in precipitation–with the increase in potential evaporation, **this results in substantial increases in drought.**

•**"In Australia, while there are uncertainties in regional drought projections due to some uncertainty in the distribution of precipitation, there are major increases in potential evaporation and %changes in area associated with PPEA and PDSI" (Burke and Brown, 2007).**

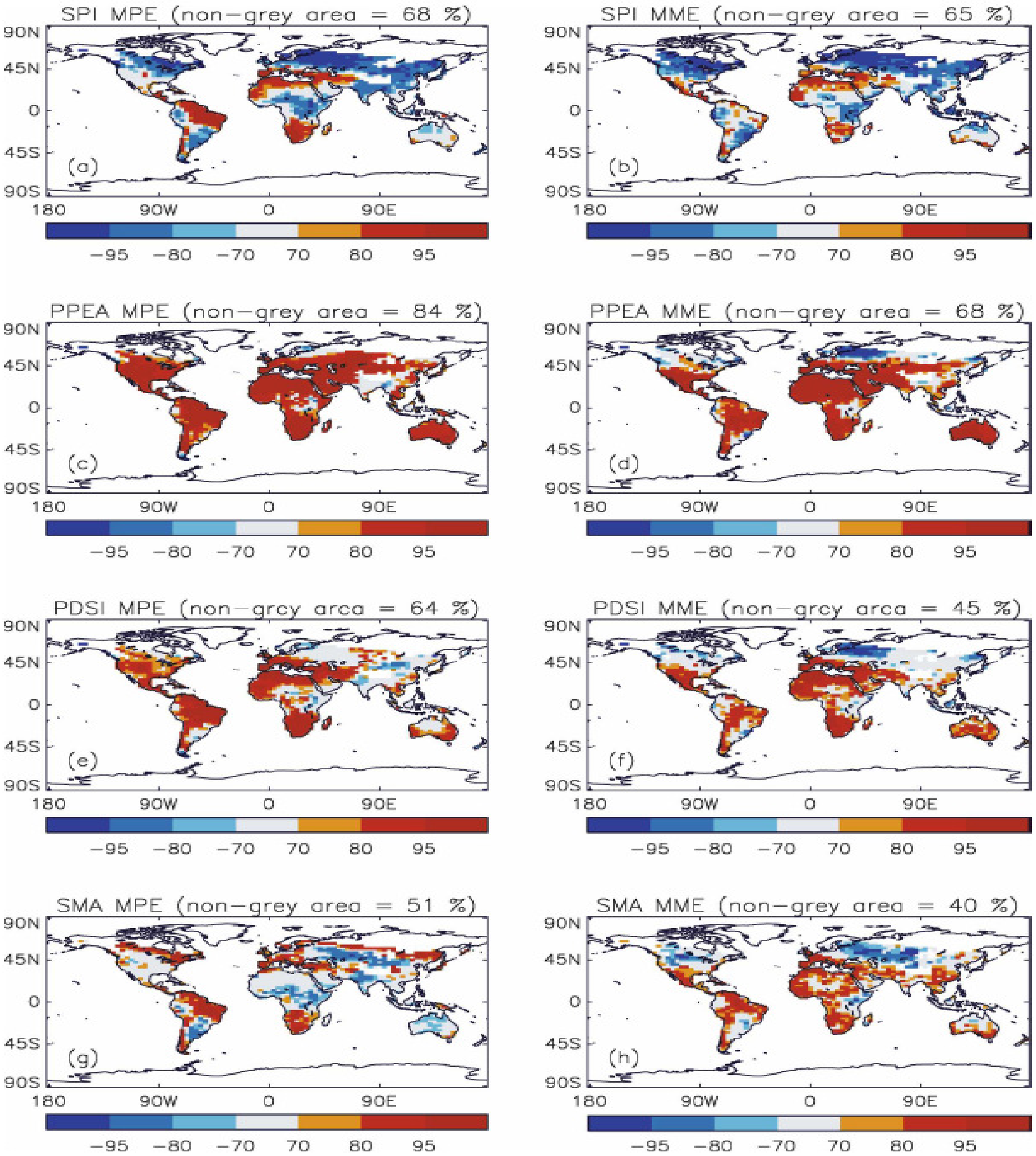
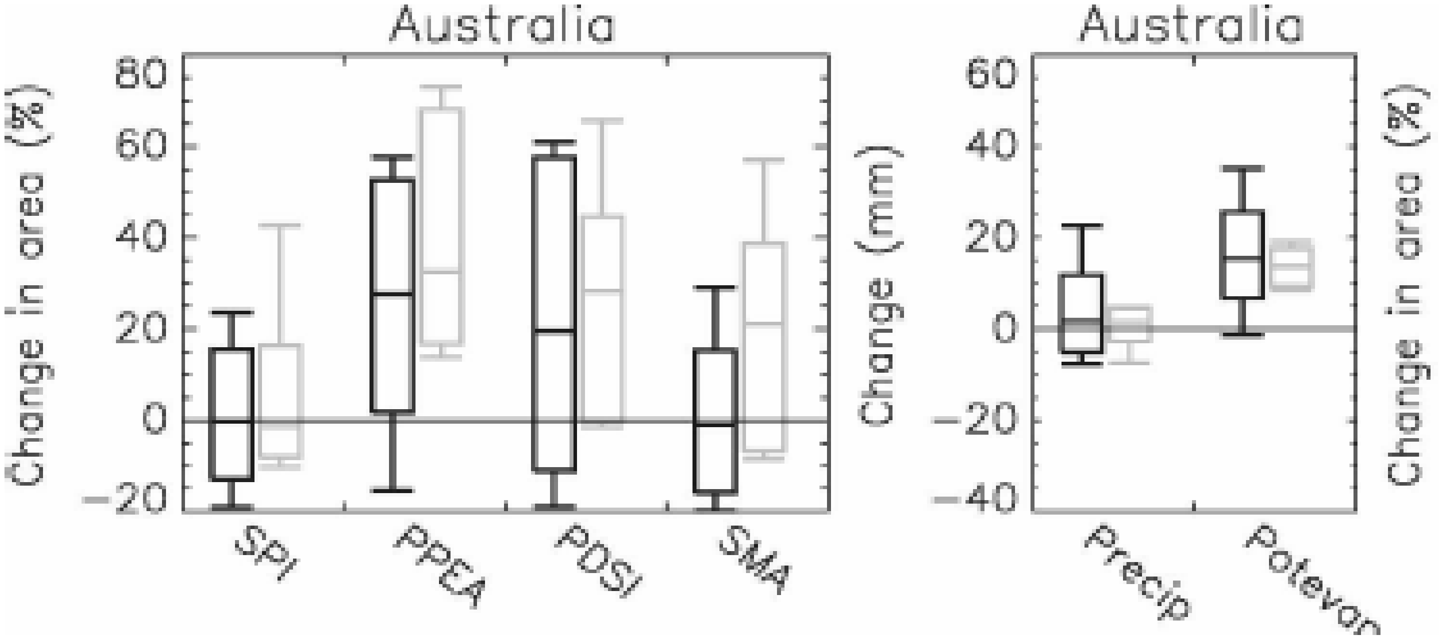


FIG. 3. Spatial distribution of the likelihood of increase or decrease of moderate drought for MPE and MME. Locations where more than 70% of the ensemble members show a decrease (increase) in moderate drought are in blue (red). Places where less than 70% of the ensemble members agree on either an increase or a decrease are in gray. The percentage of the total area where more than 70% of the models agree is given.

Spatial distribution of the increase (or decrease) in moderate drought using Hadley centre model or 11 Model ensemble (courtesy Burke and Brown, 2007)



Australian changes - change in the percentage of the land surface in drought together with the distributions associated with changes in precipitation and changes in potential evaporation (MPE black and MME in grey) (courtesy Black and Brown, 2007)

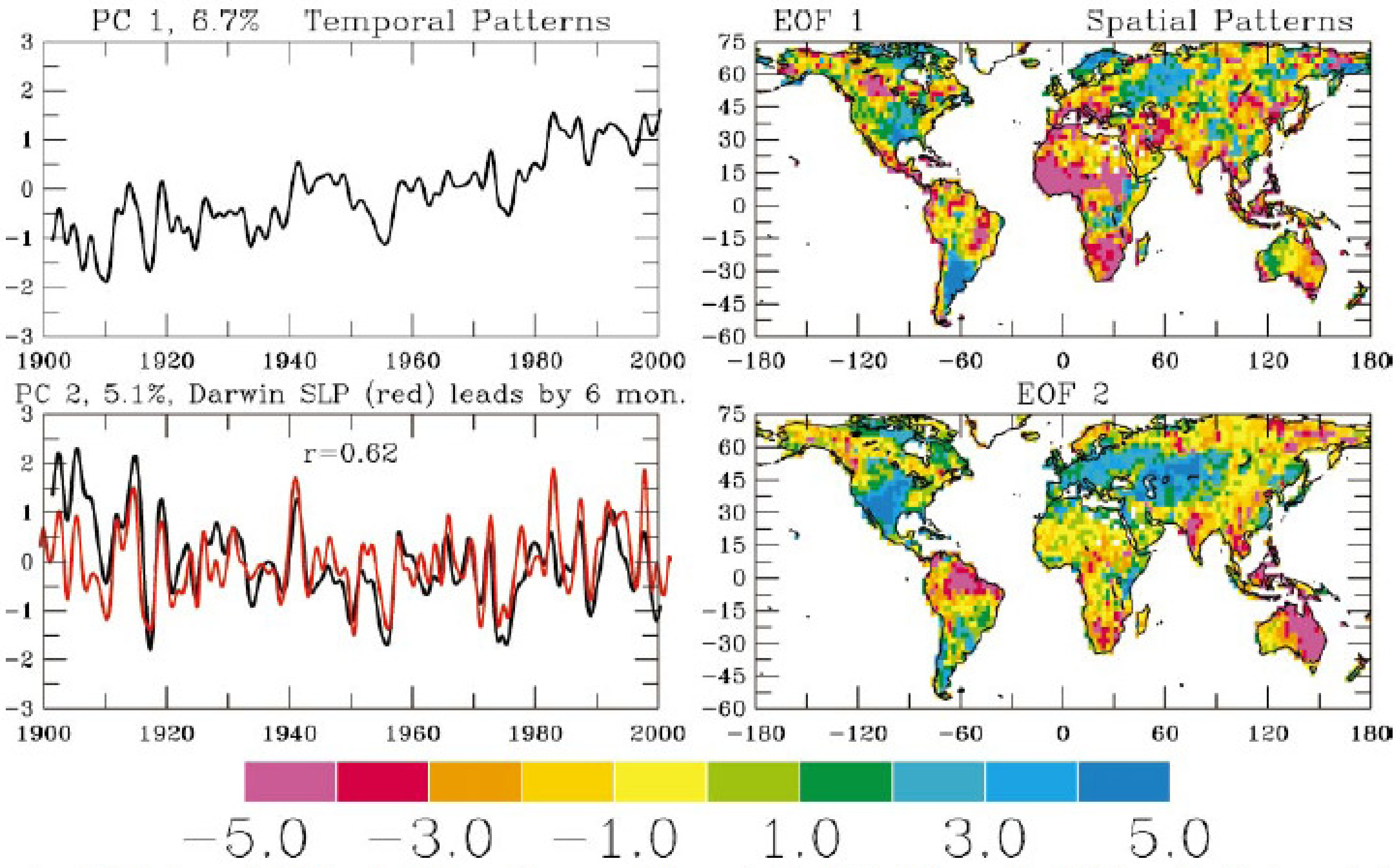
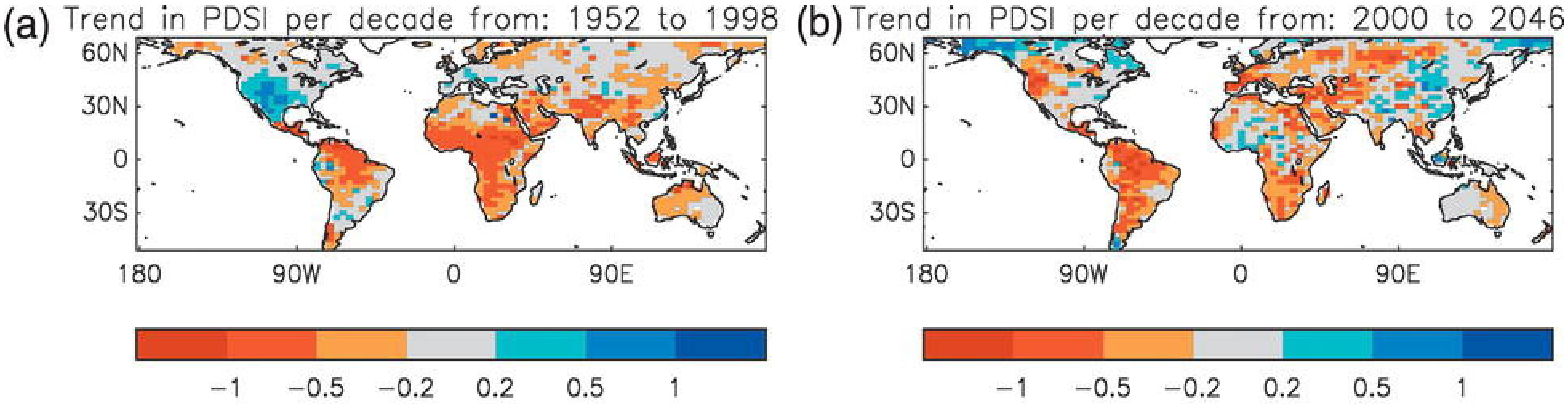
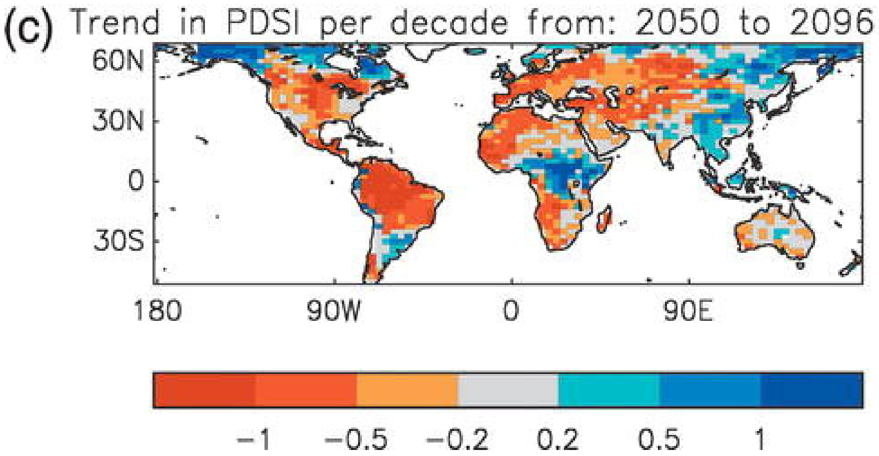


FIG. 6. (left) Temporal (black) and (right) spatial patterns of the two leading EOFs of the monthly PDSI (normalized by its standard deviation prior to the EOF analysis). Red (blue) areas are dry (wet) for a positive temporal coefficient. Also shown in the lower-left panel (red) is the Darwin mean sea level pressure shifted to the right by 6 months to obtain the maximum correlation ($r = 0.62$). Variations on <2 yr time scales were filtered out in the left panels. The percentage variance explained is shown on the top of the left panels.

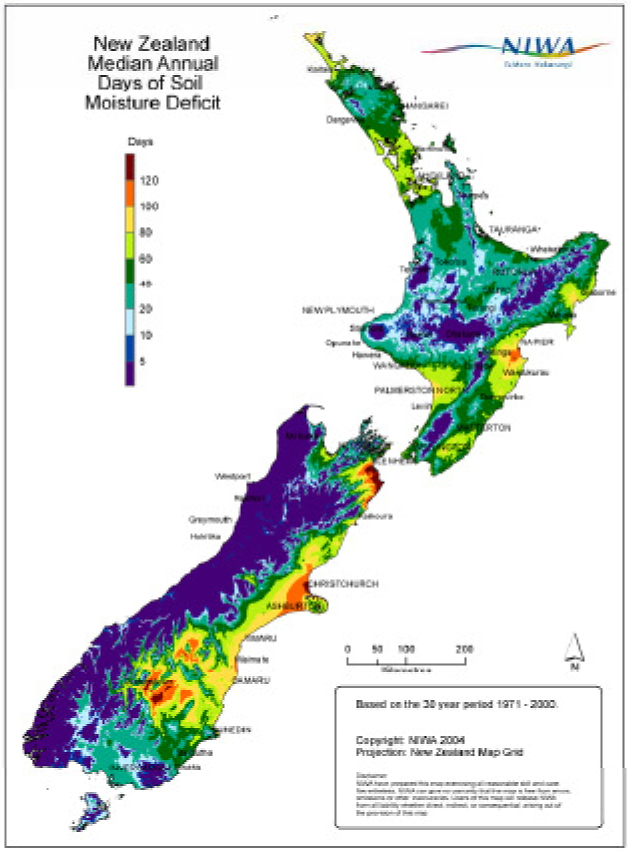
Similar results from Dai et al - Long-term shifts in monthly PDSI - Dai et al., 2004





The trend in the PDSI-PM per decade for (a) ALL-A; (b) the ensemble mean of the first half of the twenty-first century projected by SRES A2; and (c) the ensemble mean of the second half of the twenty-first century projected by SRES A2. (Burke and Brown, 2006).

New Zealand drought risk



- Main areas of drought risk are in east of both islands and inland drier areas of the South Island
- Main factor in soil moisture deficit patterns is mountain backbone across predominant westerly flow
- 1997/98 drought resulted in loss of ~$620 M to NZ economy (NZIER)
- Significant drought can occur in other regions under suitable conditions
- Regional patterns of drought are linked to favoured persistent climate patterns

Expert Team on Drought and Extreme Temperatures, 18-19 February 2009

Salinger, 2009.

•**NIWA has an 84 site soil moisture monitoring network (flux tape probes) and an active national soil water balance calculated daily.**

•Also a broad range of research to improve modelling of this process – the drought indicator mostly used is 'relative soil moisture deficit'..

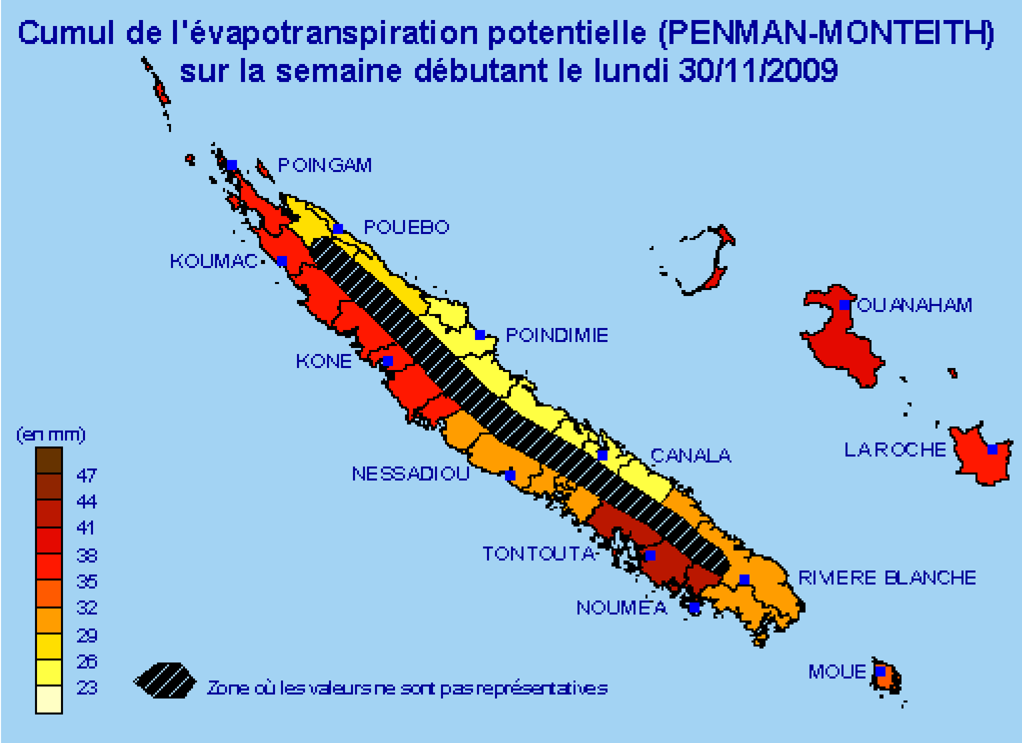
•Phillips and McGregor (P and M) Index' regarded as 'useful' as it is one where both the entry, continuation and recovery criterion are transparent.

•**P and M index has application to agronomic drought - current testing underway – highlighting strong correlation with production monitoring at regional and national scales**.

<u>**New Caledonia**</u>

•The term “drought” ‘not well defined’ in New Caledonia – its definition depends on its use...

•For agricultural purposes New Caledonia *uses a weekly estimation of the Penman Monteith potential evapotranspiration f*or various sites which gives a proxy of the stress imposed by meteorological conditions for plants ..



•Drought also *monitored indirectly* with the bushfire weather forecasting systems based on the MacArthur index.

(Source: Alexandre Peltier, Meteo-France, Nouvelle Caledonie).

Fiji Meteorological Service
Headquarters in Namaka,
Nadi Airport

Fiji: ***agricultural drought is a major issue*** **–**

•Use of SPI ....tendency to use SPI of minus 1.8 to identify severe drought (otherwise use minus 2)

However, in Fiji, use of crop and pasture simulation models useful in gaining appreciation of ranking of current and recent droughts ...

However, SPI dominates application of drought indices in SW Pacific Island Nations (eg Fiji; Cook Islands).

Conclusions:

•Drought assessment in Australia strongly driven by policy issues associated with identifying ‘exceptional droughts’

•Increasing application of both crop and pasture simulation models to assess ‘agricultural droughts’.

•Monitoring soil moisture and plant available water holding capacity important but done on a regional/State scale rather than a national scale – except for use in assessing national crop yields.

•PDSI appears to have useful application for Australia, especially for the future under climate change (Burke and Brown).

•Use of NDVI also apparent but more on an experimental basis – both predominate as indices.

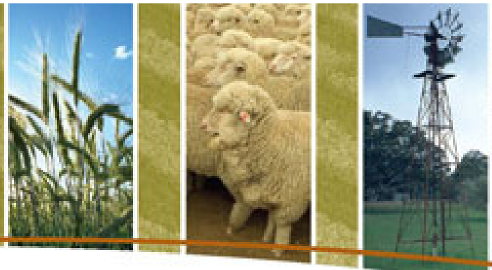
•The ‘Philips and McGregor index being tested in New Zealand - P and M index has strong correlation with production.

• A weekly estimation of the Penman Monteith potential evapotranspiration used in New Caledonia as a proxy of stress to plants caused by meteorological conditions – crop models used in Fiji..

Thank you


CANADA
NORTH
UNITED STATES
AMERICA
MEXICO
Tropic of Cancer
MARSHALL
ISLANDS
KIRIBATI
equator
International
line
PACIFIC OCEAN
COOK
ISLANDS
(NZ)
FRENCH POLYNESIA
(FR)
Tropic of Capricorn
AUSTRALIA
Antarctic Circle

NAMS
NATIONAL AGRICULTURAL MONITORING SYSTEM



Australian Climate and Agricultural Update
September 2009 Issue

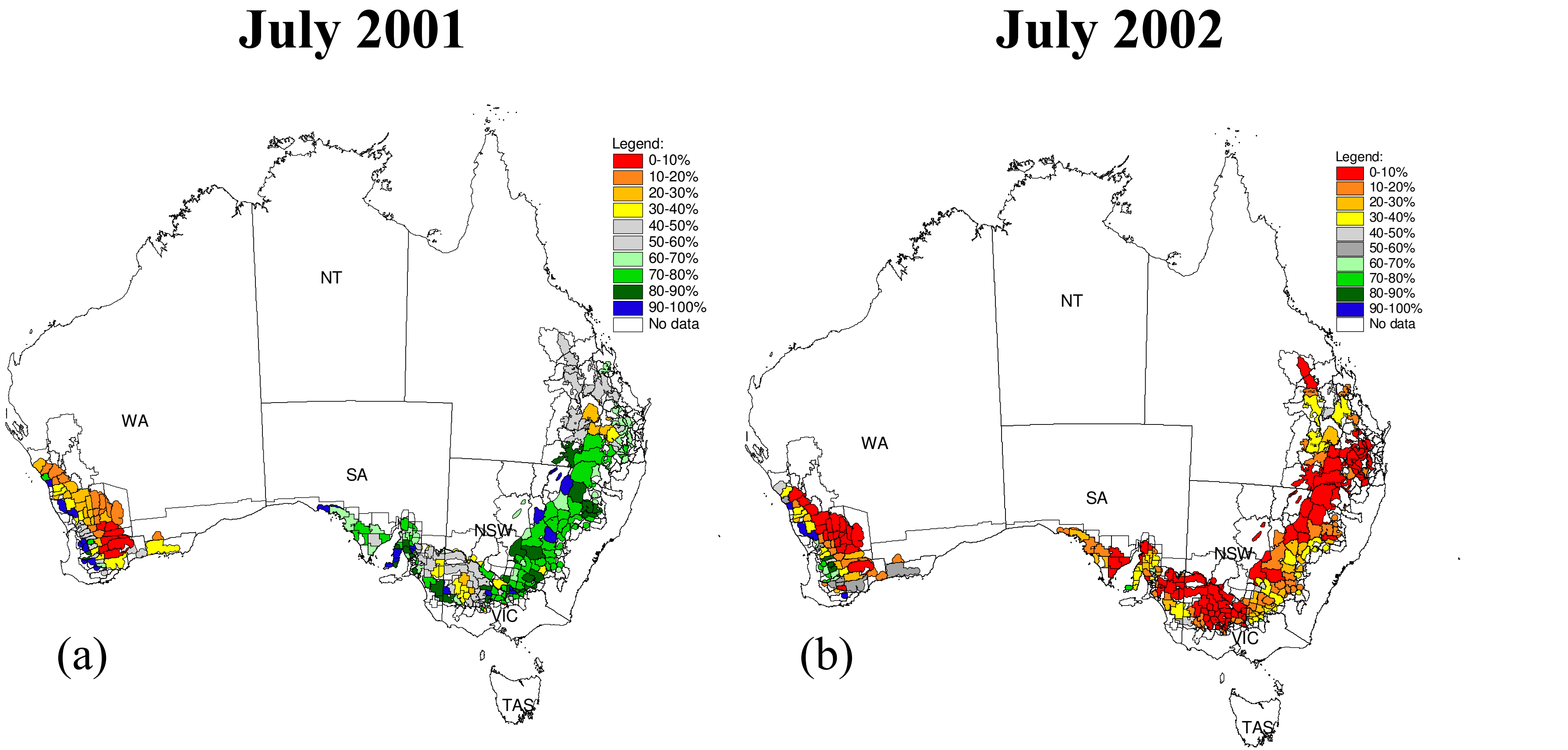
To view the September Climate and Agricultural update, go to the National Agricultural Monitoring System website <u>www.nams.gov.au and select “National Report” from under “State & National Reports” on the homepage.</u>

“Rainfall across Australia in August 2009 was well below the long-term average. Water storage levels in the Murray Darling Basin increased slightly during August and there has been a small increase in water allocations to some areas. Production conditions for winter crops remain favourable across south-eastern South Australia, Western Australia, south-western Victoria and Tasmania but the remaining regions are likely to be reliant on in-season rainfall for finishing. Beef exports for August 2009 were greater than the same time last year in response to increased demand from Korea, the USA and Indonesia. Climate models continue to predict the development of an El Niño event for the remainder of 2009 that could lead to below normal rainfall in the second half of the year across southern and eastern Australia”.

TABLE 1. The mean change in the percentage of the global land surface in drought with the 5th–95th percentile range shown in brackets. Figure 1 shows the distribution of the change in ΔD^{20} for the different indices.

	MPE: mean (5th–95th percentile)			MME: mean (5th–95th percentile)		
	ΔD^{1}	ΔD^{5}	ΔD^{20}	ΔD^{1}	ΔD^{5}	ΔD^{20}
ΔD_{SPI}	5 (3, 9)	5 (2, 10)	2 (−1, 9)	3 (2, 5)	3 (0, 5)	0 (−3, 3)
ΔD_{PPEA}	24 (15, 35)	30 (21, 41)	33 (25, 43)	21 (17, 31)	26 (22, 36)	27 (24, 37)
ΔD_{PDSI}	23 (16, 33)	26 (19, 36)	26 (19, 36)	19 (12, 25)	21 (13, 27)	20 (11, 26)
ΔD_{SMA}	14 (9, 18)	15 (10, 21)	12 (7, 19)	17 (7, 24)	18 (8, 26)	13 (6, 27)

Mean change in the percentage of the global land surface in drought for the different drought indices (SPI, PPEA, PDSI, SMA)



Use of STIN and/or OZWHEAT in assessing agricultural drought issues - probabilities of exceeding long-term median wheat yields for every wheat producing shire (= district) in Australia issued in July 2001 and July 2002, respectively.

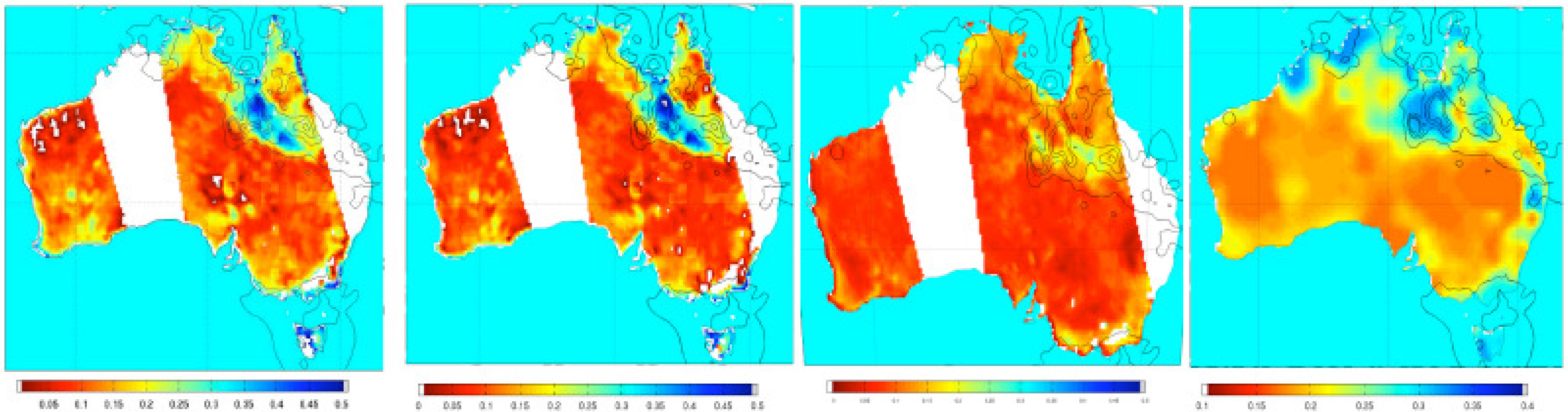
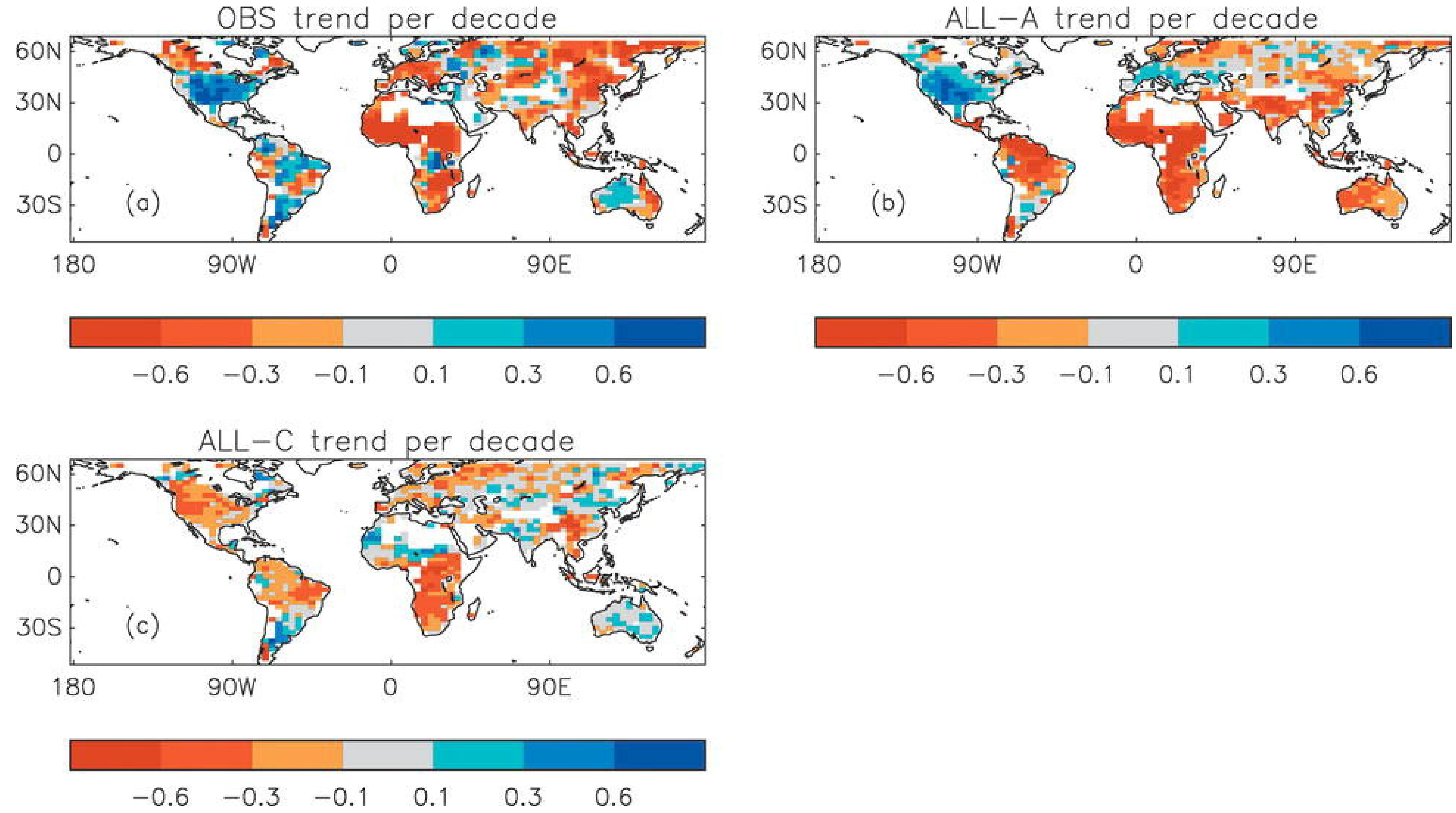
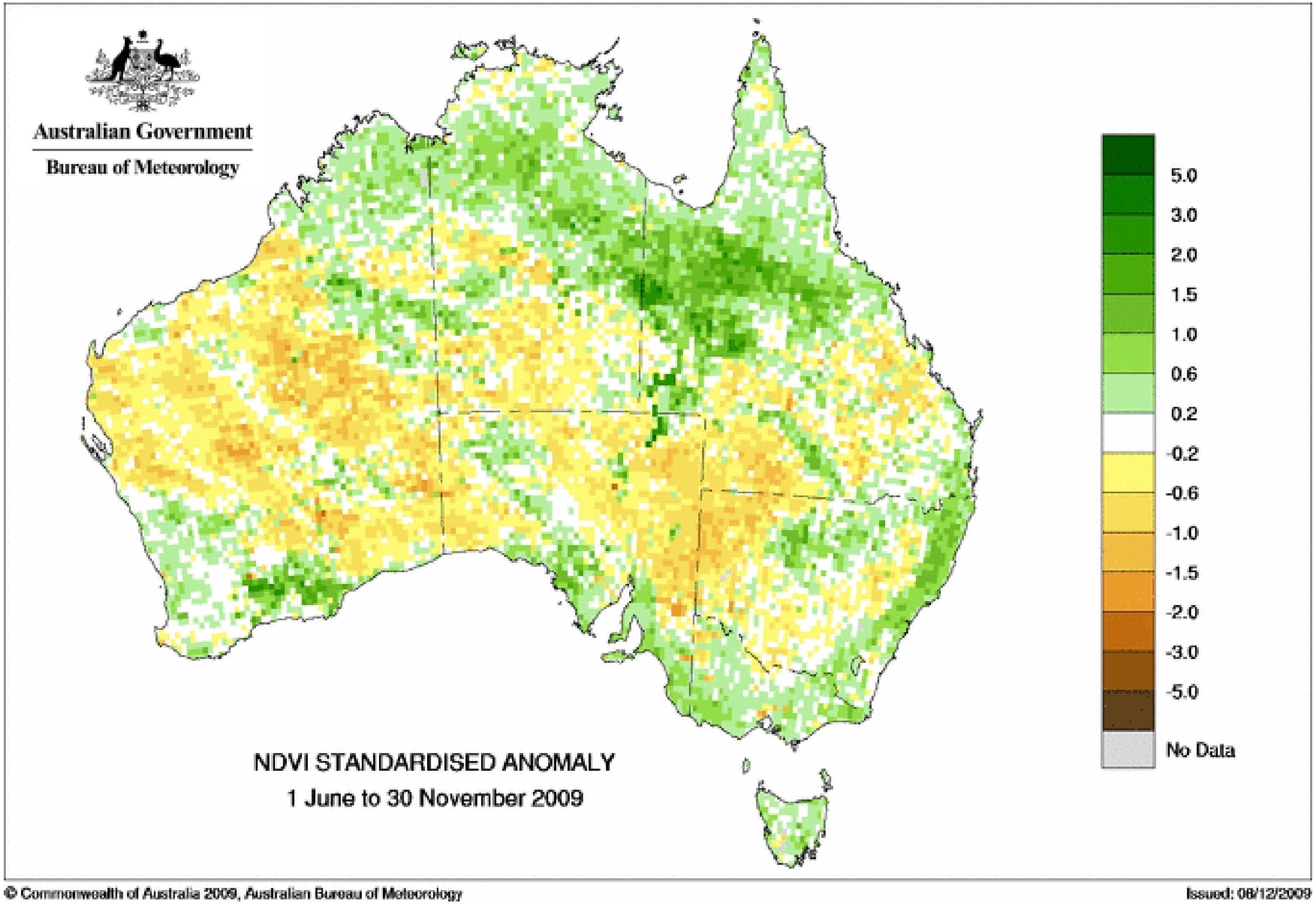


Figure 1: Maps of soil moisture on 6 January, 2005: (left to right) VUA-NASA-C, VUA-NASA-X, NASA-X, and LAPS. The black lines are 20 mm precipitation contours from the previous 24 hours. The soil moisture colour range in each panel describes the range of each product (0 – 0.5 vol/vol from AMSR-E, and 0.17 – 0.32 vol/vol for LAPS


OBS trend per decade
60N
30N
0
30S
(a)
180
90W
0
90E
−0.6
−0.3
−0.1
0.1
0.3
0.6
ALL−A trend per decade
60N
30N
0
30S
(b)
180
90W
0
90E
−0.6
−0.3
−0.1
0.1
0.3
0.6
ALL−C trend per decade
60N
30N
0
30S
(c)
180
90W
0
90E
−0.6
−0.3
−0.1
0.1
0.3
0.6



EXAMPLE – NDVI STANDARDISED ANOMALIES
Source: Bureau of Meteorology Australia

•Within Australia there has been limited research for linking ground-based meteorological data with the NDVI signal (Tuddenham and Le Marshall, 1996).

•More process understanding is incorporated by linking meteorological data with the NDVI time series response.

•For example, low NDVI values over a particular growing season may be the result of plant disease and not be associated with water stress.

•The next level of complexity is to link the meteorological data with plant growth models which capture greater process understanding.

•While rainfall amount during the growing season is important, the timing is just as important for plant development.

•Frost frequency, intensity and timing may also impact on crop yields.

TOTAL STANDING DRY MATTER – VALUE OF A SYNTHETIC NDVI

•The remotely sensed images and GRASP model output of TSDM have both been ground-truthed for a variety of vegetation communities, primarily focused in Queensland.

•Relationships between percentage cover for pasture and tree basal area have allowed a synthetic NDVI to be calculated - termed *ND V/GRASP. ND V/GRAS P* has been correlated, spatially and temporally, with the NDVI observed from the AVHRR, termed *ND VIAvHRR (Carter et al., 1996b); this can be calculated* for any period of imagery composition.

•This has been used to provide a measure of confidence, both spatially and temporally, in the GRASP simulations away from point-based calibration sites.

•Currently, the use of global optimisation techniques to invert GRASP model parameters by minimising the residual between the observed and synthetic NDVI signal is being explored.

For Drought Exceptional Circumstances:

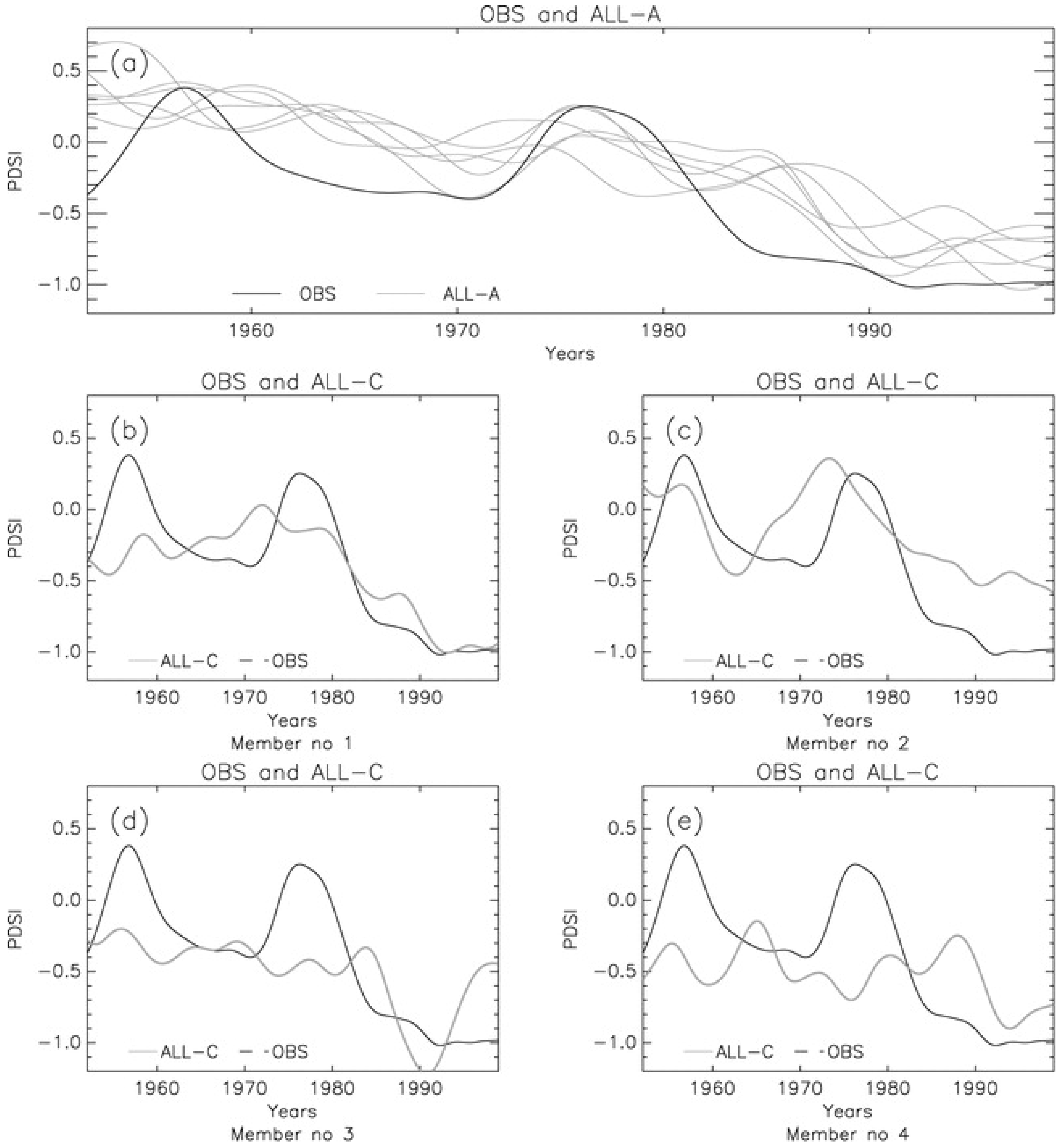
-

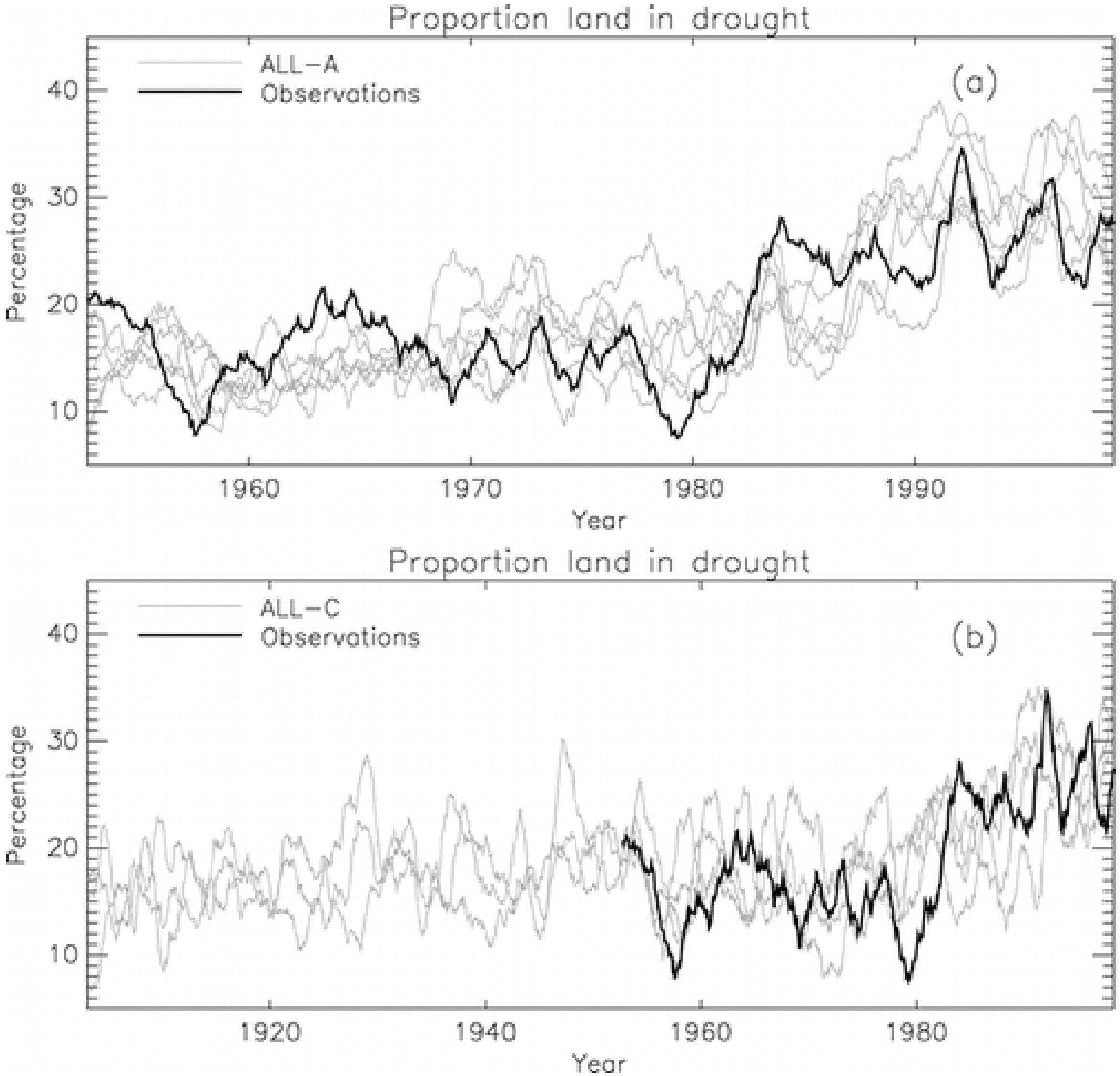
•A rare and severe event that *cannot be expected more frequently than one in twenty-twenty five years* (not just 'drought')

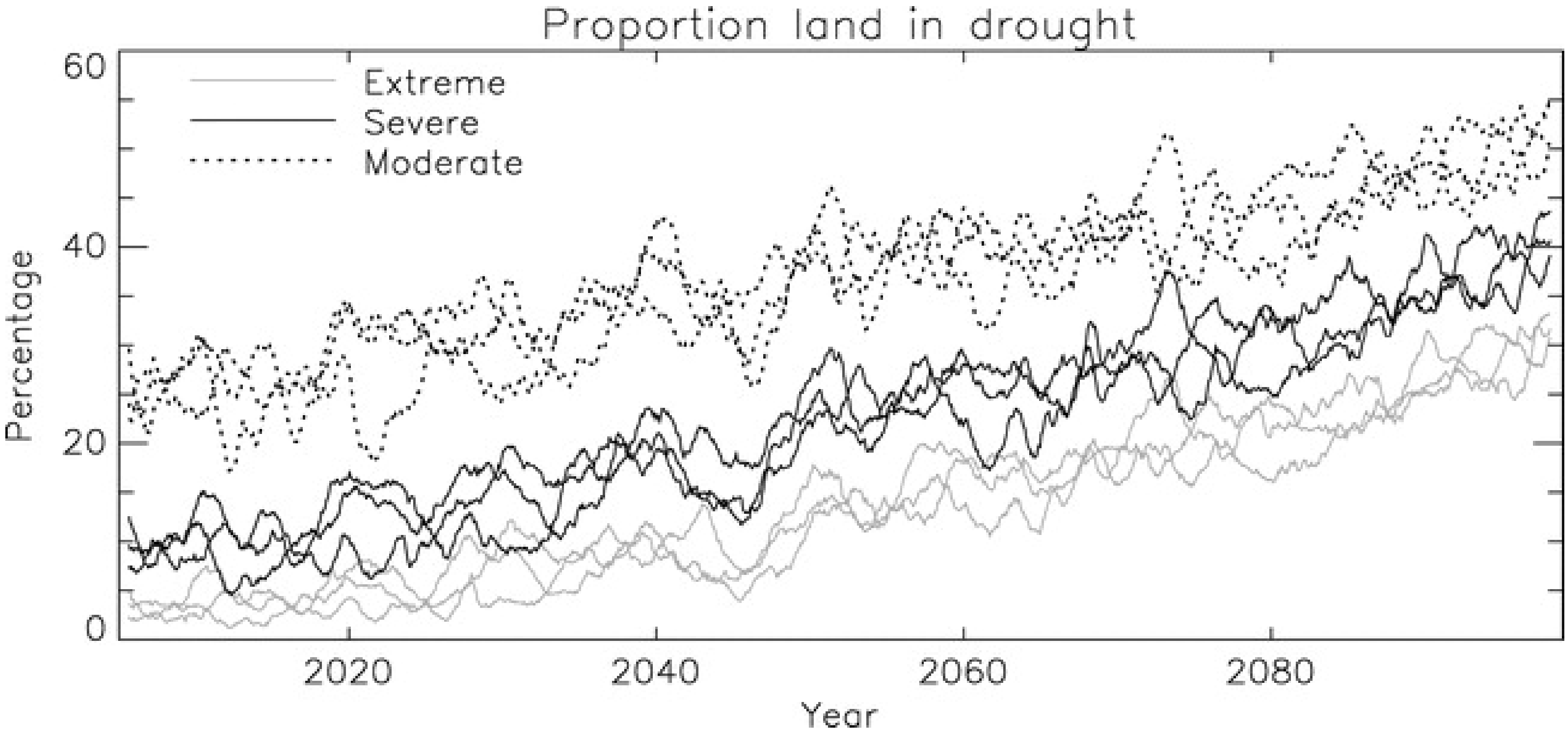
•The event must have a prolonged and severe impact *on incomes* (more than a year)

•Must not be a result of structural adjustment, and impact the majority of producers in the region.

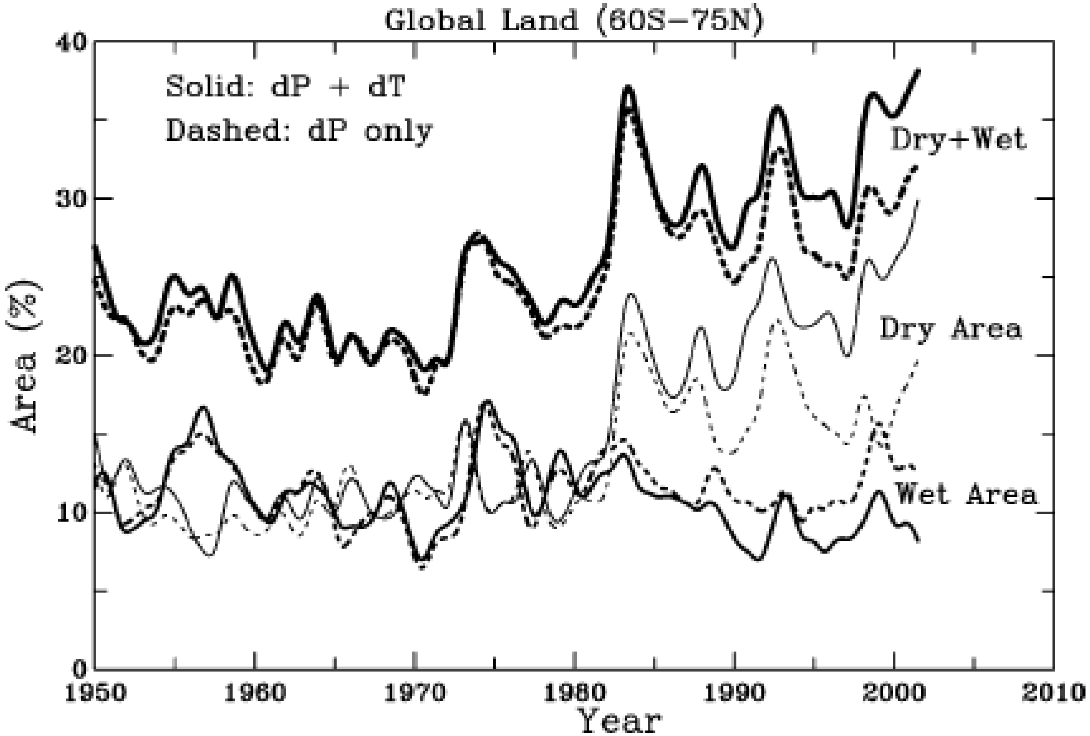
•Generally not available if assistance already provided under natural disaster relief and recovery assistance arrangements.


OBS and ALL-A
(a)
PDSI
0.5
0.0
−0.5
−1.0
OBS
ALL-A
1960
1970
1980
1990
Years
OBS and ALL-C
(b)
ALL-C
- -OBS
Member no 1
OBS and ALL-C
(c)
ALL-C
- -OBS
Member no 2
OBS and ALL-C
(d)
ALL-C
- -OBS
Member no 3
OBS and ALL-C
(e)
ALL-C
- -OBS
Member no 4


Proportion land in drought
ALL-A
Observations
(a)
Percentage
Year
Proportion land in drought
ALL-C
Observations
(b)
Percentage
Year

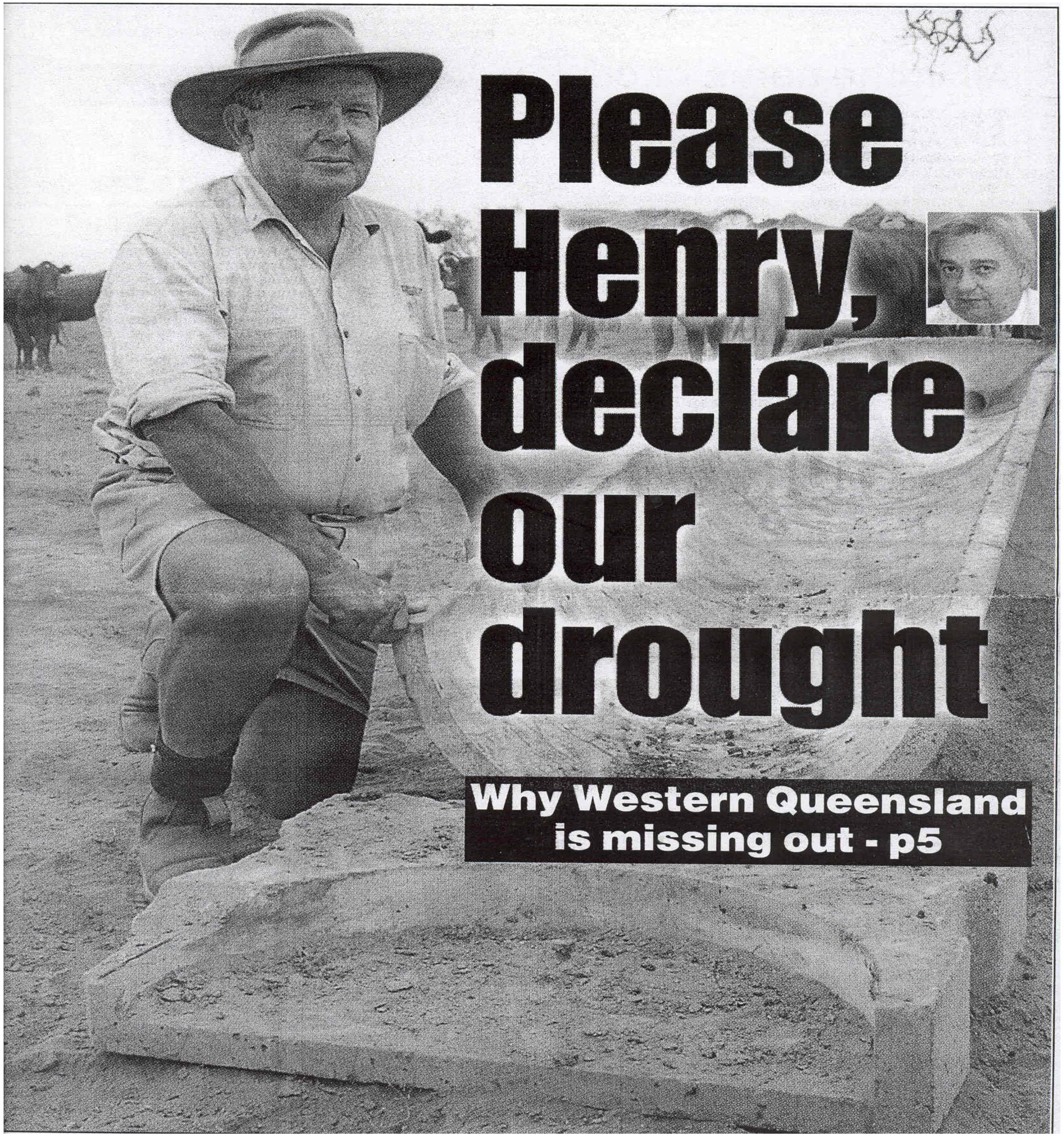


Proportion land in drought
Extreme
Severe
Moderate
Percentage
0
20
40
60
2020
2040
2060
2080
Year



Dai et al., 2004

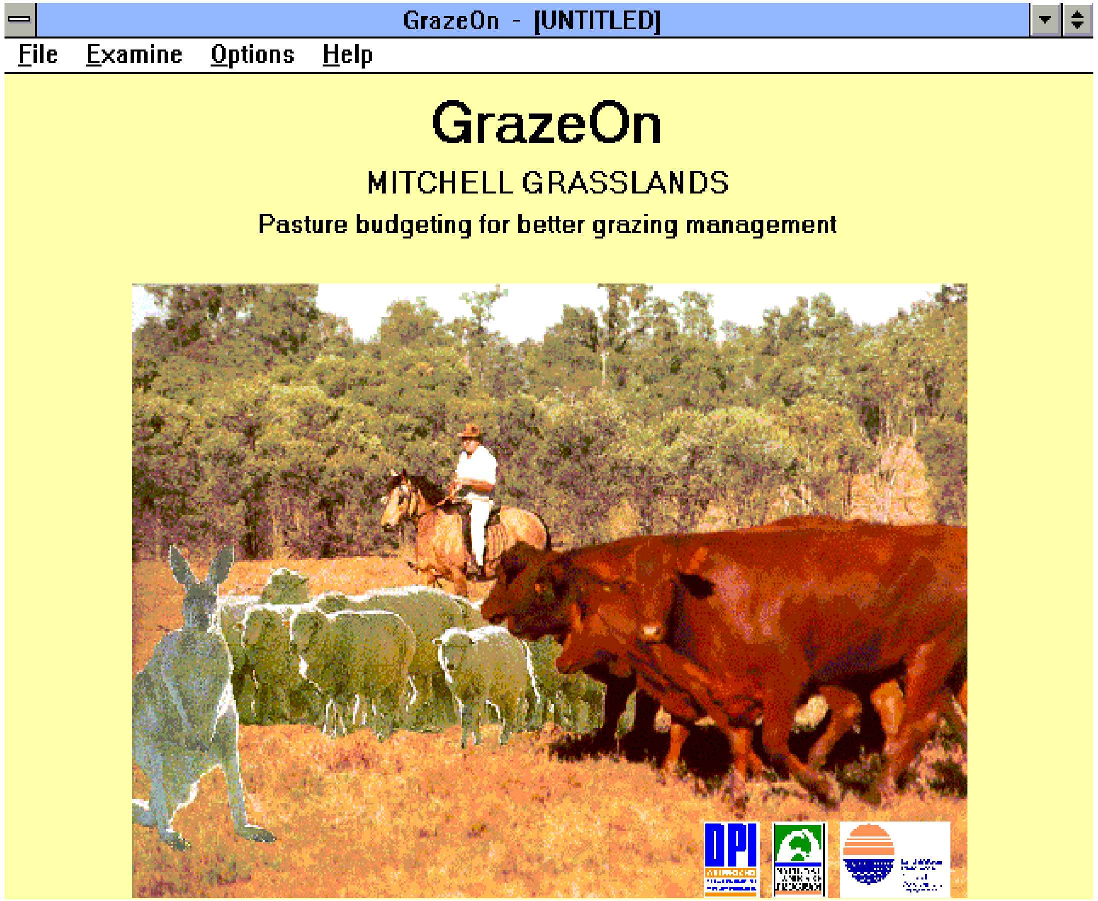
FIG. 9. Smoothed time series of the percentage of the total land areas within 60°S–75°N that were in very dry (PDSI < -3.0; thin lines), very wet (PDSI $> +3.0$; medium lines), and very dry or wet (thickest lines at the top) conditions from 1950 to 2002. The solid lines are based on the PDSI calculated with both precipitation and temperature changes, while the dashed lines are without temperature changes (i.e., due to precipitation alone).


Please Henry, declare our drought
Why Western Queensland is missing out - p5

- Climate information integrated with pasture growth models enable forward budgeting of pasture
- Value in assisting preparedness and contingency planning for drought and reduce risk by forward budgeting of pasture (for up to 2 years)

Enhancing the cooperation between service providers and sectoral users – developing useful decision-support systems that link climate information, agricultural models and user decisions …however, this needs to be done as part of discussion groups

- **estimate future stocking rate**
- **pasture budgeting**
- **monitoring**
- **Predict total grazing pressure**
- **Assist drought preparation**



•**Assessment of agricultural and horticultural industries**

•**Number of Individual Declared Properties (IDP) declarations that have been issued (there is no particular percentage of properties that need to be declared under IDP provisions for an area recommendation to be made)**

•**Whether *other abnormal factors* have affected the agricultural drought situation; for example high temperatures and winds**

Drought issues in Australia (2002/03 El Niño event)

SM 25/8/02

El Nino takes hold

Showers no use in Big Dry

By KIM SWEETMAN

SOUTHEAST Queensland back yards may look a little greener after a few days of rain but this week's showers were just false hope.

The rest of the state is still desperately dry, not a single region can be taken off drought lists and Queenslanders face months more of dry weather.

Weather experts say Queensland is now fully in the grip of the El Nino cycle, meaning significant rain could be six months away.

The wettest place in the seven days to Friday was Mundubbera, west of Bundaberg (125mm), followed by Lady Elliott Island (114mm) and the Gold Coast Seaway (103mm).

The steady falls this week relieved some of the fire danger around Brisbane and the Gold and Sunshine Coasts, reducing it from extreme to very high.

While there was a significant drop in water usage, the rain did almost nothing for dam levels.

The Gold Coast's Hinze Dam remains less than 45 per cent full and without significant rain it will drop to 25 per cent of its 160 billion-litre capacity by January. Moogerah Dam near Boonah is at less than 4 per cent of capacity.

Councils on the Gold and Sunshine coasts will press ahead with water restrictions.

The Gold Coast will not lift restrictions until 75 per cent. Sprinklers were banned in May and this week the city's 208 beach showers were disconnected.

Rain showers are predicted today for the southeast but, apart from isolated coastal showers for the next two to three weeks, there is no major rain forecast for Queensland in the short term.

Queensland Primary Industries Minister Henry Palaszczuk said the rain had done little for most primary producers. "Despite rain falling in large parts of Queensland this week, I expect further drought declarations to be made," he said.

"The rain has been of great value for many producers, but it has not fallen in all areas or in the amounts needed."

More of Queensland is now drought-declared than at any time since March 1997— 41 shires, one part-shire and more than 300 individual properties in another 34 shires.

The fire danger around metropolitan regions will not be significantly reduced by the rains. Most bush areas and parks are expected to dry out by the end of the week and the effects of ongoing drought mean there are huge amounts of flammable material lying around.

The Queensland Fire Authority has repeated warnings for all home owners, even in the inner city, to make preparations for a particularly bad bushfire sea-

Hungry emus invade towns

EMUS and brolgas are roaming the streets of country towns in central western Queensland as dry conditions force them to seek food in parks and back yards.

More than 100 emus have been spotted in Longreach *(above)*, according to the shire's chief executive officer, Bob O'Brien.

He said the latest visitors, including about 12 brolgas, were a hit with tourists.

Motorists were being forced to dodge the emus, which were also messing up walkways.

Corellas have also come into Longreach seeking food with more than 400 of them flocking to a telecommunications tower.

Member for Gregory Vaughan Johnson said emu numbers would drop off very quickly in the dry season if rain didn't come soon.

In Blackall Shire, chief executive officer Tony Gallwey said about a dozen emus had been roaming the town looking for greenery. It was the first time in 10 years he had seen so many emus in the town.

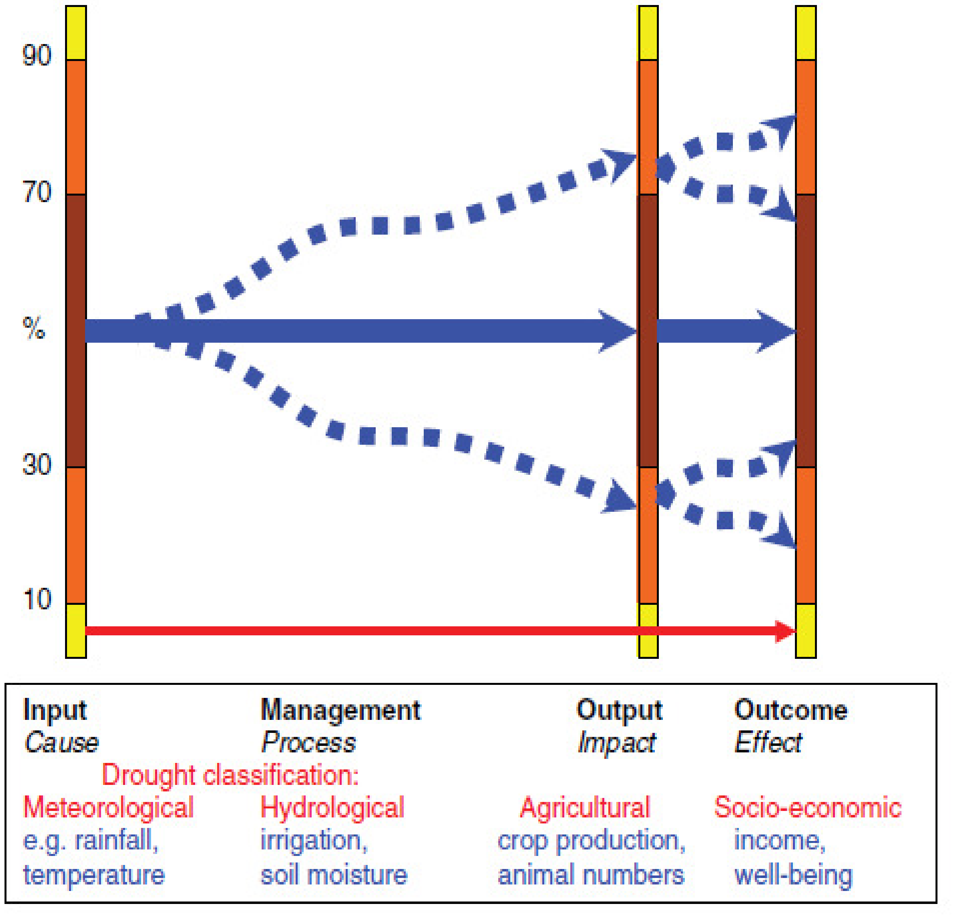
Rainfall Depreciation Method

The rainfall depreciation method is similar to the concept of a catchment wetness index where a weighted sum of previous months' rainfall is used as a measure of the water in storage. White et al. (1999) describe it as being essentially a pseudo water balance method and offer two alternative definitions: one based on compound depreciation and the other on simple arithmetic depreciation. For the Rarotonga application a simpler definition was adopted on the basis of trial-and-error calculations to produce a weighted sum index as follows:

$$DI_i = P_{i-1} + 0.9*P_{i-2} + 0.8*P_{i-3} + \ldots\ldots\ldots + 0.1*P_{i-10}$$

where
DI_i = Weighted Sum Drought Index for month i
P_{i-1} = Precipitation in month (i –1) etc.

White et al. (1999) correctly point out that this method has a number of limitations: it is not strictly an index, it can not be directly compared with values from another site and is physically unrealistic since it effectively assumes that rainfall losses are a fixed fraction of monthly rainfall. Nevertheless, the simplicity of the method (it is very simply calculated in EXCEL) and the intuitive connection with the concept of 'catchment memory' offers some advantages for use by non-specialists.



A simplified model of agricultural production to show relationships between inputs, outputs, and outcomes with various classifications of drought. With permission: White and Walcott (2009) adapted from Walcott and Clark (2001)

- “Within the (then) Queensland Department of Natural Resources (QDNR) there was a policy change to *declare drought based on rainfall effectiveness rather than rainfall percentiles*.

- This is because rainfall effectiveness has been deemed a more objective criterion than rainfall percentiles alone”.

•GRASP is a mostly empirical model that aims to simulate the effects of climate and management options such as burning and grazing pressure on the growth of tropical native pastures (McKeon *et al. 1990).*

•*Some* improved pastures can also be modelled and the effect of trees on pasture production estimated.

•The model was developed in Queensland but has performed credibly in the rangeland areas of Western Australia, New South Wales, and the "Top End" of the Northern Territory.

•GRASP underpins the "AussieGRASS" model (Hall *et al. 1997; Carter et al. 2001) that is used within a* Geographical Information System to spatially and temporally.

- ‘Pickup uses a relatively simple herbage growth algorithm in combination with remotely sensed data.

- FLOW was developed in order to estimate spatially distributed herbage production and consumption by grazing animals from rainfall and evapo-transpiration in rangelands.

- Even though it was developed for the arid rangelands of central Australia, the basic approach of linking a relatively simple model to remotely sensed data is probably capable of wider application.

- The appeal of “Pickup” is in its ease of calibration, simplicity, and modest data requirements.

•Remote sensing offers a unique view into the spatial and temporal variability of vegetation condition and moisture availability.

•Remotely sensed data must be viewed as one of a number of possible data sets to assist in determining DEC and these data sets should viewed as complimentary, not competitive.

•For example, it is very unlikely that remote sensing alone will be able to delineate a 1:20-year from a 1:15-year drought event.

•Such events are likely to be delineated by integrating the long history of meteorological data with the spatial resolution offered by remotely sensed data.

•When integrated correctly remote sensing provides extra information to the decision-making process for DEC declaration.