Estimating the extent and severity of drought

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Abstract. The National Drought Policy was ratified by the Commonwealth, States and Territories in 1992. However, before it was fully implemented, one of the most severe droughts on record was already establishing itself across Australia. The Commonwealth government therefore devised measures to determine which areas had been exposed to exceptional drought so that financial assistance could be directed as effectively as possible. Six criteria were agreed to nationally, namely meteorological, agronomic, and environmental conditions, water supply, net farm income, and the spatial extent of the drought. Assessments during 1994-95 had to account for the wide range of environments and farming systems. Useful data were often at a premium. Here we describe some of the ways in which these criteria have been estimated and assessed. Ways in which simulation models can be used to objectively estimate the extent and severity of drought are also demonstrated and discussed.

1. INTRODUCTION

The objectives of the National Drought Policy (NDP), agreed to by Commonwealth, State and Territory Ministers in 1992, are to encourage primary producers and other sections of rural Australia to adopt self-reliant approaches to managing for climatic variability, to maintain and protect Australia's agricultural and environmental resource base during periods of extreme climate stress, and to ensure early recovery of agricultural and rural industries, consistent with long-term sustainable levels.

As a consequence of the NDP, Australian farmers are now expected to assume greater responsibility for managing the risks arising from climatic variability. Managing these risks effectively requires the integration of financial and business management with production and resource management to ensure that the financial and physical resources of farm businesses are used efficiently. Features of the NDP are described by White *et al.* [1993a].

Drought conditions prevailed over much of Australia in 1994. In some areas this drought began as early as 1991. This resulted in all States and the Northern Territory making submissions to the Commonwealth Minister for Primary Industries & Energy to have large areas declared as experiencing 'drought exceptional circumstances', which would qualify producers to apply for Commonwealth financial support. Consistent with the overall thrust of the National Drought Policy, support under the 'exceptional circumstances' provisions of the Rural Adjustment Scheme (RAS) is only triggered where the Minister for Primary Industries & Energy considers that drought conditions are exceptional, being beyond those that could be expected to be factored into normal risk management practices. It is also important that financial assistance does not reward poor management, such as by encouraging overstocking.

Declaration of drought exceptional circumstances is intended to provide short term targeted assistance for long term profitable businesses. Interest rate subsidies of up to 100 *per cent* of existing and new loans for farm businesses considered to have prospects of profitability in the long-term are available for eligible businesses. Family income support is also provided through Drought Relief Payments. These payments are subject to an incomes and off-farm assets test. Additional assistance is also available to assist people to leave the land when their properties are no longer financially viable. Given the large total cost, together with considerations of accountability, equity and political pressure, the existence of 'exceptional circumstances' needs to be assessed as objectively as possible.

2. DROUGHT EXCEPTIONAL CIRCUMSTANCES

Declaration of drought exceptional circumstances is based on an assessment process involving analysis of objective scientific information and independent advice from the Rural Adjustment Scheme Advisory Council (RASAC). Final decisions are made by the Commonwealth Cabinet. RASAC comprises eight members including representatives from the Commonwealth, the States and the National Farmers Federation (NFF) as well as members with expert qualifications in the areas of economics, financial administration, banking, sustainable agriculture, farm management or training.

In October 1994, the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), comprising Commonwealth and State and Territory Ministers for agriculture and resource management) agreed on six core criteria for drought exceptional circumstances. These core criteria are: meteorological conditions, agronomic and livestock conditions, water supplies, environmental impacts, farm income levels, and scale of the event.

3. MEASURING THE CRITERIA

In determining the six core criteria for assessment of whether an event satisfies this description, ARMCANZ agreed that requests for support should first satisfy the meteorological criterion before the five remaining criteria would be assessed. The process is described in more detail by White and O'Meagher [1995].

3.1 Meteorological Condition

For the meteorological conditions being experienced to constitute a 'rare and severe event', it must be established that they are likely to occur only once in 20-25 years and to be of greater than 12 months duration. To allow for differences between different geographical locations and agronomic systems, cognisance must be taken of the effectiveness of any rainfall that occurred. Typical growing seasons were therefore determined. For example, if pasture growth is commonly maximised in autumn (March to May in Australia) and spring (August to October), then the rainfall deciles for these months were emphasised. If winter growth is considered critical then the rainfall deciles for March to October were considered. Rainfall over a 12-month period was used where rainfall at any time of year can lead to effective growth.

Complete historical rainfall records (extending over at least 70 and generally more than 100 years) for each site were then obtained from the Bureau of Meteorology. The data were analysed to determine whether the lack of rainfall over the agreed growing seasons represents a one in twenty to twenty-five year event. Tables were developed for each area setting out the number and frequency of similar rainfall events, the duration of the current event, and whether the current event qualifies or when this is likely to occur. Other rainfall information (e.g. cumulative rainfall anomalies and two- and three-year moving averages; Clewett *et al.* [1994]) was also used to help put the current rainfall event in perspective.

3.2 Agronomic and Stock Condition

Different approaches have been used in different parts of Australia to assess conditions against this criterion. Brook and Carter [1994] of the Drought Research Group of the Queensland Department of Primary Industries have made extensive use of soil moisture and vegetation growth models (tested against field and remotely sensed data) and Geographic Information Systems to determine the extent and severity of drought. Though similar models have also been developed and tested in other parts of Australia, as shown by White *et al.* [1993b], not all States have had the confidence or expertise to use them. A water balance model was used in Western Australia to estimate the length of the growing season.

Extensive farm surveys were carried out in New South Wales, South Australia, and most recently in Victoria to assess the impact of drought. Farmers were asked questions about pasture cover, supplementary feed reserves, stock sales and intended sales should the drought continue.

Other information used included remotely sensed information (NOAA AVHRR NDVI) to estimate when grasslands and crops 'dried off' and the spatial extent of the drought. Data from the Australian Bureau of Statistics were used to assess land use, and to put crop yields and stocking rates for 1994 in context with historical data. This process is illustrated by Hamblin and Kyneur [1993] who examined wheat yield trends from 1950 to 1991 for many Local Government Areas throughout Australia.

3.3 Environmental Condition, Water and Scale of the Event

Vegetation cover is important as an indicator of available fodder and to protect the soil resource from erosion. Cover can be estimated using remote sensing, pasture and crop models and farm survey data. It is important to identify soil types that are naturally vulnerable to erosion. It is also important to ensure that financial assistance does not reward poor management (e.g. through overstocking).

Information on stock water, and farmer reliance on dams or artesian water, was determined mainly from farm surveys. The scale of the event was also recorded, giving an indication of how far feed or stock needed be transported, and the availability of off-farm agistment. This criterion also enables account to be taken of the geographic spread of the event. In general, a significant land area and a significant number of farm businesses need to be affected. As the drought spread and intensified in 1994, farmers in south-eastern Australia that were earlier donating truck and train-loads of fodder to farmers in Queensland very quickly found themselves short of feed.

3.4 Net Farm Income

Every year the Australian Bureau of Agricultural and Resource Economics (ABARE) surveys a sample of about 1800 broadacre and dairy industry properties across Australia for production and financial statistics. RASAC also used this information to provide the financial profile of farms in areas being assessed for exceptional circumstances. The aim was to ensure that the general economic circumstances of farms in these areas were 'severe' enough to warrant assistance under these NDP measures. In most instances the data indicated that farm incomes were well below longer term averages.

4. IMPROVING THE INFORMATION BASE

Many farmers already had sizeable debt problems at the commencement of the drought, and were ill-prepared to cope with its duration and intensity. There were, therefore, understandable negative reactions from many people in areas that were not deemed to be experiencing exceptional circumstances. This resulted in considerable pressures on decision makers. The decisions as to which areas were experiencing drought exceptional circumstances may well have been the best that could have been made given limitations in the data, but the need for improved information acquisition and processing systems was apparent from the start.

Research is now being undertaken by BRS, ABARE and other research institutions to develop regionally-sensitive scientific and economic indicators for each of the core criteria so that objective and consistent declarations across Australia can be assured. Simulation models will complement field data in improving the determination of effective rainfall and growing seasons. This research should also provide clear guidance regarding the extent to which individual enterprises will be able to, and expected to, prepare themselves for future droughts.

5. USING SIMULATION TO ASSIST THE PROCESS

Southern Australia is characterised by a Mediterranean-type climate with cold, wet winters and hot, dry summers. Annual pastures in the south usually germinate between March and May in response to autumn rains, growth being most active in spring before senescence in October-November. The north of Australia experiences a monsoonal climate, most of the rainfall occurring in late summer-autumn (January-May). A large part of eastern Australia experiences a more uniform distribution in mean monthly rainfall, even though year-to-year variability is often high. Growing seasons therefore differ considerably throughout the country.

5.1 Climate Variability and Crop Yield

The relationship between crop yield and rainfall during the growing season is generally poor, because yield also depends greatly on the timing of the rain, as shown by Hammer *et al.* [1993]. The relationship deteriorates even further with fallow-crop systems where cognisance must be taken of rainfall and soil moisture stored over the previous summer, as shown by O'Leary [1994]. Where cropping is the dominant enterprise then evaluations of individual seasons can be based on yield. Since crop failures within a 12-month period are not considered exceptional, the 'analysis window' will usually be between 1.5 and four years, depending on the variability in rainfall and production at a specific location.

For example, B.R. Keating, G.M. McKeon and J. Dime [pers. comm.] have simulated the grain yields of winter wheat and summer sorghum over more than 100 years, both separately and within the one farming system, at different locations throughout Queensland and northern New South Wales. This enabled them to determine cumulative yield probabilities for these crops. They then ranked the mean grain yield over the past four years against the historical probabilities of such yields. This showed that grain yields for 1991-94 relative to the long-term means at both Dalby and Goondiwindi in southern Queensland were much less than at Moree in adjoining northern New South Wales.

5.2 Climate Variability and Pasture Yield

During 1994/95 the impact of rainfall deficits were analysed, for many areas, on the basis of rainfall during the main growing seasons. For grazing properties in southern Australia this meant that the rainfall deciles during autumn and spring were used as the major indicator of drought intensity, so that no account was taken in this particular analysis of rainfall at other times of the year. Rainfall at different times of the year varies in its impact on production and net farm income. It may even have a negative effect if seedlings germinate in response to rains in late summer or early autumn, but then senesce when there is no follow-up rain.

For example, the significance of late autumn rains on the germination on ungrazed annual pasture is shown in Figure 1, using functions from the model of Bowman *et al.* [1993]. This shows that if germination does not occur until after mid-April in the Heathcote environment of northern Victoria, the consequence will be much less winter feed. This is primarily because cold temperatures and relatively low incoming solar radiation will limit pasture growth.

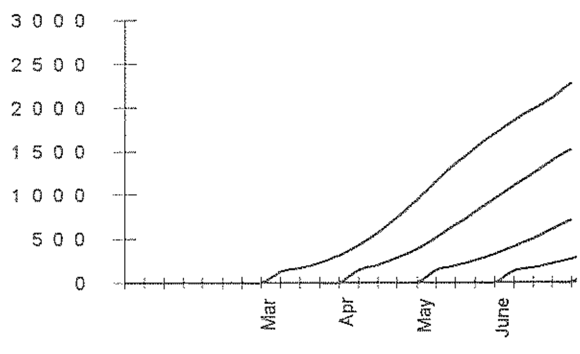

Figure 1. Pasture yield (kg DM/ha) in relation to month of germination, northern Victoria

The value of extra pasture production also varies with the time of year, and with changes in stocking rate and other management inputs, as shown by White [1988] and Donnelly *et al.* [1994]. A more holistic approach to analysing the effect of rainfall on grazing and agricultural systems is therefore favoured.

The CSIRO GrazPlan suite of models has been used by Moore *et al.* [1993] to simulate changes in soil moisture and pasture availability at eight different localities in the lamb-producing areas of southern Australia. For each locality they produced cumulative probability distribution functions of the start and finish of the pasture growth season, and the median and 10th and 90th percentiles of available green and

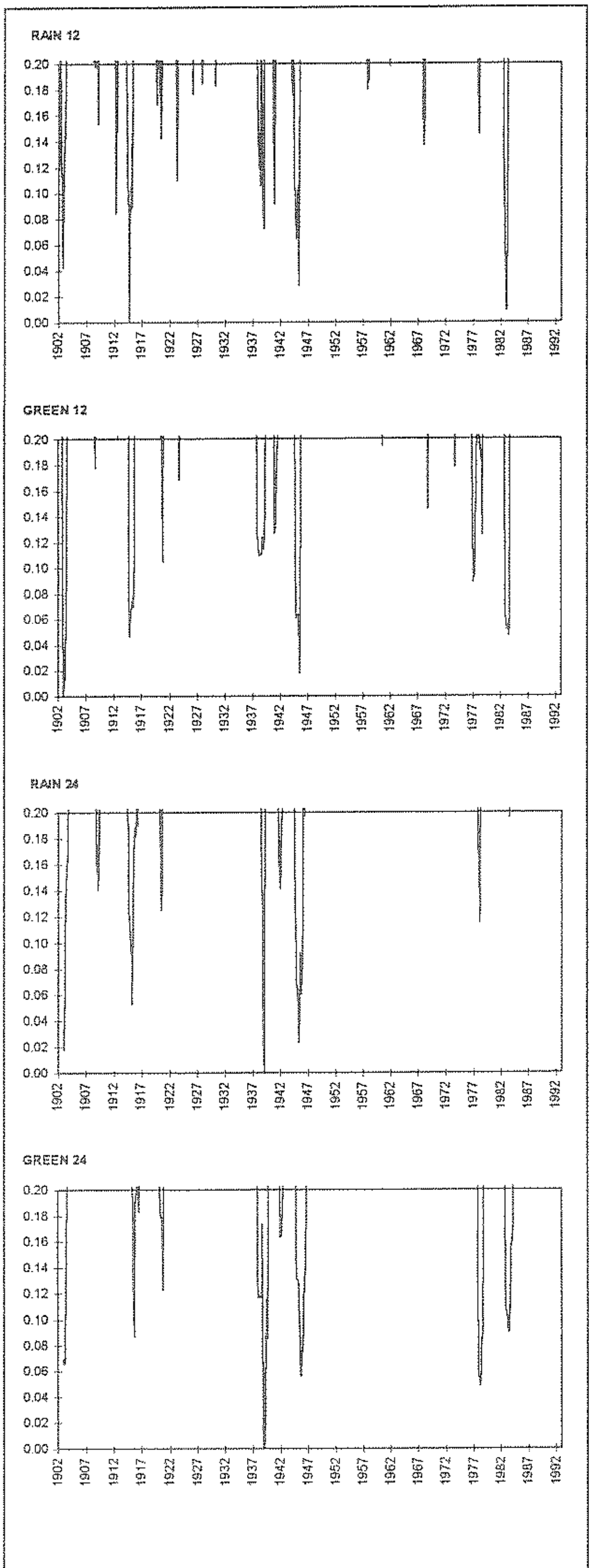

Figure 2. Deficits of rainfall and available green pasture between 1901 and 1992 at Heathcote in northern Victoria expressed as a fraction of the range, using 12 and 24 month moving averages.

dead herbage, based on simulations of 13 to 31 years. In each year the start of pasture growth is defined by the start of the germination event that results in the growth of 500 kg per ha of herbage dry matter. The finish of the growing season is defined as the week when the simulated sward enters its senescent phenological stage.

The above analyses compared levels of pasture production between different years. In determining exceptional circumstances, however, it must be shown that the current meteorological conditions constitute not only a one in 20-25 years event, but that they are also of greater than 12 months duration. This means that simulated changes in pasture biomass need to be evaluated using moving 'analysis windows' of say 15 to 48 months. In the more arid areas where climate variability is high and long dry periods are not uncommon, the period of below-average rainfall that constitutes an exceptional event may last several years.

5.3 Simulating Changes in Pasture Availability

As a demonstration, the DYNAMOF model of Bowman *et al.* [1993] was used to simulate weekly changes in soil moisture and pasture availability from 1 January 1901 to 31 December 1992 at Heathcote in northern Victoria. Daily rainfall for this period was input in to the model of a Merino ewe flock grazing an annual ryegrass and subterranean clover pasture. The pasture was stocked at six breeding ewes per hectare lambing in late autumn, which is a common practice in the region.

The aim of the study was to determine whether there was any significant advantage in having information on changes in available green pasture (GREEN, kg dry matter per hectare), over and above the rainfall data, in assessing the severity of drought in this environment.

Annual rainfall between 1901 and 1992 varied between 242 mm (1982) and 968 mm (1974), whilst the maximum amount of GREEN in any one year was estimated to vary between 970 kg/ha (1902) and 5739 kg/ha (1974). Moving averages of both rainfall (RAIN, mm) and GREEN for the previous 12 or 24 months, calculated at monthly intervals, were expressed as a fraction of the range to give a scale of 0 (minimum) to 1 (maximum) for each variable recorded over the period of the simulation. For ease of interpretation only values of less than 0.2 are presented in Figure 2, these representing the most rainfall-deficient periods.

The major droughts discussed by Gibbs and Maher [1967] are evident in Figure 2, though important differences in ranking can be seen according to the variable being used. Major droughts are evident in 1901-02 (actually 1895-1902), 1913-15, 1937-45 (broken by some useful rains in 1939 and 1941) and 1982-83, with less severe droughts in this environment in 1911-12, 1922-23, 1967-68 and 1976-78. Of course, the impact of an 18-month drought will not be fully apparent using a 12-month moving window, and can be obscured by intense post-drought rains using a 24-month moving window.

For example, the 1937-39 drought appears more severe using a 24 month moving average whereas the 1982-83 drought appears more severe using a 12 month moving average (RAIN 12 v RAIN 24, and GREEN 12 v GREEN 24). GREEN 12 is more significant than RAIN 12 in 1976-78, whereas GREEN 24 is much more significant than RAIN 24 in 1982-83. Work is continuing using intermediate analysis windows (15, 18, 21 months) and industry data to assess the relative severities of these droughts and further validate the process.

The significance of the timing and intensity of the rains, low temperatures and solar radiation during winter, and the phenology and senescence of the annual pasture plants that make them unresponsive to summer rains is evident in the weekly and seasonal changes in simulated pasture growth. These show that rainfall is a reasonable but by no means a perfect proxy for agricultural drought. In some years the effects of minor rainfall deficits are amplified, whereas in other years the effects of below-average rainfall are less than might at first be expected in that the rain that did fall was particularly effective in promoting plant growth.

6. CONCLUSIONS AND RECOMMENDATIONS

Water balance, pasture-livestock and crop models, complemented by climate, farm and remotely sensed data, will inevitably become more and more important in the objective definition of effective rainfall seasons and when exceptional drought circumstances occur. The model-based analyses presented here are an important initial step in this direction. However, much has yet to be done in developing fair and equitable systems for evaluating droughts, and assisting farmers when a sequence of adverse seasons exposes them to physical, biological and financial circumstances that are beyond those that could be expected to be factored into normal risk management practices. The relative importance of the different criteria and components of the assessment process will vary between environments and farming systems.

7. ACKNOWLEDGMENTS

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