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A Prototype National Drought Alert Strategic Information System for Australia

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Introduction

Defining and categorizing drought in a quantitative and scientific manner are important national issues for Australian state and Commonwealth governments, landholders, and agribusiness. The challenge for modelers of Australia's grasslands is to integrate biological models, geographic information systems (GIS), satellite imagery, economics, climatology, and visual high-performance computing into an Internet-deliverable application that can provide easily understood monitoring and prediction advice in near real-time—a national drought alert strategic information system.

Although NOAA satellite-derived imagery has been somewhat useful in the broad-scale spatial assessment of green cover, especially the spatial response of vegetation to rainfall events (Smith, 1994; Dudgeon et al., 1990; Filet et al., 1990), it has inherent limitations in providing a total solution for drought and rangeland monitoring; biomass relationships are not good, tree cover confounds the signal, and a future projection of the current situation is not inherent. Also, the interpretation of the imagery does not usually consider the effects of soil type, vegetation structure, or rangeland "condition." Similarly, rainfall analyses alone do not necessarily reflect the quantity and quality of pasture available on the ground. In the recent 1991–95 record-breaking drought in Queensland, rainfall analyses did not map the drought-declared southwestern areas of the state as droughted, and, conversely, coastal areas of the state were classed as droughted by rainfall analyses, when there was no community push for their declaration. Measures of **rainfall effectiveness** expressed as measures of plant biomass are required for drought definition. Improved assessments of the quantity and quality of biomass are needed, as well as consideration of herbivore densities and future climatic scenarios.

Land Condition Alerts

The Queensland Department of Natural Resources (QDNR) systems approach to the management of native grasslands recognizes that rainfall drought occurs at a regional scale, and that impacts on livestock and natural resources can be forecast using simple models of soil water, plant growth, and animal performance. Our vision for a comprehensive national drought alert strategic information system is a system that consists of the best combination of rainfall analyses, seasonal climate forecasts, satellite and terrestrial monitoring, and simulation models of meaningful biological processes. The information would be available on an Internet web server run as a joint facility by the various state departments.

The QDNR drought research program aims to predict the occurrence of land condition alerts on a quarter to half local-government area (shire) basis. This will provide a rational basis for large-scale management decisions by graziers, extension workers, and politicians. Land condition alerts are likely to be issued when approaching an El Niño summer with low pasture cover, high stocking rates, fragile soils, and a high probability of a change in the species composition of the pasture. Land condition alerts currently comprise maps of ground cover and pasture utilization that are output layers from the spatial simulation.

Given the varying perceptions of actual drought compared to long-term probabilities, the model also needs to be run over the historical weather record to determine real-time risk as determined by the current plant biomass and stock numbers.

The GRASP Simulation Model

The core simulation model used by the project is the GRASP (GRASs Production) pasture simulation (McKeon and Littleboy, 1996). This model has been developed as a result of a number of Queensland Department of Primary Industries (QDPI) and Rural Industries Research and Development Corporation (RIRDC) research projects. GRASP combines two successful approaches in modeling plant growth—those of Fitzpatrick and Nix (1970) and McCown et al. (1974). The soil water budget is simulated using four layers (0-10 cm, 10-50 cm, 50-100 cm, and a deeper tree layer), and the processes of runoff, drainage, soil evaporation, and transpiration are separately calculated on each day from inputs of rainfall and pan evaporation (Rickert and McKeon, 1982). The soil variables required include available soil-water range for each layer, maximum rate of bare soil evaporation, and infiltration parameters. A daily plant-growth index is calculated from a soil water index, plant growth response to average air temperature, vapor pressure deficit, solar radiation, and nitrogen availability. Plant growth is calculated as a function of growth index, plant density, and potential regrowth. As green cover increases, plant growth is calculated from a combination of temperature response, transpiration, radiation, temperature, and nitrogen uptake. Tree density, expressed as trunk basal area, is used to adjust the soil water balance and pasture production of the model. A number of nitrogen submodels are being evaluated to improve estimates of pasture quality, plant growth rates, and liveweight gain. On a daily basis, animals remove green and dry biomass, and animal liveweight gain is calculated from empirical relationships derived from grazing trials.

The main plant parameters are derived from calibrating the model against field data. In the Queensland Grass Under Nutritional Stability, Yield Nitrogen and phenological Development (GUNSYNpD) program (McKeon et al., 1990), a group of pasture ecologists is collaborating in calibrating the GRASP model from more than 75 site and treatment combinations. Some calibrations have now been achieved using site data from other states. Validation has also been conducted from use of other pasture production measurements and historical grazing trial data.

The model produces estimates of pasture growth, biomass in green and dead pools, green cover, soil moisture, runoff, animal liveweight gain and pasture utilization on a daily basis, and can be run forward up to 180 days into the future (although typically only 90 days). When pasture production is combined with stock estimates, calculations of the degree of pasture utilization can be made and displayed as maps of feed availability and land condition, with a resolution of a quarter to half a shire. These maps form a core product of the strategic information system.

The National Spatial Model

A national spatial modeling framework has been developed that allows agricultural simulation models to be run at a continental scale on a 5 km grid. The model structure takes advantage of the high performance vector architecture of Cray supercomputers, which allow simultaneous transformations of state vectors. To attain maximum speed-up, at every model iteration (a daily time-step), the spatial model simultaneously evaluates all simulation state-variables across the entire 250,000 land pixels. The model is capable of efficiently running any daily time-step biological simulation model, provided the model is re-coded to run for all pixels a day at a time.

The spatial framework comprises some 3,400 lines of FORTRAN 90, while GRASP has another 2,000 lines of FORTRAN 90. The Agricultural Production Systems Simulator (APSIM) model was also included in the spatial framework for modeling wheat crops, but program execution was quite slow because APSIM has not been re-coded for optimum use of the Cray's architecture.

Seasonal Climate Scenarios

The spatial model uses interpolated historical and near real-time meteorological data to run the model up to a known point in the past or the current day. At the present stage of system development, the spatial model simulates

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pasture yields into the future an ensemble (5-10) of analogue years derived from an analysis of the current Southern Oscillation Index phase (Stone, 1992). The mean and coefficient of variation of all relevant system-state and accumulated variables from the ensemble runs are displayed as the final output scenario. This system is also used to hindcast past scenarios to test the accuracy of the system.

A limited evaluation of the system ran predictions ahead from October to December (~90 days), and from October to the following March (~180 days). Spatial correlations for a 90-day forecast of total standing dry matter varied from 0.41 in the exceptional El Niño year of 1982 to 0.75 in 1994. The 180-day predictions were worse, ranging from 0.18 in 1982 to 0.42 in 1994. In general, only the 90-day prediction would be used.

Resources and time have not yet permitted an exhaustive test of the predictability of all the model outputs, analysis of the spatial variance of the simulation predictions (from coefficient of variation maps), a complete testing of all years, or a comparison of different sources of predicted meteorological information such as the Australian Bureau of Meteorology's own analogue system or General Circulation Models.

Percentile Outputs

The central aspect of the Australian government's Exceptional Circumstances criteria for rural assistance during drought is that these criteria would only be met a few times each century—that is, conditions are in the percentile 5-10 class or lower. This project aims to produce percentile views of meaningful biological and agricultural variables. So it is possible to construct a percentile view of grassland production and condition that is more aligned with actual droughtedness than are rainfall percentile maps. This month's or season's grass biomass can be compared with the last 30 or 100 years of biomass that would have existed at that location. **Preliminary analysis suggests that the year ranking according to rainfall may be quite different from the year ranking from simulated percentile pasture growth.**

The current system can generate probability distributions of selected variables (such as total standing dry matter) from 1957 on, but interpolated daily rainfall data exist that would potentially enable the model to run from the 1890s if raster surfaces of the other meteorological variables such as temperature, humidity, and radiation could be derived.

The Current State of Operation

A prototype of a national spatial-modeling framework has been developed and demonstrated. This substantial technological achievement was possible only through the excellent collaboration of a large number of QDNR and interstate scientists across a number of disciplines. The system now produces pasture biomass, percentile pasture biomass, ground cover, and utilization maps for inclusion in Queensland's applications for Rural Adjustment Scheme Exceptional Circumstances assistance from the Australian Commonwealth Government. Further refinement of the system in other Australian states is required, and a second phase of technological development and refinement of the system is expected to commence in 1997.

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