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A decision support system for predicting seasonal rainfall variations in sub-humid and semi-arid high country areas

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Abstract

The variable seasonal pattern of pasture production is dominantly influenced by rainfall in the semi-arid and sub-humid high country regions. A decision support system for predicting seasonal rainfall has been developed and tested using the rainfall data from 14 sites in the semi-arid, sub-humid and humid high country zones. The prediction system improves the chances of making a correct or incorrect but conservative risk management decision from 50:50 to as much as 92:8 dependent on the site's weather characteristics and the length of rainfall records available. The system provides support for risk management decisions such as whether to employ the buffers of stocking rate adjustments and feed conservation measures usually present in most high country farming systems to cope with the variability in seasonal pasture growth. The method has particular applicability in the semi-arid and sub-humid areas of the inland basins and foothills and the mid Waitaki area.

Keywords: decision support, high country, rainfall, risk management, semi-arid, sub-humid

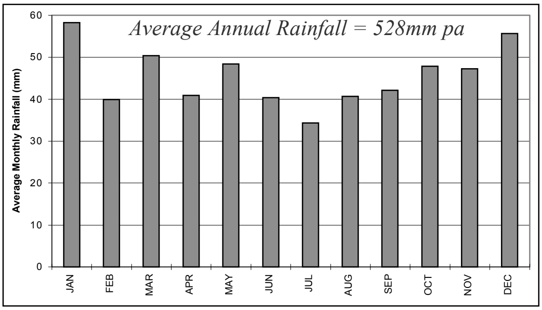
Introduction

To be useful, "weather information" should help in making decisions. These decisions may be based directly on the information content of data or indirectly through the way in which the information affects a decision variable, such as an environmental production function (Revfeim & Hurnard 1980). In the harsh high country environment, seasonal pasture growth is highly variable from year to year. The seasonal pattern of pasture production depends on a number of factors but is dominantly influenced by rainfall in the sub-humid region of the high country including the intermontane basins and the mid Waitaki (O'Connor 1968). Farmers in this environment have historically had no management tools that can effectively assist them in predicting a season's likely pasture growth pattern. Even faithfully recorded monthly or daily rainfall data have not been very useful in improving predictability of the nature of the upcoming growth season in comparison with making a random choice at the decision time based on instinct, experience and the chance probability (similar to tossing a coin) of getting it right on average at least 50% of the time. The challenge to science is to see whether a model incorporating objective rainfall data can provide a reasonably simple but better method for farmers to improve the odds in their favour of making a correct decision (or at least a conservative decision if wrong) on rainfall expectations for the next six months.

Background

The concept of a predictive model has been developed and initially tested using 45 years of rainfall records at AgResearch Tara Hills High Country Research Station at Omarama in an attempt to address this challenge.

Figure 1 Annual average rainfall at Tara Hills High Country Research Station, Omarama.



The average monthly rainfall data for Tara Hills High Country Research Station from 1950 to 1995 (Figure 1) creates the impression that the monthly rainfall pattern is remarkably consistent at 34–58 mm. This averaged monthly rainfall data in fact mask a wide range of extremes in which any month can receive a rainfall varying between 2 mm and 204 mm (Figure 2). Identifying some sort of pattern within this wide variability (CV%=70) is difficult but necessary if the aim is to improve the odds for good decision making. The combination of low rainfall, high altitude and inland location make Tara Hills an extreme farming environment. Monthly rainfall probabilities do not favour sustained pasture growth at any time of the year; although a positive soil water store coming out of winter means there is always some sort of plant growth in spring (Wardle *et al.* 1992). The average pattern of expected dry matter production for the research station (Figure 3) shows that most of the effective feed is produced in three spring months of the year (October–December), that an autumn flush of feed is not reliable and that there is a long winter period during which the property relies on various forms of conserved feed and controlled grazing. High wind run in conjunction with high temperatures, high sunshine hours and low humidity virtually nullify the effectiveness of summer rain, despite precipitation being evenly spread throughout the year.

Therefore, soil moisture over summer months is usually insufficient to support sustained pasture growth (Wardle *et al.* 1992). The need for conservative management with large buffers in the farming system and useful decision support tools becomes more apparent in this environment.

Method

A computer-based model, initially for predicting rainfall and likely growth season (November–April) rainfall in relation to previous rainfall, was developed and tested using the 45 years of rainfall records at Tara Hills High Country Research Station from 1950 to 1994.

The model was also tested using a range of cumulative rainfall periods (from 1 to 12 months) to ascertain which was the most appropriate to give the best chance of improving the odds of better rainfall prediction. A flexibility component was also built into the model on the assumption that if the resulting rain fell somewhere within a range of the prediction, it would still have given an acceptable rainfall prediction for use in management decisions. Differences greater than the flexibility component would give predictions that were either highly conservative (a much wetter year occurs than predicted) or wildly optimistic (a much drier year occurs than predicted).

The model was tested on a range of semi-arid, sub-humid and humid rainfall sites in the high country area

Figure 2 Variability in Monthly Rainfall at Tara Hills Research Station.

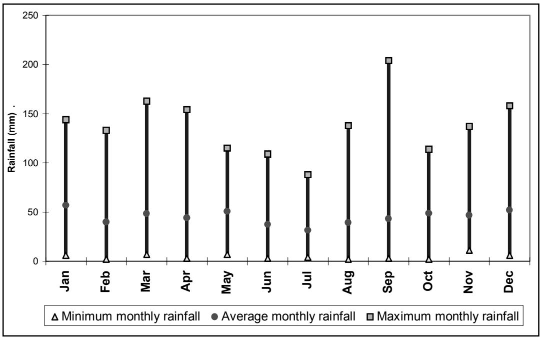


Figure 3 Average total dry matter production at Tara Hills Research Station.

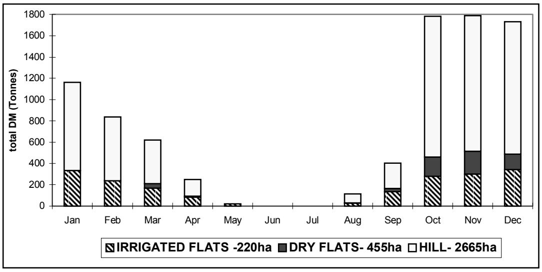


Table 1 How well did the model predict the next six months rainfall from 1 August for the period 1970–1980 at Tara Hills Research Station?

Year	Annual rainfall (mm) (Feb–Jan)	Model Prediction for next 6 months from 1 Aug–31 Jan	Outcome for 6-month period from 1 Aug	Actual rainfall (mm) for 6 months from 1 Aug	Outcome vs model prediction
1970	613	significantly less than average	significantly more than average	434	0
1971	486	significantly less than average	about average	298	0
1972	538	about average	about average	317	+
1973	418	significantly less than average	significantly less than average	250	+
1974	519	significantly more than average	significantly less than average	193	-
1975	565	significantly more than average	significantly less than average	185	-
1976	431	significantly less than average	significantly less than average	255	+
1977	336	significantly less than average	significantly less than average	143	+
1978	511	about average	about average	268	+
1979	732	significantly more than average	significantly more than average	396	+
1980	580	about average	about average	308	+

Average annual rainfall = 544 mm (Feb–Jan)

+ = correct prediction
0 = wrong but conservative prediction
- = wrong & over-optimistic prediction

to see whether the results were repeatable at other places with reasonable length of rainfall records. The model was then adjusted to test the quality of seasonal (6-month) rainfall prediction results at various decision points throughout the year at the same range of rainfall stations.

Results

The model was tested using lesser and greater lengths of historical records to identify its predictability over a range of periods but the best results were obtained in predicting what the next 6 months of rainfall were likely to be. The use of 6 months as the prediction period also has some practical rationale in that this would be likely to be the maximum period of consequential benefit of a significant rainfall event within a farming system in the sub-humid zone before that water is effectively lost to the pasture system through evaporation or groundwater flow. The 6-month prediction period also has some correlation with the reported cycle length of the El Nino/La Nina weather systems which markedly influence New Zealand weather. This was also recognised as the likely seasonal period for which predictability advice would be of most benefit in management decisions.

The model indicates that in the case of Tara Hills, either a correct prediction or a poor but conservative prediction would have been made in 76% of the years and in only 24% of years would a decision based on the prediction have been a bad or over-optimistic one (Table 2).

This is a distinct improvement on the 50:50 odds of any decision based purely on instinct. An example of the model's prediction and actual outcome for the 6-month rainfall period from 1 August in 1970 until 1980 at Tara Hills. Similar or better results were obtained for the seven other sites in the sub-humid zone that were tested except for Tekapo (74%) and Omahau (72%) where the model gave worse results but still enabled decisions to be correct or poor but conservative for significantly more than 50% of the time. The model gave a high level of predictability at the two semi-arid zone sites, with correct or poor but conservative decisions being made in 92% of years at Ranfurly and 86% of years at Otematata.

The accuracy of decisions in the humid zone above 650 mm drops significantly back to almost the random choice odds of 50:50 but as the annual pasture yield in this zone is little influenced by year-to-year variations in rainfall (O'Connor *et al.* 1968), there is less likelihood of rainfall being as important in the decision process.

The model was then tested at the range of sites for its variability when different decision points are chosen. A number of other prediction points were tested and

Table 2 Testing the model at various rainfall stations: how accurately did it predict the growth season's rainfall at a November decision point?

						Predictability model outcomes		
Rainfall Station	No. of records	Average annual rainfall (mm)	Max. annual rainfall (mm)	Min. annual rainfall (mm)	SD	Correct decisions	Wrong but conservative decisions	Wrong and over-optimistic decisions
Semi-arid rainfall zone (300–450 mm pa)								
Ranfurly	48	424	607	269	73	79%	13%	8%
Otematata	36	435	604	267	87	72%	14%	14%
Sub-humid rainfall zone (450–650 mm pa)								
Grays Hills	46	457	627	334	76	67%	13%	20%
Cliffside	42	504	679	270	88	62%	19%	19%
Tara Hills	45	528	772	344	105	60%	16%	24%
Waipiata	53	550	752	244	87	78%	13%	9%
Omahau	25	566	821	377	115	44%	28%	28%
Tekapo	69	601	881	324	126	54%	20%	26%
Naseby Forest	72	607	879	419	89	67%	15%	18%
Glenbrook	19	607	794	425	112	68%	16%	16%
Humid rainfall zone (650–1500 mm pa)								
Wanaka	64	678	952	418	138	44%	27%	30%
Fairlie	53	728	1061	467	136	44%	26%	30%
Ben Ohau	29	742	1079	504	136	48%	24%	28%
Lake Coleridge	46	851	1161	557	142	59%	20%	22%

NB
"Wrong but conservative decisions" are those where the prediction is wrong but the consequences for management are minimal.
"Wrong and over-optimistic decisions" are those wrong predictions with major consequence for the management process.

while the percentage of predictability varied between prediction dates, the model continued to give results that were much better than the 50:50 odds of an instinctive decision (Table 3).

Table 3 Testing the model at various rainfall stations: how accurately did it predict the next six month's rainfall for a different decision point (April)?

Rainfall station	No. of records	Average annual rainfall (mm)	Correct or wrong but conservative decisions	Wrong & over-optimistic decisions
April Decision Point				
Semi-Arid Rainfall Zone (300–450 mm pa)				
Ranfurly	48	424	96%	4%
Otematata	36	435	92%	8%
Sub-Humid Rainfall Zone (450–650 mm pa)				
Grays Hills	46	457	80%	20%
Cliffside	42	504	86%	14%
Tara Hills	45	528	95%	5%
Waipiata	53	550	94%	6%
Omahau	25	566	80%	20%
Tekapo	69	601	81%	19%
Naseby Forest	72	607	89%	11%
Glenbrook	19	607	85%	16%
Humid Rainfall Zone (650–1500 mm pa)				
Wanaka	64	678	82%	18%
Fairlie	53	728	80%	20%
Ben Ohau	29	742	72%	28%
Lake Coleridge	46	851	72%	28%

Discussion

With the use of rainfall data and a relatively simple model, a reasonable level of confidence can be achieved in predicting the nature of the likely growing season by the usual critical decision time in early November. The model also gives a reasonable level of confidence to 6-month rainfall predictions for decision making at other times of the year.

It should be emphasised that this is not a perfect model; it cannot accurately predict likely rainfall on a daily or monthly basis, particularly in the highly variable sites in the sub-humid and semi-arid zones of New Zealand, but it can definitely improve the odds for rainfall prediction for better decision making on a seasonal basis.

The decision support system can be used by most farmers who either operate a rain gauge on their property or have an official meteorological station in their vicinity and are aware of the variations in rainfall patterns between the station and their own property.

Obviously, length of records will have a major impact on the quality of the prediction; Stations tested to date have had at least 19 years of rainfall records and it is suggested that at least 15 years of records are required before any patterns of predictability begin to emerge.

The method has the potential to incorporate objective predictive measurements to give more confidence to the risk management decisions on whether to employ the buffers usually present in most high country farming systems to cope with the variability in seasonal pasture growth. Most buffers involve seasonal decision-making responses rather than daily, weekly or monthly responses. These buffers usually involve the manipulation of stocking numbers, or other risk management decisions such as the level of feed conservation to employ (hay, silage, crops or saved pasture). The model has potential to improve the quality of decision making on a seasonal basis.

The method has applicability in the semi-arid and sub-humid area of the inland basins and foothills and the mid-Waitaki area where seasonal fluctuations in pasture growth are often observed and rainfall is the main limiting factor to pasture growth, but will not be as effective in the humid areas of the upper montane zone where year-to-year variations in rainfall have little effect on annual yield. The model has wider applicability than just the farming community; other seasonal weather-dependent decision makers such as power generation authorities and tourist operators may also gain benefits from better seasonal prediction methods.

The model would still benefit from more extensive testing over a wider range of climatic zones but has the potential to become the basis of a useful decision support tool especially for farmers for use in farm management decision processes. The model is currently being developed into a commercial decision support tool (called HUSERAP) by AgResearch. Details of the methodology are therefore limited by the need to protect the intellectual property involved.

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