ASSESSMENT OF RELIABILITY OF QUICK TO MEDIUM MATURE MAIZE PRODUCTION IN AREAS OF VARIABLE RAINFALL IN QUEENSLAND AND NORTHERN NSW

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Abstract
Simulation studies of early to mid season dryland maize production in areas of highly variable rainfall in Queensland and northern NSW were undertaken using APSIM configured for maize using long term weather data and a range of genotypes. The studies focussed on planting time options, population density, varieties and water availability at planting and through crop life. Outputs of the studies included predicted mean and median yield, assessment of variability of yield using standard statistical techniques, riskiness of production and cumulative distribution functions. The study showed that optimum planting date varied with location, and that low populations were more reliable, despite some potential yield losses in favourable years. The results of the simulation study provide estimates of yield and thus economic viability of maize production that are interpreted in terms of seasonal variability. They indicate that maize is a viable dryland cropping option provided cultivar, planting time and starting water conditions are optimised. Non-optimal conditions of water supply at planting should be avoided, as greater variability in yield and thus viability are predicted.

Introduction
Maize production in areas of marginal rainfall (<600 mm annual rainfall) is considered less reliable than grain sorghum (Routley and Robertson 2003) and has been subject to several studies using both field experimentation and modelling approaches (Robertson et al. 2003, Routley and Robertson 2003, Madhiyazhagan 2005). It is considered by many farmers to be one of the riskiest crops to grow (Robertson et al. 2003). In Australia there is an increasing need for feed grains and silage, and maize is recognised as a premium quality source of both: this paper concentrates on maize for grain. The future reliability of supply of feed grains in the northern region of Australia was examined by Hammer et al. (2003) using a modelling approach. They found the proportion of years in which grain supply deficit occurred was sensitive to seasonal conditions, being most likely in El Nino years. The modelling also indicated that increased planting area would be required to meet future demand. Opportunities for expansion are mostly in areas of high intra-seasonal variation in timing and amount received and large variations in annual rainfall, meaning that water stress is a major production limitation. There are, though, some higher rainfall locations where expansion could occur, provided maize was economically competitive. In many areas of northern Australia where additional maize production could occur soils have moderate to high water holding capacity, meaning water can be accumulated in soil for later use by plants. Also, for an extended period in each year, temperatures are above minima necessary for maize production, meaning planting could occur over a long period. However, high temperatures may adversely affect maize leading to reduced grain set (Madhiyazhagan 2005) and ultimately reduced yield. Taken together, these factors impose a level of risk on maize production, that is related to variability of water supply and the thermal environment.

‘Risk’ in agricultural decision-making is predominantly considered to be exposure to the chance of making a loss. The types of risk that must be considered depend in part on the outcome of interest and have been considered in detail in Boehlje and Eidman (1984). Knight (1921) defined the risk situation as one in which the decision maker knows the alternative outcomes and the probability associated with each outcome. However, uncertainty exists when less information about the alternative outcomes and their probability is available, either because the probability of an outcome is unknown, or not all the possible outcomes are known (Knight 1921).
More recent discussions on agricultural decision-making do not distinguish between the terms ‘risk’ and ‘uncertainty’ both terms indicating that the action a decision-maker selects has alternative outcomes (Boehlje and Eidman 1984).

Climate variability and associated risks and uncertainty influence decision-making in agriculture, affecting best management practices of farmers, agribusiness managers, governments (taxation and drought policies), and by numerous others (Hammer and Nicholls 1996). Climate variability generates risks because outcomes of decisions cannot be predicted with any surety (Hammer and Nicholls, 1996). The extent of climate variability in Australia means the range of possible outcomes associated with some key decisions is immense, creating risks of adverse outcomes and opportunities to make financial or environmental gains (Hammer and Nicholls 1996). Climatic risk is particularly relevant to dryland cropping areas of northern Australia, with weather and climate being the biggest single management consideration in primary production (Plant 2000). Attitude to risk can affect a farmer’s decision making processes and vary depending on the individual’s objectives and financial resources. Farmers tend to be risk averse, and that maize has not found widespread acceptance in marginal rainfall as it is considered a ‘riskier’ crop than grain sorghum (Routley and Robinson 2003) is consistent with this attitude. Widely accepted strategies among dryland farmers to manage risk include fallowing, selection of cultivar, plant population density and planting date. These strategies are concerned with managing water supply to and demand by the crop. Another strategy - limiting inputs - can be seen as managing the loss that may occur should the crop fail.

This paper seeks to extend concepts explored in Robertson et al. (2003), Routley and Robinson (2003) and Madhiyazhagan (2005). A modelling approach was used to explore a wide range of options for maturity type, planting time, water supply at planting and locations with varying climatic characteristics from northern Queensland to central New South Wales to better quantify the probability of achieving certain yields based on long term historical weather data.

Material and methods

The APSIM model (Keating et al. 2003) was configured for maize and run for the following sites and conditions combinations using long term weather records:

(a) Sites: Atherton, Lakeland, Mareeba, Clermont, Emerald, Springsure, Rolleston, Duaringa, Biloela, Monto, Theodore, Wandoan, Roma, Chinchilla, Dalby, Kingaroy, Murgon, Warwick, Goondiwindi, St George, Moree, Narrabri, Gunnedah, Tamworth;

(b) Soils: selected from the APSIM soils data base, representing dominant soils of sites in (a)

(c) Cultivars: very quick (CRM around 90 – 95 days), quick (CRM around 100 - 110 days), medium (CRM around 110-125 days) and slow (CRM above 125 days) maturity;

(d) Planting dates: 15th of August, September, October, November, December, January and February;

(e) Starting soil water contents: 100, 67 and 50% of maximum plant available soil water, using calibrations in the APSIM soils data base;

(f) Plant populations: 2, 4, 6 and 8 plants m\(^{-2}\).

This analysis produced a large number of predictions, a selection of which is presented. Predictions are presented as box and whisker plots with reference to cumulative distribution functions for selected locations and conditions. Box and whisker plots show extremes (vertical bars), 70 and 30 percentiles (top and bottom of box) predicted mean (PMean) and median (PMY) yields (broken and solid horizontal lines) for each site.

Results

Box and whisker plots of predictions for quick and medium maturity cultivars planted on 15th November at populations of 2 and 4 plants per m\(^{-2}\) with planting soil water conditions at 100 and 67% of plant available water holding capacity (PAWC) to 1 m are presented for a selection of sites listed above, supported by comments on other options.
Also, plots of PMean (t ha\(^{-1}\)), as an indicator of profitability against risk of not producing 2 t ha\(^{-1}\), an approximate break-even yield and thus an indicator of making a loss were prepared for Dalby, Kingaroy and Quirindi for 15th November planting and Emerald for 15th February planting. Dalby and Emerald were chosen as areas of potential industry expansion, with Kingaroy and Quirindi included as examples of established production areas.

**Geographic range**

From North to South PMY in excess of 5t ha\(^{-1}\) are possible at Lakeland, Atherton, Kingaroy, Warwick, Pittsworth, Gunnedah and Quirindi when planted on 15th November at 2 or 4 plants m\(^{-2}\) (and 6 plants m\(^{-2}\) at Atherton) on a full profile of plant available water (Figure 1, Tables 1, 2). PMY between 3 and 5 t ha\(^{-1}\) were shown for a range of other sites, but were much lower for sites such as Goondiwindi, St George, Chinchilla, Roma and Moree, especially when the medium maturity cultivar and/or higher plant population was used (Tables 1, 2). When planting on 67% of PAWC, PMY were lower for all sites except Lakeland and Atherton. From East to West (Tables 1, 2) Pittsworth and Warwick have the highest PMY followed by Dalby for both PAWC levels at planting. Kingaroy had a high potential yield, but is less reliable. Sites further West (Chinchilla, Wandoan, Goondiwindi, St George and Roma) have lower potential yield, lower PMY and higher probability of crop failure.

The box and whisker plots showed wide variability in predicted yield at almost all sites. The least reliable sites with significant probability of complete crop failure at the higher plant population in the cumulative distribution function included Goondiwindi and Moree. Figure 1 includes examples of crop failure or achieving a very low yield, and though quite high yields are possible at some sites, the range from the 30 to 70 percentile and overall range is quite wide in most sites. The pattern is generally consistent across the region studied, exceptions being Lakeland Downs and Atherton. The predictions show that the most appropriate combination of cultivar type, planting time, planting rate and PAWC at planting varies widely across the region.

**Relationship between predicted mean yield and probability of exceeding a nominated yield**

The relationship between PMean and the risk of not producing 2 t ha\(^{-1}\) is presented for selected plant populations and maturity types for planting on 15th November (Dalby, Kingaroy, Quirindi) and 15th February (Emerald) (Figure 2) in a manner similar to Lyon et al. (2003). In these plots, points in the:

- (a) top left indicate moderate to high PMean, low risk of yield less than 2 tha\(^{-1}\);
- (b) lower left indicate low to moderate PMean, low risk of yield less than 2 tha\(^{-1}\);
- (c) lower right indicate low PMean and substantial risk of yield less than 2 tha\(^{-1}\).

These show that planting on less than a full profile of water (ie. 100% PAWC at planting) carries a substantial risk of reduced yield and of not exceeding 2 t ha\(^{-1}\). They also show that populations of 4 and 6 plants m\(^{-2}\) in the locations illustrated can lead to substantial reduction in PMean (Dalby, Emerald) or at least very little benefit from the higher populations (Kingaroy, Quirindi), especially when planted with 67% PAWC.

**Plant population**

Plant population had very substantial effects on both PMY and range in predicted yields, especially in more western locations and Central Queensland (Figures 1, 2, Table 1). Using plant population of 2 plants m\(^{-2}\) improved PMY and reliability at locations such as Kingaroy, Emerald, Roma, Wandoan, Chinchilla, St George, Goondiwindi and Moree, though some yield penalty compared to 4 plants m\(^{-2}\) was incurred at more favoured sites such as Warwick, Pittsworth, Gunnedah and Quirindi (Figure 1, 2). At Atherton, 2 plants m\(^{-2}\) suffered substantial yield penalty, while even at this favoured site 6 plants m\(^{-2}\) added little to PMY for 4 plants m\(^{-2}\). The high population was unsuited to most environments, regardless of maturity type grown (Figure 2).
Planting date and maturity type

While many other options exist, a very early, mid season and late planting were chosen for presentation in Tables 1 and 2, because of the range of environments being sampled. Results for

Figure 1. Box and whisker plots of predicted yield of quick and medium maturity maize grown at 2 and 4 plants m\(^{-2}\) planted on 15\(^{th}\) November in a North South transect from Lakeland to Quirindi with 100% and 67% of plant available water (PAWC) to 1 m at planting.

(a) Quick maturity, 2 plants m\(^{-2}\), PAWC = 100% (left), PAWC = 67% (right)

(b) Quick maturity, 4 plants m\(^{-2}\), PAWC = 100% (left), PAWC = 67% (right)

(c) Medium maturity, 2 plants m\(^{-2}\), PAWC = 100% (left), PAWC = 67% (right)

(d) Medium maturity, 4 plants m\(^{-2}\), PAWC = 100% (left), PAWC = 67% (right)
Table 1. Summary of Predicted Median Yield (PMY, t ha\(^{-1}\)) for quick and medium maturity maize cultivars planted at 2 plants m\(^{-2}\) on three dates into soil with plant available water of 100 and 67% of capacity to 1 m (Italicised – PMY = 0).

<table>
<thead>
<tr>
<th>PMY range (tha(^{-1}))</th>
<th>Planting 15 August</th>
<th>Planting 15 November</th>
<th>Planting 15 February</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quick</td>
<td>Medium</td>
<td>Quick</td>
</tr>
<tr>
<td>&lt;2.0</td>
<td>Rma</td>
<td>Gwd</td>
<td>Gwd</td>
</tr>
<tr>
<td>2.0 – 3.0</td>
<td>Rma</td>
<td>Kry</td>
<td>Chn</td>
</tr>
<tr>
<td>3.0 - 4.0</td>
<td>Kry</td>
<td>Wdk</td>
<td>Gdh</td>
</tr>
<tr>
<td>4.0 – 5.0</td>
<td>Kry</td>
<td>Wdk</td>
<td>Gdh</td>
</tr>
<tr>
<td>5.0 – 7.0</td>
<td>Wdk</td>
<td>Gdh</td>
<td>Qnd</td>
</tr>
</tbody>
</table>

Key: Ath = Atherton, Bla = Biloela, Chn = Chinchilla, Dby = Dalby, Emd = Emerald, Gdh = Gunnedah, Gwd = Goondiwindi, Kry = Kingaroy, Lkl = Lakeland, Mre = Moree, Pwh = Pittsworth, Qnd = Quirindi, Rma = Roma, StG = StGeorge, Wwk = Warwick, Wdn = Wandoan

populations of 2 or 4 plants m\(^{-2}\) planted on 15\(^{th}\) August, November and February are summarised in Table 1 (quick maturity) and at 4 plants m\(^{-2}\) (4 or 6 plants m\(^{-2}\) for Atherton) for medium maturity (Table 2). These show that for most locations such as Kingaroy, Dalby, Pittsworth, Warwick, Gunnedah and Goondiwindi, November planting into soil holding 100% of PAWC to 1 m provides moderate to high PMY, with Atherton being highest. Other locations generally have lower PMY, and at 4 plants m\(^{-2}\), PMY can be very low in locations such as Goondiwindi, Roma, Moree and St George.

Very early planting can provide reasonable PMY, but has greater variability and hence risk, especially with the medium maturity cultivar type. Late planting is most beneficial in areas such as Roma, St George, Goondiwindi, Emerald and Biloela, with evidence that quick maturity types should be preferred. In cooler areas such as Quirindi, Pittsworth and Warwick late planting can lead to complete crop failure.
Table 2. Summary of Predicted Median Yield (PMY, t ha⁻¹) for a medium maturity maize cultivar planted at 4 plants m⁻² on three dates into soil with plant available water of 100 and 67% of capacity to 1 m (except Atherton, 4 and 6 plants m⁻²).

<table>
<thead>
<tr>
<th>PMY range (t ha⁻¹)</th>
<th>Planting 15 August</th>
<th>Planting 15 November</th>
<th>Planting 15 February</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100% 67%</td>
<td>100% 67%</td>
<td>100% 67%</td>
</tr>
<tr>
<td>&lt;2.0</td>
<td>Lakeland, Emerald, Goondiwindi, Moree, St George, Chinchilla, Roma, Atherton (6)</td>
<td>All except those listed below</td>
<td>All except those listed below</td>
</tr>
<tr>
<td>2.0 – 3.0</td>
<td>Biloela, Kingaroy, Wandoan</td>
<td>Warwick, Pittsworth</td>
<td>Chinchilla, Wandoan</td>
</tr>
<tr>
<td>3.0 – 4.0</td>
<td>Dalby, Gunnedah, Quirindi</td>
<td>Emerald, Biloela, Kingaroy, Gunnedah, Warwick, Pittsworth</td>
<td>Biloela</td>
</tr>
<tr>
<td>4.0 – 5.0</td>
<td>Warwick, Pittsworth, Atherton (4)</td>
<td>Dalby, Quirindi</td>
<td>Emerald, Lakeland, Lakeland</td>
</tr>
<tr>
<td>&gt;5.0 – 7.0</td>
<td>Gunnedah, Quirindi, Atherton (4)</td>
<td>Gunnedah, Quirindi, Warwick, Pittsworth</td>
<td></td>
</tr>
<tr>
<td>9.0 – 10.0</td>
<td>Atherton (4), Atherton (4), Atherton (4), Atherton (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;10.0</td>
<td>Atherton (6), Atherton (6), Atherton (6), Atherton (6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Soil water at planting

With the possible exception of Atherton and perhaps Lakeland, planting on less than a full profile of stored water carries a substantial penalty in PMY, especially in the more marginal areas such as Roma, Goondiwindi, St George, Emerald and Biloela (Figures 1, 2, Tables 1, 2).

Discussion

The approach here utilises the capacity of WhopperCropper (Cox et al. 2004) to access in a useable way the results of detailed analyses described here. It is clear that careful consideration must be given to plant population and soil water supply at planting if satisfactory maize yields are to be achieved under dryland conditions. This study indicates that mid season (November) planting provides acceptable MPY values in established maize production areas that generally have relatively favourable water and temperature regimes, but that either early or late planting is preferable in more marginal drier and higher temperature environments (Tables 1, 2). Though quick maturity types may not have the same potential yield in favourable years, this study indicates that improved reliability of production with much lower risks of failure should be major considerations in selecting cultivar type. The greater risks of producing low yields with the higher plant populations indicate that using low plant population is preferable, except in favoured areas such as Atherton and Quirindi (Table 1, Figure 2). Plant population needs to be constrained to around 2 plants m⁻² in most areas, and even then the ability to manage risks associated with less than 100% PAWC at planting by choice of plant population may be limited (Robertson et al. 2003). Only in the favoured areas does significant yield benefit accrue when higher populations are used, but in most cases, the risk of producing a low yield also increases. Also, predictions that late planting e.g. February are likely to produce higher yields with greater reliability in areas such as Moree, St George, Goondiwindi, Roma, Biloela and Emerald can be explained by the crop being grown under more moderate weather conditions than earlier planting times, which are likely to encounter high temperatures and high evaporation rates.
Figure 2. Predicted mean yield (t ha\(^{-1}\)) and probability of not exceeding 2 t ha\(^{-1}\) for 15\(^{th}\) November planting at Dalby, Kingaroy, and Qirindi and 15\(^{th}\) February at Emerald for quick (%) and medium (%) cultivars planted at 2, 4 and 6 plants m\(^{-2}\) with 100 and 67% of plant available water in soil. Labels on symbols represent plant population followed by plant available water at planting. (Note the differing x axis scale for Emerald).

Nevertheless, the importance of 100\%PAWC at planting and low populations remain paramount. Clearly, though, decisions will ultimately be a trade-off between seeking high yield (profitability) and minimising the risk of failure – the analyses reported here, while providing general guidance rarely indicate that particular options should not be considered – exceptions being planting on less than 100\%PAWC at Emerald and Kingaroy (Figure 2).

These findings are similar to those of Robertson et al. (2003) for Dalby, and confirm that down-side risks for using high plant population are likely to outweigh any yield benefit in occasional very favourable seasons. In fact, the simulations showed a fairly flat response to plant population at most sites, and therefore use of high populations would not be justifiable. The greatest difficulty is choosing an appropriate plant population and cultivar when planting opportunities arise, though starting water supply may be highly variable. The choices made are likely to depend on the farmers attitude to risk, including level of confidence in seasonal outlook forecasts. Seasonal outlook forecasts may provide an opportunity to alter crop management by changing plant population and other inputs either at planting or later to optimise choices made at planting in relation to seasonal expectations (Nelson et al. 2002).

Conclusion

This paper has quantified risks associated with plant population, planting time and PAWC at planting, and while only a limited number of the assessments have been presented in full, it provides a framework for consideration of risks associated with maize production and the trade-offs that are necessary between maximising profitability and minimising risk in producing the crop. The principal findings are that low plant populations of quick maturity cultivar type are likely to be the ‘best bet’ in many environments, and that early or late planting can be superior to mid season planting, especially in areas of marginal water supply and/or constraints due to high temperature.
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References


