A simple spreadsheet model of the area of irrigated cotton to plant

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Selection of the area of irrigated cotton to plant is a perennial problem. Research by the Centre for Water Policy Research (1989) has shown that growers solve this on the basis of their total water allocation and expectations about the price of cotton. Hearn (1988) has shown how the yield of cotton changes in different years with different field allocations of irrigation water, using a cotton water balance model. However, this analysis is in tabular form and difficult to customise to suit individual situations with different land area, water supply, irrigation efficiency, soil water deficit for irrigation, maximum yield, cotton price and variable costs. In this paper, we show how a lookup table of the kind provided by Hearn can be re-formulated as a spreadsheet template in order to simplify the analysis of the underlying lookup table and provide a tool for decision support.

Hearn's original lookup table is reproduced here as Table 1. The yield data refer to each of 27 years of Myall Vale weather with different assumptions about the availability of water (from 1 to 9ML for each hectare). In the spreadsheet template, the water allocation per hectare is represented as numbers of irrigations rather than megalitres, Table 2. If, for this example, we assume that the soil water deficit which triggers an irrigation is 75mm, and the water use efficiency (*i.e.* water used by the crop/water pumped) is 75%, then the table can be interpreted directly in terms of number of irrigations. This makes the sums easy but is at the low end of the range for the soil water deficit at irrigation. It would be necessary to re-calibrate the model to fit individual conditions that differ from this example. Appropriate lookup tables could be provided for users.

In order to generalise the spreadsheet model for differences in potential yield among sites and management practices, the yields shown in Table 1 were divided by the maximum yield obtained (1769kg/ha). The relative yield coefficients which result need to be multiplied by the maximum yield which is expected for a particular site and level of management in order to estimate the yield with different supplies of water.

Table 1 Estimated cotton yields (kg lint/ha) at Myall Vale over 27 years with a range of water allocations (ML/ha)

Probability	9Ml	8ML	7ML	6ML	5ML	4ML	3ML	2ML	1ML
	1528	1528	1528	1356	811	536	269	269	301
	1604	1604	1558	1388	1051	604	323	408	304
90%	**1627**	**1627**	**1579**	**1431**	**1156**	**831**	**457**	**421**	**372**
	1634	1634	1604	1462	1264	1051	505	543	421
	1636	1636	1626	1473	1297	1085	536	546	424
	1654	1654	1627	1528	1350	1156	623	577	633
75%	**1655**	**1655**	**1634**	**1559**	**1388**	**1226**	**662**	**623**	**643**
	1659	1659	1636	1569	1422	1242	680	709	653
	1660	1660	1654	1579	1466	1245	709	710	669
	1662	1662	1655	1580	1528	1264	780	748	675
	1664	1664	1659	1594	1559	1297	958	768	711
	1668	1668	1660	1634	1561	1347	1242	780	722
	1674	1674	1662	1654	1575	1410	1294	806	804
50%	**1679**	**1679**	**1664**	**1655**	**1634**	**1466**	**1317**	**1003**	**816**
	1679	1679	1668	1659	1652	1523	1362	1051	822
	1680	1680	1674	1660	1654	1528	1426	1201	870
	1686	1686	1679	1662	1660	1549	1454	1263	1048
	1687	1687	1679	1664	1674	1552	1483	1300	1051
	1690	1690	1690	1679	1688	1561	1495	1483	1229
	1707	1707	1707	1690	1690	1621	1515	1495	1300
25%	**1714**	**1714**	**1714**	**1714**	**1693**	**1634**	**1528**	**1497**	**1332**
	1725	1725	1725	1725	1714	1660	1549	1543	1461
	1751	1751	1751	1751	1725	1690	1610	1610	1473
	1753	1753	1753	1753	1751	1718	1660	1629	1496
10%	**1754**	**1754**	**1754**	**1754**	**1753**	**1725**	**1690**	**1660**	**1533**
	1764	1764	1764	1764	1754	1753	1725	1690	1660
	1769	1769	1769	1769	1764	1754	1753	1725	1690
Mean	1680	1680	1669	1619	1527	1371	1133	1039	930

Source: Hearn (1988)

Only three weather scenarios are included in the spreadsheet template: dry, average and wet (Table 2). Average years correspond to the median (50% line) in Table 1;

dry years to the lowest 10% line; and wet years to the highest 10% line. Also, the ninth irrigation has been omitted since the yields are the same as for eight irrigations.

The maximum land area available for cotton cultivation, the maximum yield obtainable under ideal growing conditions, the prices of cotton and water, the amount of allocated water and expected free flow, the water use efficiency and the soil water deficit for irrigation are all entered in the template by the user (Section A of the template, Table 2).

In the example, the water use efficiency and soil water deficit at irrigation only adjust the amount of water used. In practice, it may be necessary to adjust the relative yield coefficients as well.

The technical relative yield coefficients are used to generate a table of "economic" relative yield coefficients by comparing the expected revenue with the variable costs, Section D. If the breakeven point is not reached for any cell in the table, the relative yield coefficient is replaced with a zero. This partitions the lookup table in the same way as the breakeven line in Table 1. It simplifies use of the spreadsheet since only those combinations of weather scenario and number of irrigations which flag a positive contribution to the gross margin need be considered.

The gross margin corresponding to various combinations of areas with different numbers of irrigations, for different weather scenarios, is calculated within the spreadsheet by entering values in the appropriate line of the "area grown" table, Section B. As different combinations are tried, and the corresponding gross margins recorded, a "what if" analysis is possible. Risk analysis is provided by comparing the same combination of areas for each of the three weather scenarios.

Table 2 The spreadsheet template

Calculation of the area of cotton to grow			version 6th March, 1990		
A					
land area	600	ha	allocation	3000	ML
maximum yield	6	bales/ha	free flow	200	ML
price of cotton	450	$/bale	efficiency	75	%
price of water	10	$/ML	deficit	75	mm
variable costs	1500	$/ha			

B

		area grown							
		number of irrigations							
gross margin	rainfall	1	2	3	4	5	6	7	8
$0	dry	0	0	0	0	0	0	0	0
$571,360	average	0	0	0	0	400	200	0	0
$0	wet	0	0	0	0	0	0	0	0

C

constraints

	actual		limit		
land	600	<=	600	0	833
water	3200	<=	3200	0	22

D

relative yield coefficients (economic)

	number of irrigations							
rainfall	1	2	3	4	5	6	7	8
dry	0.00	0.00	0.00	0.00	0.65	0.81	0.89	0.92
average	0.00	0.57	0.74	0.83	0.92	0.94	0.94	0.95
wet	0.87	0.94	0.96	0.98	0.99	0.99	0.99	0.99

relative yield coefficients (agronomic)

	number of irrigations							
rainfall	1	2	3	4	5	6	7	8
dry	0.21	0.24	0.26	0.47	0.65	0.81	0.89	0.92
average	0.46	0.57	0.74	0.83	0.92	0.94	0.94	0.95
wet	0.87	0.94	0.96	0.98	0.99	0.99	0.99	0.99

If a linear programming add-in is available for the particular spreadsheet package used (such as What's*Best!*® for Lotus 1-2-3® and Symphony®), the cotton area which gives the maximum gross margin can be calculated directly. Linear programming is a mathematical procedure that will maximise expected gross margin subject to linear constraints. This decision problem is subject to two resource constraints: (1) the land used for cotton cultivation should not exceed that available, and (2) the water used should not exceed that which is either known to be available (allocated supplies and on-farm storage) or which might reasonably be expected to be available (the sum of allocated supplies, on-farm storage and expected off-allocation flow). These two constraints are shown in Section C of the template. Alternative uses for these resources (*e.g.* irrigated soybeans) could also be incorporated in the model if their response characteristics are known.

If a linear programming add-in is not used, care needs to be taken when doing "what ifs" that the levels of land and water used in the spreadsheet model do not exceed the limits set. A spreadsheet macro could be used to do this.

The appropriate balance between research and software development in the construction of farm-level decision support systems is a problem in research design. The validity of the spreadsheet model relies on the validity of the underlying crop model used to generate the table of relative yield coefficients. This represents a substantial research input. On the other hand, a spreadsheet template provides a readymade interface which is both cheap and flexible. This releases research resources from software development.

References

Centre for Water Policy Research (1989). A study of reliability of water supply for irrigated cotton in the Namoi valley. 206pp.

Hearn, A.B. (1988). Water use by cotton: an update on strategies. *Proceedings of the 1988 Australian cotton conference*, August 17th-18th, Surfers Paradise, Queensland, pp.249-255

Acknowledgements

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