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EXPLORING THE INTERFACE BETWEEN AGRICULTURAL SCIENCE AND PUBLIC POLICY

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EXPLORING THE INTERFACE BETWEEN AGRICULTURAL SCIENCE AND PUBLIC POLICY

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"While there is no common recognition within an organisation of the ideal goal and the obstacles to its attainment, managers' energies are all aimed in different directions, and progress toward remedying the problem is all but impossible. Once such a common recognition is achieved, however, all concerned can apply their joint energies to removing the obstacles to their solution. Thus, by directly challenging the constraints, the strategic thinker usually finds that in reality they are far less formidable than they had appeared."

Kenichi Ohmae, *The Mind of the Strategist*, p. 87

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CHAPTER 3: PROVIDING POLICY-RELEVANT INFORMATION FROM AGRICULTURAL RESEARCH

BY BOB MCCOWN, DAVID FREEBAIRN, GRAEME HAMMER, BRIAN KEATING AND PETER CARBERRY[3]

INTRODUCTION

Agricultural research has a potential for aiding policy planning and analysis by improving prediction of economic and environmental consequences of relevant actions and strategies. But how can APSRU agricultural systems research provide useful information for policy-makers? And can APSRU contribute to policy development in other ways? These issues were addressed on the afternoon of the first day of the Workshop. The session included several presentations by members of APSRU.

Appropriate economic analysis is central to policy-relevant analyses. Although the methods for economic analyses are well-developed, use of these is often precluded by lack of appropriate data. Agricultural simulation models can effectively reduce this constraint for some problems. APSRU has developed an agricultural production system simulation model (APSIM) that can provide realistic prediction of crop and pasture production and soil changes from inputs of weather, soil and management information.

This chapter begins with a sketch of the concepts of simulation. The main body of the chapter consists of four examples of simulation studies which are relevant to public policy. They all concern the issue of sustainability of cropping in climatically marginal lands.

Figure 1 sketches the major aspects of a grain/grazing system that are treated in APSIM. The effects of weather, soil properties, and many aspects of management on both production and the soil resource can be simulated. The interactions are updated daily, and the effects are cumulated for the duration of the model run.

CASE 1: APPLICATION OF CROPPING SYSTEM SIMULATION IN THE MANAGEMENT OF LAND RESOURCES

Soil degradation is one of the major threats to long-term agricultural production. The off-site effects of agriculture are also a cause of community concern. There is not much quantitative information available about land degradation. Up to now, we have relied largely on anecdotal evidence and a limited collection of solutions. Some of these are highly visible, but not necessarily effective e.g. the near-exclusive use in the recent past of contour banks to reduce erosion. These structures are clearly visible and they do reduce gullying. Yet, when used alone, they are only effective in reducing soil losses by about 50% and have substantial capital and operating costs.

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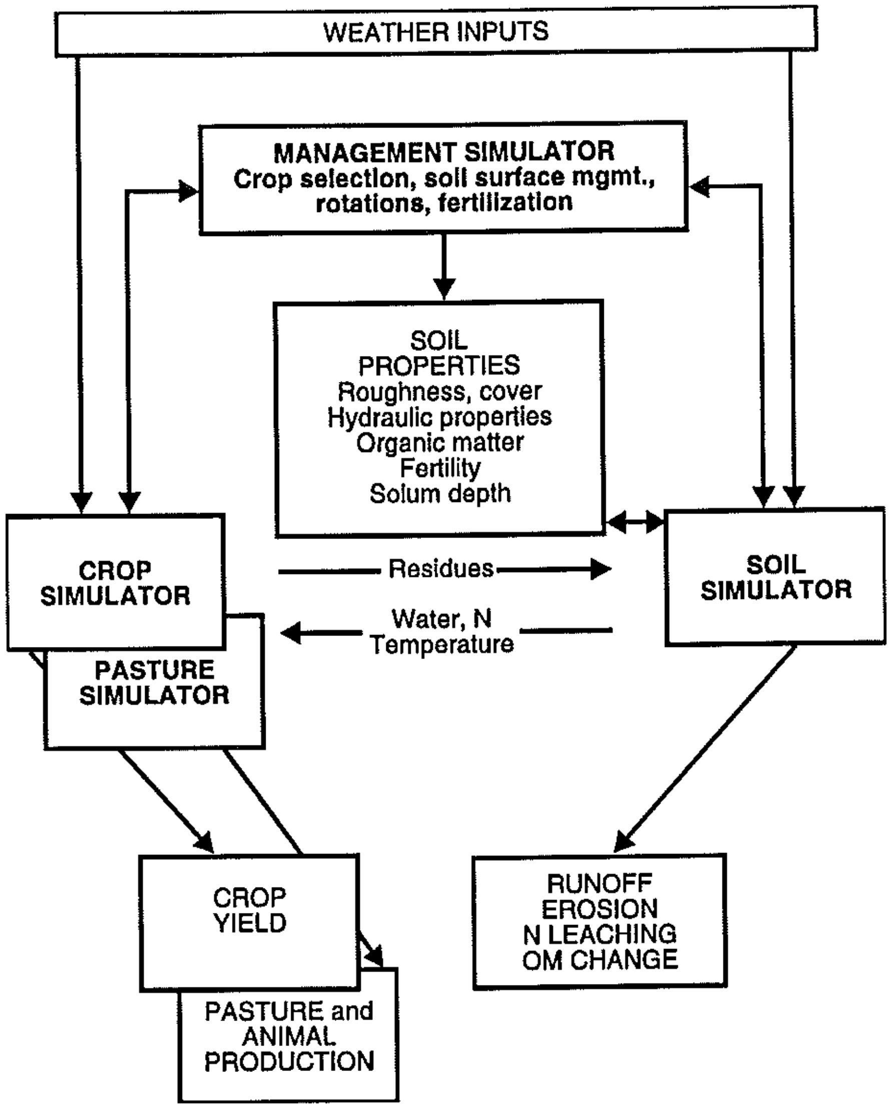
Figure 1: A schematic view of an agricultural production system simulator



More recent approaches to the study of land degradation have focused on the effects of various types of land management on measurable parameters such as soil erosion rate and water balance. A major limitation of such information is that it has only been collected at a few locations, and results are very soil-, site- and management-specific. The sporadic nature of erosion makes it difficult to rely on experimental results. For example, average erosion rates for three consecutive four-year periods on the eastern Darling Downs were 16, 78 and 14 tonnes per hectare per year.

One function of simulation models is to describe the major processes involved in land degradation so that such results can be reproduced for the sites where they were measured. We can then estimate what is likely to happen under different conditions and provide estimates of long-term rates of degradation. In this way, a relatively short record is extended to a 100-year estimate.

Such estimates of the rates of soil degradation are not very meaningful on their own. A key issue is: what is the effect of such processes on the productive potential of the soil? With the ability to predict runoff and erosion, it is a simple step to link loss of soil to decline in soil depth, and its subsequent effect on crop growth.

The characteristic effect of erosion on production is that yield differences are highly variable (reflecting the fact that soil depth is not always the limiting factor) and that changes in production potential are gradual. It is unlikely that such differences would be noticed by land-users. These differences can have a large impact on profitability; a common rule of thumb is that a 15% decrease in yield can halve profits.

While field studies alone might eventually provide management answers - if the research could be sustained - models based on sound experimental studies, and which incorporate the major physical and chemical features of the system, can be used to generalise site- and time-specific data and guide best-bet management scenarios. Indeed, if there are well-defined trends or cyclical patterns in weather (as we believe to be often the case), models might be the only feasible way to understand what is happening.

Agriculture can no longer be regarded in isolation. With increasing community awareness of environmental issues, more attention is being focused on what agriculture is contributing to the quality of air and water resources. For example, fish kills in rivers have been associated with cotton production. Movement of chemicals (insecticides, herbicides and fertiliser) in the environment is an issue which agriculture has to deal with if it is to be regarded as a socially acceptable activity. Simulation models will allow us to put together many of the processes involved in movement of water and associated chemicals in landscapes. Some of the key processes such as runoff, erosion, degradation of chemical and risks associated with irrigating at different times are understood to some degree, but often in isolation from each other. These elements need to be brought together to examine the risks associated with various management scenarios for the whole system (which would include the river).

In most environmental management issues, a range of objectives can be defined, such as maximum profit or minimum environmental damage. Table 1 shows some characteristics of three hypothetical cropping systems. These characteristics are typical outputs from a cropping system model.

Table 1 Hypothetical attributes of three cropping systems.

	Profit ($\$$ ha^{-1})	Erosion (tonnes ha^{-1})	Drainage (mm year^{-1})
System A	200	50	10
System B	180	2	20
System C	190	20	1

System A is desirable in terms of profit; system B in terms of erosion control; and system C in terms of drainage control which might be a major issue in an area with rising saline watertables. How do we decide which is the best practice in the short- and long-term? Having the above information is an essential start to the process of determining what are appropriate forms of land management from both individual and social points of view.

CASE 2: CROPPING AT THE MARGINS - AN ANALYSIS OF SHORT-TERM YIELD VARIABILITY AND LONG-TERM FERTILITY DECLINE.

Few farmers growing wheat on the western limits of cropping on the Darling Downs would disagree with the assertion that it is a risky business. All would be aware of the short-term risk posed by erratic rainfall patterns which is a disincentive to investments in bought inputs such as fertiliser. Fewer would be aware of the longer-term threat posed by declining soil fertility that results from nitrogen being removed in the grain and other losses. The year-to-year variation in crop yields associated with rainfall variability tends to mask a more gradual decline in crop yields and grain nitrogen levels due to soil degradation.

While there have been some long-term field trials that demonstrate these temporal relationships, experimental quantification of long-term trends is difficult because of the time and costs involved. Assessment of the economic value of fertiliser to supplement declining natural fertility is also complicated by seasonal variability in rainfall. In this case study, we used a model of the wheat crop-soil system to explore the short- and long-term temporal variability in wheat yields and profitability.

The model and the method

The model : The model simulates wheat growth, yield and grain protein in relation to weather, management, genotype and soil factors. Soil nitrogen (N) supply is simulated by models of mineralisation, immobilisation, leaching and denitrification. We are currently testing and developing this model using data from the Hermitage (Warwick) long-term trial and customised experimentation.

The system : The wheat model was used to simulate wheat production from a summer fallow-winter wheat system at Roma, on the western margins of the cropping zone in southern Queensland. Water and nitrate were allowed to accumulate over the summer fallow and simulated planting took place in response to planting rains in a window from 1st May to 31st July. Genotypic coefficients were those developed from experimentation on the variety Hartog.

The soil : Soil water, carbon and nitrogen properties were those assessed for the Waco Black Earth at the Hermitage trial site. While such a soil may not be widespread at Roma, the general principles of the analysis should apply to the heavy clay soils used for cropping in the Roma district. Earlier research has shown large declines in soil carbon and nitrogen with cultivation. We chose three soil fertility states to cover this range, differing in total N, total C and nitrate-N present at the start of the fallow period.

The problem : Wheat-cropping in the marginal rainfall areas of Australia's northern cereal belt has traditionally exploited the high natural fertility of the vertisols that dominate the soils of the region. There has been little incentive to replace harvested nitrogen. In recent years, large declines in grain protein has called attention to the fact that it is only a matter of time before N fertiliser and/or legumes becomes central to cereal production in these regions. In this study, we use the model described above to explore:

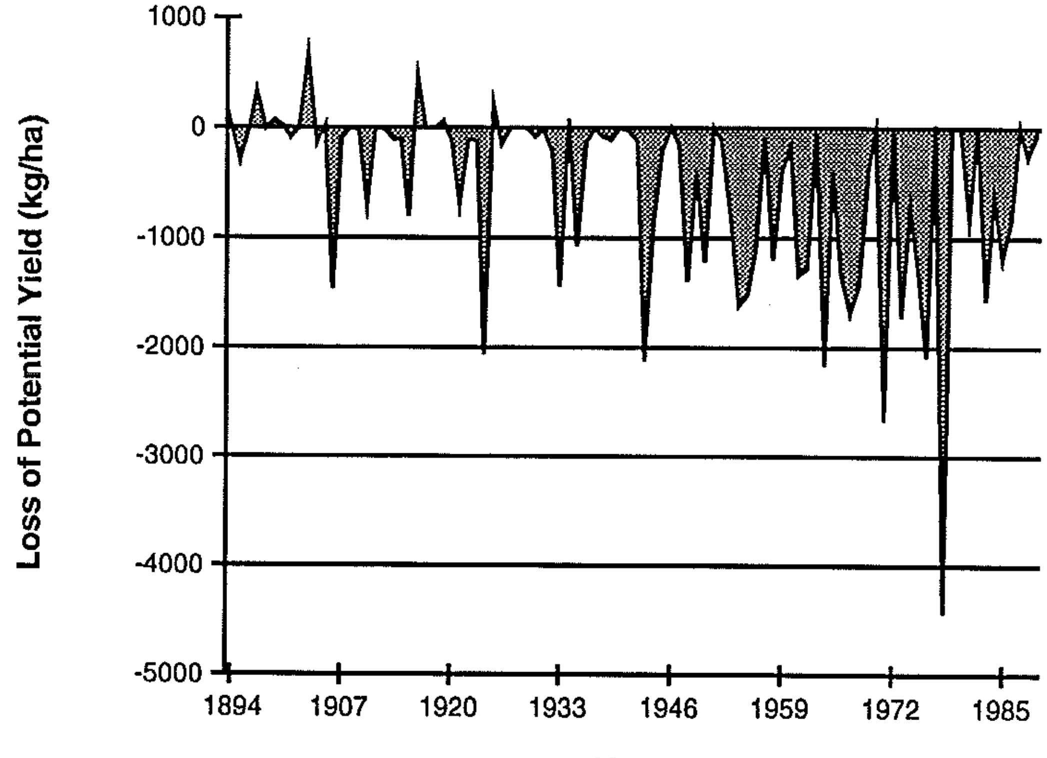
- variation in wheat yields in relation to seasonal variability;
- long-term trends in yields in relation to the exploitation of inherent soil fertility; and
- variability in the effect of nitrogen fertilisation on yield and profitability.

Short-term variability and long-term trends in wheat yields

Two scenarios were examined. In one, the soil was maintained in a highly fertile state throughout the simulation. While this may not be feasible in practice, it provides a useful contrast with the second scenario, where soil organic N was allowed to decline over time because of N losses and crop removal.

Yields ranged from zero to just over 7000 kg ha^{-1}. Crops were not sown in the simulations in approximately 17 percent of seasons due to failure of planting rains according to the criteria used. The most striking feature of the simulated yields was the short-term variability. This was associated with variation in the amount and timing of rainfall in both the crop season and the preceding fallow period. The longer-term trends in yield were more difficult to discern, given the short-term seasonal "noise". Such trends become more obvious when the difference between the *constant fertility* and *declining fertility* scenarios is plotted over time (Figure 2). Managers may be excused for failing to appreciate fully such a long-term trend given the year-to-year variability.

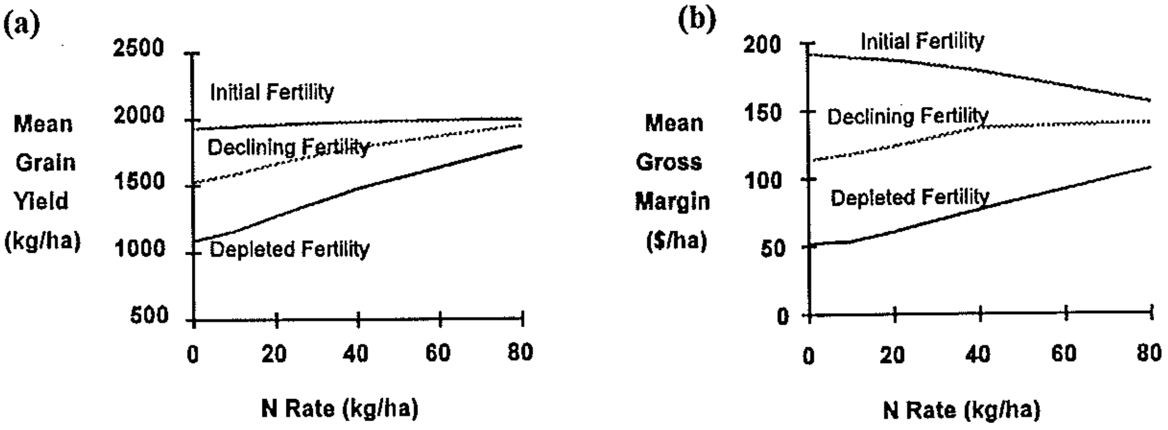
Figure 2. Grain yields simulated for wheat grown at Roma from 1894 to 1989. Impact of fertility decline in terms of lost production on a seasonal basis.



Variability in response to fertiliser nitrogen

The simulation showed that, on average, wheat yields respond little to nitrogen when soils are in their initial high-fertility state in this environment (Figure 3a). This result is consistent with farmer experience in the early years of cropping on these soils. The responses get larger at medium and depleted soil fertility levels. While average gross margins are increased by using N fertilisers on low and medium fertility soils, they can never reach the level achieved when the soils are in their initial fertile state (Figure 3b). This reflects the fact that profitability falls when fertility has to be purchased as fertiliser, rather than exploited from a natural soil resource.

Figure 3. Average responses to N fertiliser for soils differing in N status simulated for Roma from 1894 to 1989. (a) Grain yield (kg/ha), (b) Gross margin ($/ha).

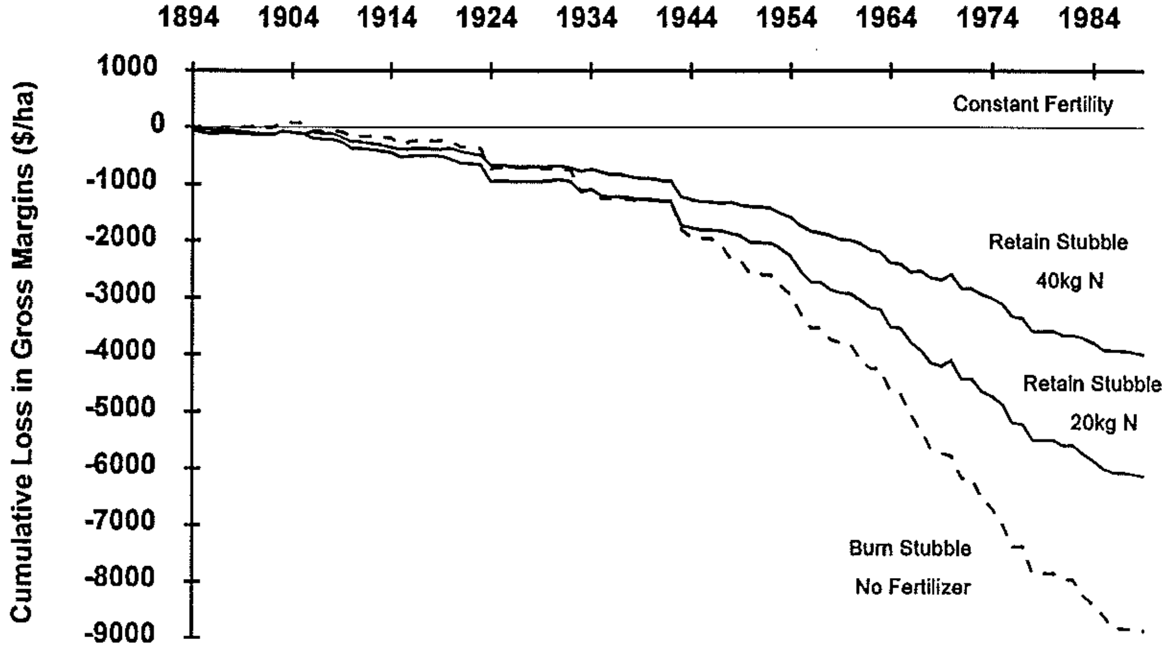


Placing a value on soil fertility

The previous case study highlighted the risks associated with the depletion of natural soil fertility by crop production in marginal areas and demonstrated the short-term economic logic of exploiting natural soil fertility. The results indicate the inevitability of soil fertility depletion overtaking water supply as the major production limitation and for the costs of fertiliser inputs to become significant. (But note that no distinction has been made between the present value of the soil resource *versus* its potential value in the future i.e. we did not try to incorporate changes in the shadow price of land.)

Simulation can contribute to this by assigning current market values to the inherent soil fertility that may be diminished by exhaustive cropping practices. Cumulative reductions in gross margins over almost 100 yrs of "exploitative" cropping (continuous cereal production, burning crop residues, no fertiliser inputs), relative to a hypothetical "forever-fertile" soil, amounted to approximately $9000 ha^{-1} (Figure 4). Practices which maintain soil fertility, such as adding N fertiliser, while initially less profitable, raised profitability in the long-term.

Figure 4. Cumulative impact of fertility decline simulated for Roma from 1894 to 1989 and presented in terms of losses in gross margin relative to soil maintained in a pristine state. (No discounting applied).



CASE 3: PROSPECTS FOR CROPPING IN THE SEMI-ARID TROPICS OF NORTH QUEENSLAND

Fortunately, climate-induced yield variability can be simulated and production risks analysed. In the semi-arid tropics of north Queensland, climatic and soil surveys have identified land with potential for cropping and there have been periodic occurrences of land clearing, most recently in the mid-1980s on the western margins of the Atherton Tablelands. Almost without exception, such cropping development has been short-lived. The question arises as to whether the potential for crop production is high enough for it to be viewed as a resource worth exploiting. It is an important question for potential investors, for research organisations, and for those concerned with the ecological implications of improper land use.

Realistic estimation of the potential for agriculture in climatically-variable environments is difficult. Judgement on the basis of commercial performance is hampered by both the small sample of seasons and the enormous variation in seasonal yields. Judgement based on analysis of weather records alone is hampered by the complexity of the relationship between rainfall and yield. This case study used crop simulation models to evaluate the potential for dryland cropping of lands marginal to the Atherton Tablelands in north Queensland, and to identify management practices that provide the best compromise between economic returns and risk.

Crop models for maize, sorghum and peanuts were used to predict yields from the historical weather record at 14 locations situated both on the Atherton Tablelands and in the more marginal regions to the north and south-west of the Tablelands. Probability distributions of simulated crop yields and gross margins were derived and the tradeoffs between return and risk were quantified under different cropping scenarios. The management strategies analysed included: time of planting; genotype selection; plant population; and nitrogen fertiliser rate.

The most striking difference between Atherton, Mt Garnet, and Mt Surprise is in the yield variability. Rarely at Atherton does unfavourable weather reduce yields directly. Another feature is the evidence for runs of good and bad years e.g. the 1970s *versus* 1980s at Mt Garnet. This clearly illustrates the temporal sampling problem with traditional field experimentation in variable climates where it is generally only possible to conduct experiments for a limited number of years. Estimates of prospects for cropping at Mt Garnet would differ greatly depending on the decade in which the experimentation was conducted. A simulation approach gets round this problem because it simulates yield in all years for which rainfall records are available.

By using average simulated yields to calculate gross margins, the expected returns for maize, sorghum and peanut crops grown with strategies which maximise yields can be determined for each site. This showed that expected returns from dryland cropping at sites on the Atherton Tablelands were very much higher than those for crops grown in the adjacent regions. Expected returns for peanuts were also higher than for the cereal crops. Katherine (in the Northern Territory), with the same soil and economic environment as north Queensland, showed considerably poorer prospects for cropping than areas in north Queensland such as the Mt Garnet district. This procedure also quantified the risks associated with different crops in the five regions.

An attractive feature of the simulation approach is that yields are available for a large number of years and so yield frequency distributions can be drawn. Climatic risk can therefore be assessed in probabilistic terms as the proportion of years where yield or gross margin fails to reach target values. At Atherton, any of the four cropping combinations would be profitable in at least 90% of years, but a peanut/maize combination resulted in highest margins. A peanut/maize combination also appeared optimal at Mt Garnet, although returns were lower than for Atherton. However, cropping at Mt Garnet was risky for any crop combinations - financial losses from a maize/peanut farm occurred in about 4 out of 10 years. Of the four cropping strategies at Mt Surprise, sorghum production involved the least risk, but it covered fixed costs in only 44% of years. The highest returns were obtained from a peanut/sorghum combination, but only in 31% and 25% of years were returns for peanut/sorghum and peanut/maize combinations, respectively, greater than the level of fixed costs. An experimental approach to getting this information would have required 400,000 plots (treatments *times* years), even if unreplicated! And even if feasible - which it isn't.

CASE 4: THE POTENTIAL FOR SEASONAL WEATHER FORECASTS TO REDUCE RISKS OF POOR RETURNS TO N FERTILISATION OF WHEAT.

The high rainfall variability in some parts of Australia results partly from the effects of the meteorological phenomenon known as the Southern Oscillation. The Southern Oscillation Index (SOI) measures the relative strength of the Southern Oscillation. There is some skill in forecasting seasonal rainfall from the trend in the SOI prior to that season. The median winter rainfall is about 50 mm greater in years when the SOI is trending upwards from February to May compared with those years when it is trending downwards. Information from a seasonal forecast may be useful to a decision-maker, particularly where climatic variability has such great impact on production risk. It is unclear, however, just how valuable the current level of forecasting skill is.

In northeast Australia, wheat is planted between April and July depending on the timing of planting rains and the level of stored soil moisture in the soil profile. The level of production achieved varies greatly with the time of sowing, soil conditions at sowing, variety choice and nitrogenous (N) fertiliser rate. The high cost of fertiliser at economically optimal rates in good seasons, coupled with the high risk of other-than-good seasons, constrains outlays on fertiliser. Advance knowledge about the potential response to fertiliser use during the next season could result in a more risk-efficient fertiliser decision.

At Goondiwindi, when all years are considered, there is a 50% chance of exceeding about 2 t ha^{-1} and a 25% chance of exceeding about 3 t ha^{-1} of wheat, based on model predictions. The potential effect of a seasonal forecast can be examined by looking at the probability distributions derived from model runs for those years when the SOI was trending either upwards (positive trend) or downwards (negative trend). The grain yield probability distributions shift in both sets of years. When the SOI-trend prior to planting was positive, the median yield increased to about 2.5 t ha^{-1}. When the SOI-trend was negative, the median yield decreased to about 1.5 t ha^{-1}. The yield range is not greatly affected: there are some high-yielding years when the SOI is low, and some low-yielding years when the SOI is high.

The effect of using different N fertiliser rates can be simulated in the same way and the production outcomes converted to gross margins, assuming a particular price and cost structure. When all years are considered, the maximum average gross margin is about $140 ha^{-1} and occurs at a N fertiliser rate of 40 kg ha^{-1}. In years when the SOI-trend is positive, the average gross margins are greater, reaching a maximum at about $175 ha^{-1} at a N fertiliser rate of 80 kg ha^{-1}. In years when the SOI-trend is negative, average gross margins are lower, with a maximum at about $100 ha^{-1} at a N fertiliser rate of 0 kg ha^{-1}. Thus, knowledge of the SOI-trend prior to sowing could influence decisions on N fertiliser rate in these circumstances and reduce the risk of not recovering fixed costs. The shift from 40 to 80 kg ha^{-1} in years with a positive SOI-trend would increase returns by about $15 ha^{-1}. The shift from 40 to 0 kg ha^{-1} in years with a negative SOI-trend changes the gross margin little but allows the same outcome with less cost.

POLICY IMPLICATIONS

In all four case studies, there are clear policy implications associated with the kind of research APSRU is already doing.

Case 1 (*Soil erosion*) showed how we can use simulation models to analyse the attributes of different cropping systems, in this case in terms of profit, erosion and drainage. This sort of information will be increasingly important in evaluating alternative farming strategies in terms of a range of different indicators to do with economic viability and ecological sustainability.

In case 2 (*Economics of soil fertility decline*), we showed how we could use models to project the rate and extent of long-term soil fertility decline (without added inputs or changes to the way the agricultural production system is managed) even against a background of substantial short-term yield variability. This sort of analysis helps to make the case for changing the way these systems are managed if agricultural production is to be sustained in the long term.

Case 3 (*Potential for dryland cropping in the tropics*) has important policy implications for regional development.

In case 4 (*Evaluation of the SOI*), we have seen how seasonal weather forecasts might contribute to more efficient use of inputs (in this case, fertiliser) in agricultural production in marginal areas. This is potentially important in maintaining Australia's competitive edge in agricultural production, as well as helping to contain environmental contamination with chemical inputs by targeting their use to situations where they are likely to be most effective.

These four examples do not exhaust the ways in which APSRU could contribute to policy analysis and development. Together, they do show something of the range of issues that we are already addressing, and why we believe our work does have significant policy implications.