Agriculture in south-western Australia in a greenhouse climate

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Introduction

Agriculture, as currently practiced in south-western Australia, is an adaptation of a European production system imposed on a hostile environment by determined men. The adapted system has met with some productive success as evidenced by $2.9 billion gross value of production in 1987/88. This production was obtained from 15.5 million ha of cleared land of which 5.4 million ha were cropped and 7.5 million ha sown to improved pasture.

Agriculture in south-western Australia is diverse, ranging from extensive grazing and cropping to intensive horticulture and animal production. The extensive agricultural industries are conducted at the climatic margins for cultivation; the intensive industries are undertaken in more favourable climatic regimes and the climate often modified by glasshouse, shed or irrigation. The extensive industries cannot economically modify the climate and are therefore fully and immediately exposed to any change in the climate. Operators of intensive industries can, to some extent, modify their production climate and hence, at least in the short term, counteract climatic change. In the longer term these industries could be affected if the climatic change is adverse and impacts on resources required for modifying their climate, such as energy and water.

Agricultural production processes

Stripped naked, agriculture is a biological conversion process which converts water, air and earth elements into fibre and animal food. The rate of the conversion process is determined internally by plant genetics and externally by the fertility of the growing medium, the availability of water, the ambient temperature and radiation load, and the concentration of CO_2 in the atmosphere. Changes in any of these factors will affect the conversion rate per se and hence agricultural production is very sensitive to climate and the constituents of climate - weather. Since plant and animal production responds directly to weather it is more appropriate to consider the impact of future weather on the production process than to talk about future climate. Climate is an abstract concept and is only determined by comprehensive calculations. Geiger (1) defines climate as the sum total of all meterological occurrences at a given place, comprising the average conditions and the regular sequences of weather and repeatedly observed special phenomena.

Agricultural production falls into two broad categories - animal production and crop production. Animal production in south-western Australia relies largely on animals directly grazing pastures. Pasture available to the animals at a given time depends more on the weather during the preceding few weeks than on the overall seasonal weather conditions. This contrasts with crop production where the only output is the final yield, be it grain, fruit or vegetable, and the final yield is determined by the seasonal conditions. Thus a weather sequence which has a dramatic impact on, for instance spring pasture production, may have little impact on crop yield in the same region.

The intimate relationship between specific weather events, weather sequences and individual agricultural production enterprises makes it nigh impossible to generalise about the possible impacts of climatic change on agriculture.

Inertia of agricultural systems

The common perception that climatic change will have a dramatic effect on agriculture implies that agricultural systems are inertial, that is, they are very resistant to change. Current predictions of global climatic models are that large changes in climate will occur over the next 50 years and the implication is that agriculture will not be able to cope with these changes without a large input of resources into research and planning.

The history of agricultural development in south western Australia demonstrates that agricultural systems are very dynamic and can very quickly adapt to change. The south coast sandplain of Western Australia was largely developed within 20 years of the discovery of methods of overcoming trace element deficiencies in the area. Lupin growing for grain began in Western Australia with the release of Uniwhite in 1967. Twenty years later almost one million ha of lupins were being grown. The introduction of lupins has required substantial change in farming practices: rotations have changed from cereal-subterranean clover to cereal-lupin; stock management practices have been adapted; farmers have learnt how to grow a new crop; marketing systems have been developed and an entirely new field of research has been developed to support, sustain and promote the industry.

These two major developments in Western Australian agriculture have taken place over a time span less than half of that predicted for current climatic change to fully manifest itself. Thus, agriculture has the capacity to adapt to innovation. Agriculture also has the capacity to adapt to adverse or favourable external forces, such as market forces, as evidenced by the rapid fluctuations in sheep numbers influenced by prevailing wool prices.

The changes in agriculture that have occurred in the last twenty years have taken place during a period of climatic change. The analysis done by Broadbridge (2) suggests that rainfall in the south coastal district has declined by about 20 per cent in the last 40 years with most of the decline in the last 20 years. At the same time mean temperature has increased, although by less than 0.5?C. These changes have not wrought havoc on the agricultural systems because they are slow changes in the long term mean and are largely masked by seasonal variability. So the question is whether future changes in climate will have a noticeable impact on agriculture or not?

Future trends and uncertainty

Global climatic modellers have presented planners, researchers and practitioners with a dilemma. The modellers have confidently predicted that climatic change will occur, and will occur at an unprecedented rate, but they are not yet able to predict the rate or direction of change of important climatic parameters on a regional basis. There appears to be some consensus that temperature will increase. Pittock (pers. comm. 1989) suggests that mean temperatures in southern Australia will increase by about 3?C. However, Pittock and his colleagues are cautious about predicting future rainfall. Thus the user groups of the climatic information must make decisions in a very uncertain environment.

There are a number of ways of coping with decision making in the face of uncertainty. One way, adopted by Sadler et al. (3), is to apparently reduce the uncertainty by adopting some given scenario. Sadler et al. were confronted with planning future urban water resources - a process that must account for the likely water resources available during the life of a major dam, perhaps 50 or 100 years. Their approach was to construct a worst case scenario and plan on that basis. This would seem an appropriate approach in that if the worst case did not eventuate then they would have an excess of the resource.

Hille (4) prepared regional climatic scenarios for the Greenhouse 88 conference in Perth. As an aid to discussion at the conference, Hille presented two scenarios - a most probable and an extreme with respect to temperature rise and sea level rise. From the temperature changes he argued that certain changes in the weather pattern would occur which would result in changes in rainfall quantity and distribution, and the occurrence of extreme events. Thus the public were presented with two scenarios on which to base their deliberations. Scanning the conference report indicates that the participants ignored the more benign option and chose to address their remarks to a future of almost unbearable heat, insignificant rainfall and devastating extreme weather events.

A further option for addressing uncertainty is to plan a resilient system which has the capacity to cope with change. In planning such a system it is essential that future options not be excluded. I contend that agriculture in south western Australia has a degree of resilience, but is in danger of permanently removing some options unless change occurs to conserve the land resource base.

Impact on agricultural production

Cereal Cropping

An increase in temperature, an increase in atmospheric CO_2 concentration and a change in rainfall quantity and distribution will affect all aspects of agricultural production in south western Australia. The nature of future climatic effects is open to conjecture. While the effect of individual climatic components can be defined the net effect on the biological production process is unclear.

There is a considerable body of evidence that increased CO2 concentrations stimulate plant growth. Gifford (5) cites the typical magnitude of the CO_2 fertilizing effect to be a 30-40 per cent increase in yield when CO_2 is doubled from its present value to 700 ppmv. Most of the data used to determined the CO_2 fertilizing effect came from perturbation experiments, wherein plants are suddenly subjected to CO2 enriched atmosphere and the growth response measured. In reality plants are continually subjected to an atmosphere with a slowly increasing CO2 concentration. These conditions may elicit a different plant response.

Woodward (6) measured the stomatal densities on herbarium specimens of seven temperature forest tree species. He was thus able to examine the effect of slowly increasing CO_2 over a 200 year period from 1787 to 1987. He found that there was a similar relative decrease in stomatal density in all species with a mean reduction of 40 per cent. Over the same period atmospheric CO_2 increased by 21 per cent from 280 to 340 ppmv. He concluded that CO_2 has an effect on stomatal development.

With lower stomatal densities there will be less CO_2 assimilation per unit leaf area. Thus the possibility exists that plants which evolve under gradually increasing CO_2 may not have a net positive response to the CO_2 fertilizing effect.

A further confounding effect is that for annual crops, such as cereals, a warmer environment will tend to reduce yield due to a more rapid attainment of physiological maturity. Gifford (5) suggests that the effect of earlier maturation will essentially negate the CO_2 enrichment effect on currently adapted varieties. Thus, there will be a need to breed slower maturing varieties to cope with the warmer environment. There is also the need to breed CO_2 responsive varieties to counteract the possible effects postulated by Woodward.

The reported plant responses to CO_2 enrichment and increased temperature assume that water is not a limiting factor. At times during the cereal growing season in south western Australia, water is limiting and some possible scenarios for future climate suggest that winter rainfall in the region will decrease.

Wheat yield in the mediterranean environments of southern Australia is very dependent on growing season rainfall. In South Australia, French and Schultz (7) reported that 65 per cent of wheat yield variation was attributable to variation in the April to October rainfall. Yield can also be very dependent on rainfall during specific growth stages. For example Sief and Pederson (8) found that spring rainfall in the five week period around anthesis accounted for 86 per cent of yield variation in the central west of New South Wales. So a decrease in rainfall at a critical growth stage could significantly reduce yield. However, this conclusion is based on data derived from crops growing in the current atmosphere. With a doubling of atmospheric CO_2, stomatal resistance could double (9) leading to a decrease in transpiration and thus a more water conservative system. Hence, the decrease in rainfall may not have the dramatic effect on yield as previously indicated.

The direct effects of increased atmospheric CO_2 on plant production processes may be largely countered if there is an increase in ultra-violet B (UV-B) radiation as a result of ozone depletion in the upper atmosphere. Increased levels of UV-B decrease the rate of photosynthesis, decrease water use efficiency, decrease leaf area and thus decrease yield in many plants (10).

One can only speculate what the net effect of the complex interactions will be on cereal yields. Modern breeding techniques and innovative agronomic practices should be able to implement changes at a greater rate than the rate of climatic change. Thus, barring very large changes in rainfall quantity and distribution, the cereal industry in south western Australia should continue beyond the year 2050.

Horticulture and Irrigation

Horticultural crops will have a similar response to increases in CO_2 and UV-B as cereal crops. Temperature increases will have a more significant impact on the stone fruits and pome fruits that have a vernalization requirement and, although changes in rainfall can be negated by irrigation, a change in rainfall will affect the availability of water for irrigation.

Chilling Requirements

Viable deciduous fruit production requires a cool winter temperature regime to ensure fruit set. The number of hours below 7?C between June 1 and mid September is now used to calculate the chilling environment in south western Australia. However, little hourly data are available and the mean monthly minimum and maximum temperatures give some indication of the potential chilling regime.

With a predicted 3?C rise in mean temperatures Table 1 shows that future temperatures at Manjimup, in the heart of the deciduous fruit growing area, will equate the current temperature regime at Geraldton. Thus, under the existing definition, there will be no chill accumulation at Manjimup in the middle of next century and the future of the fruit industry will depend on the introduction of low chill requirement varieties.

Table 1. Mean monthly maximum and minimum temperatures for Manjimup and Geraldton

		June	July	August	September
Manjimup	maximum	18.1	17.2	17.8	19.2
	minimum	9.2	8.3	8.4	9.5
Geraldton	maximum	21.2	20.1	20.7	21.9
	minimum	12.1	10.9	11.0	11.6

Irrigation

There are three sources of water for irrigation in south western Australia:

- public surface storages in the western Darling Range which supply water for flood irrigation of pastures;
- private extraction of groundwater’s from the Perth sedimentary basin;
- private surface storages.

Both the irrigation demands and the resource replenishment will be affected by a change in climate.

Flood irrigation, which is an inefficient irrigation method, relies on water from large storages fed from mainly forested catchments. The impact of increased atmospheric CO_2 and decreased rainfall on the runoff from these catchments is not at all clear. Sadler et al. (3) postulate that a 20 per cent decrease in rainfall on catchments in the region will reduce water yield by some 45 per cent. On the other hand, Aston (9) suggests that because increases in atmospheric CO_2 increase stomatal resistance, stream flow could increase by 40 to 90 per cent as a result of doubling atmospheric CO_2. The effect detailed by Aston was not considered by Sadler et al.. Thus, it is possible that the net effect of decreased rainfall and increase CO_2 on the yield of a vegetated catchment could be minimal.

An increase in temperature could increase the demand for irrigation water. Potential evaporation increases two to three per cent per ?C temperature rise. Thus a 3?C mean temperature increase will increase potential evaporation by some 7.5 per cent. This is less than the 10 per cent increase used by McMahon et al. (11).

Irrigators currently schedule on an evaporation replacement figure in the 60 to 120 per cent range. Assuming, under current conditions, a 100 per cent replacement of 1,000 mm evaporation over the irrigation season, the increased temperature will require an extra 750 kL per ha to ratify future plant needs. With limited water resources it will be necessary for irrigators to make more efficient use of water.

Animal Production

Improved pasture and water are the two dominant climatically dependent inputs to animal production in south western Australia.

Pastures will be affected by future atmospheric and climatic changes in a similar way as cereals, and one can to assume that pasture plant breeders and pasture agronomists will be able to respond to the challenges of the future.

Provision of stock water supplies is one area of animal production that could be strongly affected by future climate. Currently some 20 per cent of stock water in the agricultural areas is supplied from Government piped water schemes, 30 per cent from groundwater and 50 per cent from farm dams (12).

Future availability of stock water from Government piped schemes will depend on water availability to the scheme. If there is a limited availability then undoubtedly there will be restrictions giving priority to domestic and industrial users. Continued availability of groundwater supplies will depend on future recharge to aquifers and water salinity. Decreases in rainfall of the order of 20 per cent could reduce aquifer recharge by as much as 60 per cent (13). Farm dams rely on runoff either from agricultural catchment or improved (roaded) catchments. Runoff from roaded catchments is very dependent on the characteristics of individual rainfall events as well as the total rainfall.

Some idea of the costs of provision of future stock water can be gained by assessing the capital requirements to meet the water demands of 1,000 sheep at Ongerup. Using the DAMCAT II farm water supply design package (14), and assuming a 20 per cent decrease in rainfall and a 4?C increase in mean temperature, the requirements to meet the water supply of 1,000 sheep change from a 2,200 m^3 dam with 2.2 ha of roaded catchment to a 2,800 m^3 dam and 3.1 ha of roaded catchment. In 1989 the extra cost would be $1,500. Assuming a similar cost per head for all areas in the wheatbelt, then the cost of providing extra on-farm water resources would be about $22.5 million.

There may be some benefits to animal industries from a warmer climate. Certainly in some areas higher winter temperatures would reduce post-natal lambing losses.

Land resources and conservation

The impact of climate change on land degradation will reflect the impact on plant growth and utilization and will be determined by the management strategies adopted. It is easy to speculate on what might be the effect for instance of increased frequency of high intensity, late summer storms in the north eastern agricultural areas on water erosion, or the effect of reduced rainfall on the south coast on waterlogging. Several authors (13, 15) have made predictions of the effect of reduced rainfall, increased temperatures and increased CO_2 on salinity. Macumber et al. (15) conclude that in Victoria, soil salinity is unlikely to be greatly affected by greenhouse induced climatic change. Peck and Allison (13) consider that the aquifer response to reduced rainfall will result in lower watertables and a reduction of land salinization.

Whatever one might speculate about the impact of future climate on the land resource, the reality is that the resource must be cared for in the present. Land degradation removes options for future land use, thus restricting future production whatever the climate. Perhaps now, more than ever before, when facing an uncertain climate, it is paramount that the basic resource of agriculture in south western Australia, the land, be conserved. Agricultural production technology has the capacity to relatively quickly adapt to changing circumstances. It can only adapt and agriculture can only remain viable if the basic resource for production is intact.

Conclusion

The agricultural production environment in south western Australia in the middle of next century will almost certainly be characterized by greatly increased levels of atmospheric CO_2 and higher mean temperatures. The future rainfall quantity and distribution is unclear. Under these conditions there will be a change in the components of agriculture with a need for perhaps faster maturing cereal and pasture species and for fruit trees with lower chilling requirements. Water supplies for irrigation may be limited, requiring greater efficiency of use to maintain production and a greater expenditure may be required to provide water for stock.

The history of agricultural development in the region has shown that it is adaptive and the time scale to implement major changes is relatively short compared even to the time scale of the current predicted climatic change. Thus, provided the land resource is conserved so as not to preclude future options for use, agriculture in south western Australia will survive as a production system under a greenhouse climate.

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