POOR SOILS AND ERRATIC MARKETS: SUSTAINABILITY ISSUES FOR AUSTRALIAN GRAIN AND CANE FARMING

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INTRODUCTION

Australia's agricultural lands occupy only 2.2% of the total area of the continent, but contribute 6 - 8% of total exports, mainly wheat, sugarcane and a range of other grains. Between 20 and 25 million mt of grain and over 25 million mt of sugarcane for crushing are produced each year, mostly from low-input, rainfed farming systems. Some 75% of the grain produced, and 85% of the sugar, are exported.

FOOD PRODUCTION

The Physical Environment

Most of Australia's cropping is carried out in a narrow band lying between the 300 and 700 mm annual rainfall isohyets. In the north-east of Australia, tropical crops are grown in regions with an annual rainfall of more than 1000 mm. While there is some irrigation for horticultural crops and cotton, most grain and sugarcane is rainfed. Seasonal rainfall varies from year to year by as much as 20 - 50%. As a result, seasonal conditions are the main reason for short-term fluctuations in crop yields.

Strategies for minimizing the risk of crop losses from water deficit are built into plant breeding, agronomy and crop management systems in Australia (Richards 1991). These are summarized in Table 1. In drier parts of the cropping belt, soil evaporation can account for over 60% of total water use from seasonal rainfall (Fischer 1986). Water use efficiency can also be severely constrained by a range of soil physical and chemical problems which restrict adequate root growth, so that crop production is often reduced to between one third to a half of the potential predicted from radiation, temperature and rainfall (French and Schultz 1984, Hammer and Muchow 1991, Muchow *et al.* 1993).

Australian farmers have to cope, not only with very variable rainfall regimes, but with soils that are generally weathered and infertile. Australian arable soils have low levels of phosphate, nitrogen and organic matter; one third of arable lands are naturally acidic or are acidifying. Over half the fine-textured, arable soils are sodic (that is, they have a higher sodium plus magnesium than calcium saturation on the exchange sites of their clays). This causes dispersion of the clay when subject to mechanical forces such as raindrop impact, with subsequent collapse of soil aggregates and sealing of the soil surface (Hamblin 1985).

Sandy soils dominate the south-west of western Australia and a broad band of country which stretches across the southern fringe of the continent. These soils have low water-holding capacity and a range of chemical imbalances; phosphate, copper, molybdenum and zinc are generally deficient (CSIRO 1983). Where the sands overlie finer-textured clays, the latter have often accumulated high levels of boron, carbonates and chlorides. These toxicities inhibit deep rooting, and result in poor water-use efficiency as well as nutritional disorders.

TRENDS IN CROP PRODUCTION

Cropping Systems for Australian Conditions

The early wheat production system was a wheat-fallow rotation which rapidly depleted the natural soil fertility, and yields would have crashed if superphosphate had not been introduced in the early part of the twentieth century. Yields climbed back to around their original level by the 1940s, but again the continuous cereal or cereal-fallow rotation constrained further yield increases, both because of the decline in organic matter and soil structure, and because of topsoil loss from erosion when the soil was left bare between crops.

The great scientific advance of the 1930s and 1940s was the discovery of the benefits of rhizobially inoculated pasture legumes on soil fertility. In the 1940s and 1950s this led to the rapid adoption of "improved pastures" across the southern and eastern part of the wheat belt. Such pastures are a mixture of annual grasses and Mediterranean *Trifolium* and *Medicago* species, the clovers being better adapted to the sandier and lower pH soils, the medics to the

Table 1. Production strategies to minimize drought risk

Summer rainfall	Equiseasonal rainfall	Winter rainfall
Long fallows	Short fallows	No fallow needed
Sow only when stored water in profile > 100 mm	Encourage deep rooting to exploit water stored at depth	Grow crops mainly on growing-season rainfall
Select cultivar according to range of growing season duration	Use short/medium growing season cultivars, depending on break of season	Plant as early as opening rains allow, using direct drilling to reduce preparation time
Install furrow irrigation for sugar-cane	Reduce soil evaporation by stubble retention, and promotion of early vigor to cover surface	Reduce soil evaporation by stubble retention, maximize infiltration by good soil structure
A flexible cropping program alternating summer and winter grains	Maintain N through pastures/pulses and top up with N-fertilizers according to season	Early vigor essential, both from variety type and good supply of N and P early in the growing season

more alkaline clays. Benefits from such pastures carried through into the cropping cycle, not only in terms of fertility, but also in restoring degraded soil structure, and in higher quality feed for animal production. The pasture-cereal rotation became the basis of the optimum cropping system for Australian conditions, combining reduced risk with improved productivity.

Recent improvements in yield in the 1970s and 1980s have come from incremental additions such as better weed control from herbicides, improved machinery, reduced tillage and stubble retention, and the progressive introduction of semi-dwarf germplasm from the CIMMYT material into higher-yielding varieties. The yield advantage conferred by new varieties has been estimated to be half the total increase over the period 1965 - 1990 (Clements *et al.* 1992).

In the latter half of the 1980s, the introduction of non-cereal crops into rotations has also benefited cereal yields, wherever these more environmentally sensitive crops can be successfully grown. Pulses and oilseeds confer combined benefits of disease-break, better weed control, and improved soil-water use. As a result, agronomists now consider that these key elements of more productive systems for semi-arid environments embody many of the guiding principles of more sustainable systems (Australian Agricultural Council 1991).

The important elements for more sustainable systems are summarized in Table 2. Although we do not yet know whether the more sustainable systems will prove enduring in the long term, we do know that the less sustainable systems are inadequate, and liable to cause erosion (Edwards 1980), herbicide resistance in crop weeds (Powles and Matthews 1992), soil acidification (Helyar and Porter 1989), and yield reductions (Hamblin and Kyneur 1993), compared with their more sustainable counterparts.

Grain Production

Australia's cropping industries produce 12% of the wheat, and 15% of the barley that is traded on world markets. Because of the small domestic market (Australia's population even today is only 18 million) crop production has always been targeted towards export opportunities. With a perennial shortage of labor but much cheap land, Australian field crops are produced using low inputs and extensive techniques. Cereals have been the main traditional crop because they are adapted to a wide range of conditions, and show resilient performance under conditions of water deficit and nutrient constraints.

In comparison with other grain producers, Australia uses little fertilizer. In 1991, the combined $N + P_2O_5 + K_2O$ applied to agricultural land averaged only 22 kg/ha^{-1} compared with 75 kg ha^{-1} in India, 47 kg ha^{-1} in Thailand, and 117 kg ha^{-1} in Indonesia (FAO 1992). A single fertilizer application, and the herbicides which are applied either at sowing or at

Table 2. Key elements of sustainable cropping systems for rainfed crops

More sustainable	Less sustainable
Reduced tillage, using contact herbicides	Frequent (more than two) cultivations (often increasing to 6-8 for weed control)
Crop residue retention (with adequate stubble management to reduce pests)	Crop residues burnt (although often first utilized by livestock)
Use of lime and gypsum to alleviate acidification and deterioration in soil structure	No use of soil amendments
Long pasture phase (> 1 year) with high proportion of legumes	Short or no pasture phase, with few or no legumes in pastures
Crop rotations include non-cereals (or oats and rye) to improve the control of root diseases, weeds and pests	Crop rotations are confined to cereals (principally wheat and barley)
Regular fertilizer applications after adeqquate soil and plant testing	Little or no use of fertilizers to maintain adequate levels of P, N, S, and several minor/trace elements that are frequently deficient
Weed control by careful use of contact/ in-crop herbicides plus use of grazing animals and hay production to manage weeds in pasture phase	Over-reliance on herbicides to maintain weed control, or reliance on cultivation
Retention or planting of woody vegetation on watersheds along river banks and in gullies	All vegetation cleared. Lack of fencing to protect remaining native vegetation and river banks from stock

the seedling stage, are the only crop inputs used in most rainfed cropping systems. In the 1980s, when the number of agri-chemical applications to European field crops averaged between eight and twelve, Australian crops seldom received more than a total of three.

While the amount of fertilizer applied to grain crops has not increased much over the past fifteen years, the *type* of fertilizer has changed considerably. Imports of phosphate rock have declined since the early 1970s, and local production of phosphate fertilizers has given way to increased import of high analysis diammonium phosphate (DAP), triple superphosphate and monammonium phosphate. More than 50% of phosphate fertilizers are applied, not to crops, but to improved pastures (McLaughlin *et al.* 1991).

In contrast, the amount of nitrogen applied to crops has doubled between 1978 and 1990, with 50% applied as urea by the end of that period and 23% as DAP. These trends reflect the increased nitrogen requirements of higher yielding and higher protein grain crops, and the realization that the phosphate supply is now adequate in many older cropping soils which have received regular dressings since early in the century.

SUSTAINABILITY OF CROPPING SYSTEMS

Trends in Wheat Yields

Although sustainability cannot be judged from an assessment of yield alone, changes in the direction of yield response over time can be used, in combination with other sources of information on farming practices, to assess long-term sustainability. A recent study by Hamblin and Kyneur (1993) examined the yield trend over the past forty years. They found that wheat yields have increased steadily for the past forty years in some parts of the grain belt, but nearly 10% of the Statistical Local Areas (SLAs) which have grown wheat consistently over that period have had static or negative yield trends, and a third of the SLAs have had very slight yield increases. A statistically positive trend is associated with increased use of nitrogen fertilizers, grain legumes, reduced tillage systems and more conservative cropping intensities. Those areas where yield trends have been persistently low tend to have had a long history of very high cropping intensity (that is above 70% of land under crops every year).

Yield Stagnation in Sugarcane

Sugarcane has been grown along the northern coasts of Australia for over a hundred years. Areas of production are centered around mills, nearly all of which were established before the turn of the century. Many cane growing areas have therefore been practicing monoculture for between fifty and a hundred years. This has affected the average yield of sugarcane in the past two decades, which has shown a decline since the yield of raw sugar per hectare peaked in the late 1960s.

As a result of improvements in technical efficiency which have given higher mill extraction rates, rationalization has occurred, with some mill closures, and expansion in capacity at others. Since the potential for increasing the planted area is limited, there is considerable interest in increasing productivity per hectare, in order to maintain high milling efficiency.

Irrigation and drainage are important in increasing the regularity of the water supply to the crop (Bureau of Sugar Experiment Stations 1991). The proportion of the crop which received irrigation increased to 35% during the 1980s. Solutions to long-term yield improvement are also being sought in improved weed and pest control, breeding for improved resistance to root pathogens, and rotating or resting old cane land between ratoon cycles (Sugar Research and Development Corporation 1992). Erosion hazards, which are high in cane growing areas of high rainfall, have been markedly reduced by the practice of green-cane harvesting.

Response to Market Forces

Traditionally, Australia has been a supplier of bulk commodities to secure markets. The situation since the mid 1970s has changed dramatically, with increasingly strong trade competition and a deregulated market. Most world commodity prices have dropped steadily over this period. Farmers' terms of trade have also worsened. Increased on-farm productivity was one of the few strategies available by which individual producers could combat the erosion of their profit margins. Thus, farm output has risen at almost the same rate that terms of trade have worsened.

The other major adjustment that producers and traders have made is to diversify the end-product, not so much by processing it as by selecting specific quality traits required by particular markets. For example in wheat products, protein composition and content are key criteria. One third of Australia's wheat crop is now directed to Asian noodle markets, compared with less than 10% in 1980. Wheat sales to Asia have also risen to nearly 50% of wheat exports, often targeted to specific milled products.

The sugar export industry has had to weather enormous price variations within a short period, with swings from US$.09/kg to US$0.30 and back to US$.09 over the last decade. In Queensland, which grows 95% of the cane, there has been a considerable degree of government regulation over purchase and pricing structures, to smooth out the most severe effects of these fluctuations.

CONCLUSION

The Australian cropping industry has shown a number of ingenious adaptations to the constraints imposed by climatic and market risk, the problems of inherently low soil fertility, a small agricultural labor force, and distance from world markets. In the past two decades, as market forces have increased the cost-price squeeze, farmers and traders have adapted by:

- Reducing costs (inputs) through increasing mechanization, changing to cheaper products (fertilizers and out-of-patent chemicals), and extension of ratoon cycles in the case of sugar
- Increasing product specification, by improving post-harvest storage, commodity testing, segregation (of grains) and seeking alternative export markets for special categories of product (noodle wheats, refined sugar)
- Expanding the supply side of the industry by developing more land for production. This is a diminishing trend, however, and had almost ceased except in northern Australia by the 1990s
- Identifying alternative crops which can be introduced into the traditional cereal-

pasture rotations to give increased profits, spread market risks, and improve yields by widening the rotations

Despite these positive aspects there are a number of concerns relating to the sustainability of current production systems. In both wheat and sugar, two of the most valuable export crops, there are signs of yield stagnation or decline in some districts. These are related to the continued use of inappropriate monoculture or very restricted rotations, over-cultivation, and problems associated with weeds and diseases. The remedies for such yield declines are reasonably well established for the better production environments of the grain belt, but in more marginal (both very dry and very wet) environments, the reliability of more sustainable systems has still to be proven. In the case of sugarcane production, the option of alternative crops is only reluctantly used by producers because all the other crops give lower profits than sugar. Effective pricing signals that can act as incentives to producers to diversify or increase inputs may be required to gain widespread adoption of improved practices.

Another option is also available. During the 1980s, Australia developed a national Landcare movement (Campbell 1991). To date, some two thousand farmers and community groups have formed, to improve the agricultural environment through tree planting, rebuilding fences, adoption of soil conservation techniques and training. With very small incentives from government, these groups have adopted a wide range of land and crop management practices designed to rectify some of the problems described in this paper. Some 30% of primary producers are now associated with the Landcare movement (Mues *et al.* 1994). This is of particular importance in achieving a wide penetration of improved practices among that middle majority of farmers who are not normally able to achieve the greatest efficiency in crop production.

REFERENCES

Bureau of Sugar Experiment Stations. 1991. *Irrigation of Sugarcane*. BSES, Brisbane. 50 pp.

Campbell, A. 1991. Community participation - A new frontier in land management. In: *Sustainable Land Management*, B. Henriques (ed.). Proceedings of the International Conference on Sustainable Land Management. Hawke's Bay, New Zealand, 17-23 November, 1991, pp. 18-27.

Clements, R.J., A.A. Rosielle, and R.D. Hilton. 1992. National review of crop improvement in the Australian grains industry. *Report to the Board of the Grains Research and Development Corporation.* CSIRO Division of Tropical Crops and Pastures, Brisbane.

CSIRO, Division of Soils. 1983. *Soils, An Australian Viewpoint*. CSIRO/Academic Press, Melbourne.

Edwards, K. 1980. Runoff and soil loss in the wheat belt of New South Wales. *Agric. Engineering Conference, Geelong; Institute of Engineers of Australia*, pp. 94-98.

FAO. 1992. *Fertilizer Summary 1991*. FAO, Rome.

Fischer, R.A. 1986. Responses of soil and crop water relations to tillage. In: *Tillage*: *New Directions in Australian Agriculture*, P.S. Cornish, and J.E. Pratley (eds). Inkata Press, Melbourne, pp 194-221.

French, R.J. and J.E. Schultz. 1984. Water use efficiency of wheat in a Mediterranean-type environment. II. Some limitations to efficiency. *Australian Journal of Agricultural Research* 35: 765-775.

Greenland, D.J. 1971. Changes in the nitrogen status and physical condition of soils under pastures, with special reference to the maintenance of the fertility of Australian soils used for growing wheat. *Soils and Fertilizers* 34: 237-251.

Hammer, G.L. and R.C. Muchow. 1991. Quantifying climatic risk to sorghum in Australia's semi-arid tropics and subtropics: Model development and simulation. In: *Climatic Risk in Crop Production: Models and Management for Semi-arid Tropics and Subtropics*, C.R. Muchow, and J.A. Bellamy (eds.). CAB International, Wallingford. England, pp. 205-232.

Hamblin, A. and G. Kyneur. 1993. *Trends in Wheat Yields and Soil Fertility in Australia*. Bureau of Resource Sciences, Australian Government Printing Service, Canberra. 139 pp.

Hamblin, A. 1985. The influence of soil structure on water movement, crop root growth and water uptake. *Advances in*

Agronomy 38: 95-158.
Helyar, K.R. and W.M. Porter. 1989. Soil acidification, its measurement and the processes involved. In: *Soil Acidity and Plant Growth,* A.D. Robson (ed.). Academic Press, Sydney, Australia, pp. 65-82.
McLaughlin, M.J., A.R. Till, and I. Fillery. 1992. Operation of the phosphorus, sulphur and nitrogen cycles. In: *Australia's Renewable Resources, Sustainability and Global Change*. R.M. Gifford, and M.M. Barson (eds.). Bureau of Rural Resources, Proceedings No. 14. International Geosphere-Biosphere Programme Australian Planning Workshop, Oct. 3-4, 1990, AGPS, Canberra, pp. 67-116.
Muchow, R.C., A.E. Wood, M.F. Spillman, M.J. Robertson, and M.R. Thomas. 1993. Field techniques to quantify the yield determining processes in sugarcane. 1. Methodology. *Proceedings, 15th Conference of Australian Society of Sugar Cane Technologists.* Cairns, April 1993.
Mues, C., H. Roper, and J. Ockerby. 1994. Monitoring the achievements of Landcare: benchmark information from a national survey. ABARE Conference Paper 94. *20th National Conference of the Australian Farm Management Society, Canberra, 17-19 March, 1994.*
Powles, S.B. and J.M. Matthews. 1992. Multiple herbicide resistance in annual ryegrass (*Lolium rigidum*): A driving force for the adoption of integrated weed management. In: *Achievements and Developments in Combating Pest Resistance*, I. Denholm, A. Devonshire and D. Holloman (eds.). Elsevier Press, London.
Richards, R.A. 1991. Crop improvement for temperate Australia; Future opportunities. *Field Crops Research* 26: 141-170.

DISCUSSION

Dr. Effendi Pasandaran of Indonesia was interested in the concept of the economic optimum in the maximum use of fertilizer, and asked how Dr. Hamblin had incorporated the impact of negative external factors. She replied that to begin with, she had analyzed the efficiency of fertilizer applied to crops. For example in Western Australia, fertilizer efficiency is around 90%, and the environment is such a deficient one that there is very little loss of nutrients. In the case of sugarcane in Queensland, however, fertilizer efficiency is only 50%, and she felt that farmers should reduce fertilizer use until uptake and efficiency can be improved. In future, the Australian government agencies will probably develop ways of costing back to the farmer environmental damage such as the presence of nitrates in waterways.