ENVIRONMENTAL MANAGEMENT

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FOLLOWING 200 years of development, the values of the Australian community have shifted from a focus on economic development to a desire for a balance between economic and environmental sustainability. Today's community expects landholders to act as stewards of their farm, to manage land in a way that will maintain the integrity of soil and water resources and minimise impacts on the environment. Additionally, the prosperity of farming enterprises relies on the sustainable use of soil and water resources. Farmers are generally aware of the importance of maintaining their natural resource base and many are showing an increasing interest in the health of the environment in which they live.

Rural landscapes comprise components of the natural environment, as well as those that have been modified to provide for food and fibre production. The expansion in the world's population and the rapid progression in technology have placed increasing strain on both agricultural and natural systems throughout the world. This development has led to considerable concern over the condition of the environment and the long-term sustainability of current management practices.

Today, environmental management is a key priority at local, national and international levels. Australia is signatory to several international treaties related to the environment. Most notable of these is Agenda 21—the international agreement on ecologically sustainable development. Australia's response to this treaty is outlined in the National Strategy for Ecologically Sustainable Development. This strategy defines ecologically sustainable development as 'development which aims to meet the needs of Australians today, while conserving our ecosystems for the benefit of future generations'.

The selection of suitable land for growing cane and many aspects of farm management must be suitably managed to minimise adverse environmental impacts. The adoption of appropriate farming practices will ensure the long-term sustainability of soil and water resources, minimise impacts on downstream environments, protect or enhance regional biodiversity, and develop positive community relations.

In Australia, community expectations for environmental protection have led to initiatives such as Landcare and Integrated Catchment Management. New regulatory frameworks have been developed to enforce these expectations for good environmental management. Along with increasing demands for good environmental management, sustainability has become a matter for survival. Many rural industries, both in Australia and overseas, have determined that they must adopt best farm-management practices, and embrace the concepts of sustainable agriculture simply to stay in business.

SUGAR INDUSTRY INITIATIVES

Many environmental issues face the sugar industry, both on-farm and off-farm.

Environmental protection is best considered in two areas: expansion onto new lands for canegrowing and the management of developed farms.

The concept of environmental care is not new to the sugar industry. It has long been recognised that productive sugarcane growing relies on the sustainable management of soil and water resources. More recently, there has been a focus on the potential impacts of cane production on the off-farm environment (in particular on aquatic and marine ecosystems) and on regional biodiversity. The location of canegrowing regions along a narrow coastal strip adjacent to the unique ecosystems of the Wet Tropics World Heritage Area and the Great Barrier Reef places the industry under particular scrutiny to minimise any risk of environmental harm.

The sugar industry in Australia has responded to these concerns by taking a proactive approach to environmental management. Vision 2000, the industry's 1995 view for the future, saw a 'sustainable, competitive raw sugar industry which is environmentally responsible' and addressing community concerns. This proactive approach to environmental issues has resulted in some significant achievements by the industry.

Do canegrowers identify with the goals of sustainable development? The majority of Queensland's 6500 cane farms are family owned and operated. Many growers explain that sustainability to them is about passing on the farm in as good, or better condition as when they began to manage it. Management decisions made on the farm can be influenced by the fact that the farm is often also the home. Studies have shown that farmers whose successors are planning to take over the farm are more likely to implement practices with positive environmental outcomes. Many canegrowers are keen recreational fishers and are interested in minimising impacts on fish stocks. Many sustainable canegrowing practices offer not only environmental benefits but also financial or lifestyle incentives.

Environmental audit

In 1995, CANEGROWERS commissioned an independent Environmental Audit of the Queensland canegrowing industry. The audit assessed the environmental performance of the industry according to: (1) any off-farm impacts—by identifying waste streams and potential sources of pollution; (2) level of compliance with regulations and policies; and (3) activities related to ecological and social impact. The audit was undertaken throughout Queensland by an independent consultant to the ISO 14010 standard and the report was made publicly available.

Generally, the audit indicated a reasonably good standard of environmental management on cane farms. The report highlighted a need for more information about environmental issues and how they relate to canegrowing.

The 156 recommendations were reviewed by the industry to determine how best to respond to them. They were grouped in four major areas: the management of soil and water resources, the protection of natural ecosystems, the storage, handling and disposal of dangerous goods and wastes, and education and communication. These issues and recommendations then formed the basis of CANEGROWERS' Environmental Management Strategy.

Negotiating agreements

With the introduction of the *Environmental Protection Act 1994,* caring for the environment became a legal requirement, establishing for all Queenslanders a 'duty of care' to the environment. To meet this requirement, there was a need to define just what are 'reasonable and practical measures to minimise risk of harm to the environment' for an industry.

Environmentally relevant activities (ERAs) are required to have an environmental authority or licence. Industries with point-source emissions, such as sugar mills, are required to have an environmental licence. The number of licences required can be reduced if the organisation adopts an approved, integrated environmental management system. While these systems may be effective in many situations, they are far more difficult to apply to diffuse sources such as most agricultural systems. Environmental licences are quite onerous for a farm operator and were not developed in a manner suitable for agriculture.

Keen to avoid cumbersome environmental legislation, as has been imposed on primary producers in Europe, Queensland's farming groups advocated industry self-regulation. As a result, the *Environmental Protection Act 1994* makes provision for industries to develop Codes of Practice for endorsement by the Minister for the Environment as subordinate legislation. Queensland Farmers' Federation, representing Queensland's rural sector, developed the generic 'Environmental Code of Practice for Agriculture' for all rural industries. This Code was developed in consultation with industry and conservation groups and agreement was made that commodity groups would develop specific guidelines to complement the code.

In 1995, CANEGROWERS and BSES initiated industry consultation towards the development of industry specific guidelines. Following substantial industry and government involvement, the '*Code of Practice for Sustainable Cane Growing in Queensland*' ('the Code') was endorsed in April 1998 by the Queensland Minister for the Environment. Although compliance with this code is voluntary, demonstrated adoption of the recommendations of the Code will be a good first line defence in the case of any legal action over farm activities.

One of the most important roles of the Code is in defining what are currently regarded as sustainable farming practices. Concerns from canegrowers, governments and the community have identified the need for a clearer understanding of how canegrowers can care for the environment while producing a profitable crop. It is now better understood that good farming practices can translate to good environmental management. Further details are available in BSES manuals and this Manual. The Code draws on the knowledge of farmers, researchers and extension officers to document accepted good farm practice. It covers issues ranging from irrigation and nutrition through to waste management and chemical storage. The first section is dedicated to considerations for the development of new areas for sugar production, while the second considers the management of existing canelands. Generally, these are practices that good farmers are already employing or can readily adopt.

The Code has provided a new mode of collaboration between industry and government. This has provided a framework for further negotiations with governments to develop agreed guidelines for farm management to comply with other legislative requirements. For example, through the collaboration of industry and the Queensland Fisheries Service, a strategic permit system has been developed for maintenance activities in areas where marine plants grow.

In New South Wales, the sugar industry has worked with growers, community groups and government agencies to develop agreed management plans for acid sulfate soils. This approach has seen a significant improvement in relations with the community. By working with the community and government, the industry is able to address environmental concerns and ensure that cane farming can continue in harmony with the community and the environment.

A grower survey undertaken in 2000 has indicated strong support for self-regulation with two-thirds of Queensland growers indicating that they believe the Code is a benefit to the industry. In New South Wales, 95% of growers consider it important to have best practice guidelines.

Legislation

A large number of Commonwealth, State and Local legislations and regulations need to be taken into account when carrying out farming activities. Some of these are specifically related to sustaining the natural resource base. Legislation is changing rapidly and progressing, reflecting the rapid changes in community concerns.

CANELAND EXPANSION

Land suitability

In assessing the suitability of a site for growing cane, consideration must be given to the natural features of a site: soil type, rainfall or irrigation availability, slope, natural ecosystems, and other features such as distance from a mill, transport arrangements, economics and impacts on neighbours.

Early agricultural settlements selected areas which were most suitable for crop production on the basis of rich fertile soils, ease of clearing, slope, irrigation supplies and proximity to transport facilities. As the proximity of farms to mills was also a key priority, sugar mills are found in areas of highly productive lands. As a result, lands now available for development are, for the large part, those regarded as more marginal for cane growth. Additionally, new technologies in transport, irrigation, fertilisers and the adoption of green-cane trash-blanketing have made cropping possible on lands previously considered unsuitable for canegrowing.

Soils vary greatly in their composition and characteristics. This variation is a reflection of the climate, geology, relief, biological activity and time over which they have been formed and weathered. As the sugar industry straddles much of this variation, sugarcane is grown on almost all the major soil types and across many climatic conditions. This variability has implications for the suitability of land for growing cane and for many aspects of farm management. Land resource information has been mapped for many districts by soil surveyors. These maps, available from the Department of Natural Resources, classify the suitability of land for growing cane. In addition to the importance of understanding soil characteristics and behaviour for cane expansion decisions, it is also important to consider selection of appropriate varieties, nutrition programs, irrigation, drainage and many other management decisions.

Planning

Although sugarcane occupies only a small proportion of the catchments in which it is found (Table 1), it is the major contributor to regional economies in many districts. However, cane farms are located in areas where competition for land use is high. Competing land uses, such as urban development, tourism and industry, have resulted in the loss of some areas of good quality soils from agricultural production. Conversely, agricultural development has spread to areas less suited to cane production or to areas of conservation or recreational value.

Table 1. Prominent land uses in selected Queensland catchments

Catchment	Area '000 ha	% of catchment								
		Timber	Pristine	Grazing	Sugar	Bananas /fruits	Vege- tables	Grain	Other crops	Urban
Daintree	213	37.7	31.7	26.7	1.8	0.04	0.03	0	0	2.0
Mossman	49	30.4	11.0	44.6	10.0	0.07	0	0	0	3.9
Barron	218	36.4	2.0	47.7	2.1	0.55	0.80	3.2	0.18	6.9
Mul/Russell	202	16.9	25.1	38.9	13.1	0.15	0.02	0	0	5.8
Johnstone	233	25.3	12.8	41.6	14.8	0.89	0.01	0	0.20	4.4
Tully	169	62.5	2.1	20.7	9.6	1.53	0	0	0	3.7
Murray	114	32.9	27.3	29.6	6.1	0.88	0.02	0	0.01	3.3
Herbert	1013	9.5	9.7	71.1	6.6	0	0	0	0.36	2.7
Black	108	18.0	9.3	67.4	0.7	0	0.40	0	0.04	4.2
Haughton	365	0.8	10.8	74.0	10.4	0.36	0.05	0	0.10	3.5
Burdekin	12 986	1.0	1.3	94.8	0.2	0.01	0.04	0.5	0.22	2.0
Don	389	0.2	2.6	91.3	1.1	0.05	1.63	0	0.03	3.1
Proserpine	249	9.6	4.0	74.6	7.5	0	0	0	0.01	4.3
O'Connell	244	7.6	4.4	70.5	11.1	0	0	0	0	6.5
Pioneer	149	22.7	6.1	48.5	17.9	0	0	0	0.05	4.7
Plane	267	4.3	2.9	67.4	21.0	0	0	0	0	4.4
Fitzroy	15 264	6.7	2.3	87.5	0	0.01	0	2.0	1.27	0.2
Baffle	386	12.2	4.4	75.9	0.4	0.09	0.03	0	0.34	6.7
Kolan	298	12.5	0	79.0	4.5	0.05	0.04	0	0.18	3.8
Burnett	3315	12.9	0.4	79.9	0.8	0.11	0.05	1.6	1.03	3.2
Burrum	334	26.9	6.3	53.4	8.8	0.02	0.08	0	0	4.5
Mary	960	28.3	0.6	64.5	1.2	0.03	0.03	0	0.60	4.8

(Timber includes State Forests and Timber Reserves; Pristine includes National Parks, National Parks (scientific), Conservation Parks and Resource Reserves; Other crops include cotton, sunflower, peanuts, irrigated forage crops, etc.; Urban includes roads, railways, watercourses, dwellings, and aquaculture.)

Source: Rayment, G.E. and Neil, D.T. 1996. Sources of material in river discharge. In 'The Great Barrier Reef—Science, Use and Management'. Proceedings of a National Conference, Townsville 25-29 November 1996. (Reef CRC, GBRMPA and James Cook University, Townsville.) 42-58.

Land-use planning measures are needed to ensure the protection of good quality agricultural land and to minimise the impacts of cane expansion on the natural resource base. State planning policy in both Queensland and New South Wales aims to protect good quality agricultural land from unplanned development.

The supply of sugarcane to Queensland mills requires an approved cane production area (previously known as 'cane assignment'). Any new developments for sugarcane production must be approved for supply to the mill by a local board (Cane Production Board).

This board, comprising growers and millers, seeks advice from state agencies and BSES on the suitability of the land for production. Since the *Sugar Industry Act 1999*, these decisions must also consider requirements for environmental or sustainability issues. As a result, regional guidelines for the granting of cane production areas are being further developed to incorporate these considerations.

Typically, the decision will consider the suitability of soils for canegrowing, farm layout, buffer zones, endangered or threatened status of natural ecosystems, mill capacity and transport arrangements.

NATURAL ECOSYSTEMS

Australia boasts a wide diversity of vegetation communities that have evolved to suit the range of climatic, soil and cultural conditions in which they grow. Each of these vegetation types form unique ecosystems supporting a range of animal life. For these plants and animals to survive, large enough areas of each vegetation type to support a whole ecosystem must be preserved.

The most obvious threat to the natural environment is the clearing of lands for rural or urban development. The clearing of land for agricultural development was an heroic effort on the part of the early settlers, but today, we are discovering throughout Australia the costs of over-clearing. Currently, 40% of Queensland's regional ecosystems are considered under threat. In addition to the direct loss of vegetation communities, there are secondary impacts of over-clearing, including degraded waterways, erosion and salinity. Some parts of the landscape, such as ephemeral wetlands and riparian buffer zones, serve as natural buffering systems, filtering nutrients and sediments from run-off water. The loss of these ecosystems can have an additional impact on water quality and regional hydrology through the loss of that buffering capacity.

Sugarcane is grown primarily along the coastal floodplains along a 50 km strip of Australia's eastern seaboard and in the Ord River region of Western Australia. The areas along the eastern coast cover five biogeographic regions—the Wet Tropics, northern Brigalow Belt, Central Mackay Coast, South East and North Coast, each of which contributes to Australia's standing as one of the world's 'mega-diverse' nations. The Wet Tropics bioregion alone is regarded as one of the world's richest in plant diversity.

Extensive clearing of these catchments has occurred both for canegrowing and other land uses. Large areas of *Melaleuca* (paperbark) have been cleared from the coastal floodplain to prepare land for sugarcane with only remnants remaining. In addition to the loss of this ecosystem, the buffering function of these areas was important in protecting waterways and estuaries.

Industry policy supports the retention of riparian buffer zones, permanent and ephemeral wetlands and areas of high conservation value. Commonwealth and state legislation related to the clearing of natural vegetation need to be taken into account on both crown and freehold land.

Waterways, waterbodies and riparian zones

Streams, rivers, lagoons, lakes and swamps are vital components of the landscape, often referred to as the 'ecological arteries' of a landscape. The vegetation that fringes these waterways and waterbodies is also an important landscape feature, providing an important interface between aquatic and terrestrial systems.

Much of the rich natural biodiversity of the coastal floodplains where sugarcane is grown is reliant on these wetlands and riparian zones. Through clearing, drainage, and the movement of sediments, nutrients and agricultural chemicals, sugarcane growing has the potential to adversely impact on these vital systems. Sustainable farming practices must ensure that the integrity of these systems is not compromised. In areas where degradation caused by clearing of the riparian zone is evident, rehabilitation of riparian zones and restoration and reinstatement of wetlands are needed to return a more balanced riparian and wetland function to the landscape.

Streams, rivers and other waterways are fundamental to the hydrology of a catchment. A large proportion of the water falling in a catchment flows via run-off or perched groundwater to waterways. This water carries with it solutes and sediments, derived from weathering and erosion or pollutants from land uses. Waterways also support a range of aquatic life. The downstream flow of water carries with it carbon (energy) from terrestrial ecosystems in the form of leaf litter. This organic matter is consumed by organisms, broken down and transported further downstream, forming the basis of the aquatic food chain. Dams, weirs and the consumption of water for irrigation, urban or industrial uses, together with increased run-off and pollution rates, will affect the functioning of these waterways.

Lakes, lagoons, billabongs, swamps and other waterbodies are among the world's most productive ecosystems. They generally occupy depressions in the landscape, trapping much of the material carried in overland flow. The improved moisture conditions and rich soils formed by nutrient in-flow support a high diversity of habitats. Features such as where they are found in the landscape (near-shore marine, estuarine, etc) or their period of inundation (ephemeral, perennial) are used to describe wetland types.

Since European settlement, over half of Australia's wetlands have been drained, reclaimed or destroyed. Those that remain are some of the nation's most threatened ecosystems. This is particularly evident along the eastern coastal zone where development for agriculture (including sugarcane) and urban uses has been concentrated.

Wetland and waterway functions

Wetlands regulate the movement of water within a catchment, they store precipitation and surface flow and release it to other surface water bodies, groundwater systems and by evaporation to the atmosphere. Water in a wetland helps to maintain watertables, exerting hydraulic head that provides for groundwater recharge and discharge to other waterways and waterbodies. This regulation of flow controls the rate of water discharge from a catchment, slows flow, mitigates flood damage, reduces the risk of salt-water intrusion and protects the landscape against erosion.

The fluctuation of water levels affects some geochemical processes such as oxidation-reduction (redox) reactions. This, in turn, influences nutrient cycling, sediment and organic matter accumulation, decomposition and export, and the adsorption and transport of potentially toxic elements. Their biogeochemical cycling and storage capacity, particularly for carbon, nitrogen, sulfur, organic compounds and metals, is an important ecological function and effectively removes potentially toxic elements from the water column. Nitrification and denitrification processes in wetlands may remove 70–90% of nitrogen from water with the alternating redox conditions and high organic matter content in wetlands maximising denitrification. As the biological and chemical processes remove phosphorus that enters wetlands in solution or attached to suspended particles, floodplain wetlands are important elements of the phosphorus cycle.

Conservation and restoration of wetlands

Floodplain wetlands have been reduced by up to 70% in some sugar-growing catchments while the need for them has further increased due to the higher nutrient loads in waterways. Drainage, levee banks and increased run-off rates alter the hydrology of wetlands and the flood plain in general. Vegetation removal and water quality decline are also impacts of agricultural activities. The removal of water retention basins, natural wetlands and lagoons, combined with increased run-off rates through constructed drainage systems, can lead to more frequent and higher levels of flooding and increased erosion in lower parts of the catchment. For these reasons, it may be necessary to restore degraded wetlands and create artificial lagoons to return a more sustainable balance to some catchments.

The impacts on existing wetland systems should be minimised by appropriate land development strategies. Drainage design should be undertaken on an integrated, sub-catchment basis, making use of natural and constructed retention basins. Designs should consider the preservation of natural retention (wetland) basins and riparian zones, identify critical habitat areas and maintain natural drainage lines. Development of parallel drainage systems should augment natural waterway capacity and watertable depth.

Wetland restoration works may need to incorporate strategies for rubbish and weed removal, erosion and sediment control, improving native vegetation (revegetation), creating habitat, allowing for fish passage, and minimising the entry of harmful run-off.

Water retention basins or artificial wetlands/lagoons may be constructed to capture and moderate agricultural run-off, slow run-off velocity and allow the settling of nutrient laden silt, and provide for wildlife habitat. In some cases, tailwater recycling dams may also provide some of these values. The water retention and wildlife values of retention basins can be best achieved where a drainage master plan is used. Creating an artificial lagoon on a low lying, wet area of the farm can be an effective means to provide wetland functions, overcome weed problems in that area, and improve productivity on adjacent blocks.

Retention or detention basins may be created by the construction of a wall or embankment in low lying areas of the property where they will catch run-off water. Artificial lagoons are constructed by excavating into the existing watertable. Lagoons are best constructed in low lying areas that are not currently viable to cultivate. Care should also be taken to avoid causing harm to any adjacent, shallow but viable, natural wetlands. The removed spoil may be used to build-up low lying paddocks, increasing their productivity by reducing waterlogging. Soil tests should be taken prior to construction to ascertain whether acid-sulfate soils are present. Mildly acid-sulfate soils may be treated with lime. However, lagoons should not be constructed in areas of significant risk.

A number of factors should be taken into consideration when designing and constructing lagoons or detention/retention basins. The surface area should be as large as possible with areas that have a depth of at least 5 m during the driest period. This will help reduce the risk of the waterway being entirely choked by water weeds and provides a refuge for fish during the driest periods. Orientating the lagoon in line with prevailing winds improves oxygenation and will help improve fish habitat. A shallow, well-vegetated input drain will avoid lowering the watertable. A broad entry point on this drain will slow in-flowing water and encourage silt to settle. The outflow should be unrestrictive to allow fish to enter. A habitat island can provide predator-free nesting opportunities for birds and encourage silt deposition in the lee of the island. After excavation is completed, topsoil should be redistributed around the edge of the lagoon to improve plant establishment. Establishing a buffer of trees around the edges will shadeout weed growth, prevent over heating of the water at the surface, and provide roosting and nesting sites. Depending on lagoon size, the windward side may be left without trees. A shallow margin with sedges and similar plants should be vegetated to encourage deposition of suspended particles close to the edge for future excavation. These plants also provide habitat for many juvenile fish and water birds.

Introduced weeds threaten the viability of both natural wetlands and constructed detention/retention basins and artificial lagoons. They trap silt in waterways, smother habitat, outcompete native species, and deplete dissolved oxygen levels. There are many species of weeds that impact on the ecological function of wetlands. Possibly the greatest threat is from those weeds once promoted for ponded pastures, such as para grass (*Brachiaria mutica*) and *Hymenachne*. Their ability to compete with native plants reduces biodiversity and greatly affects ecosystem dynamics. Controlling the spread of these weeds through both natural and constructed drainage networks and wetlands is a considerable cost to landholders. Effective control of waterweeds requires a coordinated, whole catchment approach.

Riparian zone function

Aside from the quantity of water, riparian vegetation is the most significant factor influencing the features of streams and other wetland systems. The function of the riparian zone varies with the stream type and location in the landscape. The characteristics of the riparian zone will reflect the environment in which they are found. The lowland, higher-order streams typically found in sugarcane areas commonly have complex channels, extensive floodplains and complex riparian systems, adapted to valley floor environments.

Riparian vegetation provides variation in channel form that affects the patterns of water flow. Vegetation close to the stream also contributes snags or large woody debris that add roughness to the bed shape, providing habitat diversity, variable flow patterns and trapping organic matter and debris. Shading of the waterway by riparian vegetation shades out weeds that can retard flow, trap sediment and degrade stream quality. It also keeps water temperatures lower and more stable—diurnal temperature fluctuations may be 2.5 times greater in unshaded streams than shaded streams. Lower water temperatures maintain higher dissolved-oxygen levels and the regulation of temperature fluctuations is important for the survival of many fish and insect larvae.

The binding of tree roots reduces bank erodibility and vegetation provides a buffer against flood damage by slowing the flow of flood waters over the bank. Removal of the riparian zone and snags has led to stream sedimentation and resulted in bed widening. The slowing of flood waters also causes sediments and nutrients to be deposited on the floodplain rather than entering the stream. Wide riparian zones have a greater ability to slow floodwaters, reducing the erosive effects of floods and filtering nutrients, sediments and debris before they enter the stream. Significant proportions of both dissolved nutrients and those attached to sediments are intercepted by riparian vegetation.

Leaf litter and other detritus from riparian vegetation provide the major carbon food source for the aquatic food web. Where the riparian canopy cover is reduced, the aquatic system shifts from a net consumer to a net producer of organic carbon, with palatable micro-algae replaced largely by unpalatable species. Fruits and insects resident in or produced by the riparian zone are also important sources of food for aquatic species, such as turtles and fish.

In addition to the values they provide for in-stream ecology, riparian zones provide habitat and food for a diversity of terrestrial species. Many of the bird species found in a district rely on riparian zones. Where a riparian zone is continuous, it provides a valuable corridor for animal movement and the dispersal of plant species. Unfortunately, many riparian zones are no longer continuous as a result of clearing. They do still provide some corridor function, but are less effective.

Restoring the riparian zone

Traditional techniques for stream management have focussed on the control of flooding and erosion. Hard engineering solutions were generally used with little attention paid to the value of riparian vegetation, snags and variation in bed form. The dynamic nature of streams and their ecological function were not catered for. More recently, research has focussed on stream rehabilitation and re-establishing the riparian zone.

Benefits from reinstating the riparian zone identified by canegrowers include decreased erosion, stabilised watercourses, trapping of nutrients, improved water quality, rat control, decrease in insect pests, savings on pest control, healthier ecosystems, increased fish stocks, wildlife corridors, decreased algal growth, improved farm safety, protection from floods and climatic extremes, increased farm values, and aesthetic appeal. They may also provide opportunities for diversification and reduced rates and taxes. The increasing awareness among canegrowers of the value of revegetation is evident in that over 1.1 million trees were planted in canegrowing regions between 1997 and 1999. Many of these would have been planted in riparian areas. Government-sponsored programs have been available to assist in meeting the costs and providing suitable advice for revegetation programs.

In some situations, encouraging natural regeneration may be sufficient. Fencing of the area, control of weeds and fire management will assist regeneration. The success of regeneration will depend on soil condition and erosion, the presence of woody weeds, vines and grasses, proximity to seed sources, hydrology, grazing pressure, adjacent land use and fire. For example, in tidal reaches, mangroves establish particularly well by natural regeneration.

Revegetation programs require careful planning, site preparation, planting and maintenance. Costs associated with revegetation vary depending on planting density, accessibility to machinery, labour requirements and seedling propagation. On-going maintenance of revegetation sites is crucial for at least the first 2-3 years. Weed growth will be suppressed if the plantings are at a high density and include species that will rapidly establish canopy cover.

Species selection may include a full range of species for re-establishing a riparian forest or a few pioneering species may be selected to control weeds and allow other species to establish by seed from surrounding remnant forest. As this latter technique relies on seed sources from surrounding forest, it is best suited for small gaps or margins of existing forest. Direct seeding may be used but the results are variable. The intense weed competition experienced in the tropics generally limits the success of direct seeding.

Fisheries habitats

Fisheries habitats provide fish, prawns and other aquatic life with food, shelter and migratory paths. Coastal waterways adjacent to cane farms are important for fisheries, as 80% of the commercial catch and much of the recreational catch is made up of fish species that, for at least a part of their life, rely on shallow marine and estuarine habitats.

Seagrass and mangrove habitats are the powerhouses of these highly productive areas. Some fish live solely in these areas, while others, such as mangrove jack and barramundi, migrate up and down streams at different stages in their lifecycle. Inappropriate drainage works or overclearing of the riparian zone may degrade these resources. Most noticeable is the direct removal of fisheries habitats for urban, rural and industrial developments.

In Queensland, marine and estuarine fish habitats are protected by the *Fisheries Act 1994* which requires permits for the disturbance of any marine plant—be it living, dead, standing or fallen.

As many cane farms are found adjacent to areas of valuable fisheries habitat, a strategic marine plant permit system has been developed to simplify the approval process for on-farm drainage maintenance activities. The permit is obtained by the CANEGROWERS' District Executive on behalf of all growers in the district. Growers must attend an accreditation course before they use the permit.

With good management, both fresh and brackish water in creeks and drains on cane farms can provide valuable habitat for fisheries. Marine plants often establish in farm drains, forming valuable fisheries habitat. On-farm drains collect and channel water using the same hydrological functions as a creek.

As fish will use drains the same way as a creek, drains leading to permanent water should be designed to facilitate fish movement, along with the maintenance and improvement of water quality.

Structures that divert or constrict flow will increase channel velocity and may act as a barrier to fish migrations. Increases in channel velocity can be particularly damaging to the dispersal of larval fish. In areas of permanent standing water, drains should be designed to flow at velocities of no more than 0.3 m/sec. Velocities as high as 1 m/sec can be tolerated for short distances. Stream crossings can funnel water into a high velocity that prevents fish passage. To facilitate fish movement, bridges should be used for drains and creek crossings, with little or no structure in the water. If culverts must be used, they should be of the box type and as large as possible.

Drains that dry out may act as fish traps, and fish excluder devices may be advisable in some situations. However, many of these intermittently flowing drains are valuable from a fisheries perspective. Deep permanent water holes at intervals along the drains will reduce fish deaths in dry periods.

Water quality affects the fish habitat value of a waterway. Water aeration can be a problem in some drains, particularly if the bed is of an even form or groundwater enters the drain. Rock piles may be placed across the drain to enhance water tumbling and, hence, aeration. Care must be taken to ensure that these rock piles are placed in such a way as not to cause erosion.

Water weeds cause major degradation of fish habitat values. If weeds are to be mechanically removed, a weed rake fitted to an excavator arm is recommended in place of a bucket to minimise soil disturbance, particularly in areas of acid-sulfate soils.

Wildlife

Canegrowers may encourage wildlife around their farms by protecting or enhancing habitat for species native to the district. Riparian corridors, bushland, wetlands and artificial lagoons can all provide valuable habitat for native birds, fish and other animals. It may take many years before revegetation areas are established sufficiently to provide a full range of habitat values. For example, the loss of old trees with natural hollows has reduced the number of potential nesting sites.

Some canegrowers have installed nesting boxes in trees to encourage owls around their farms. As well as the wildlife benefit, owls feed on cane rats and may help to reduce rat damage to cane. These nesting boxes may be constructed from hollow logs or, preferably, from ply (Figure 1). A six-sided construction is used to avoid owl chicks being squashed in corners. The nest box should be installed 6-10 m high in a tree resting in a natural fork. One side of the nest box is strapped close to one trunk while the access hole is faced towards the branch of the opposite fork of the tree.

Construct from 12 mm structural ply, using the rough side on the inside of the box to make it easier for owls to crawl out. Fill the base with fine woodchip or shavings to a depth of 100 mm. Rest the box in the fork of a tree and attach using galvanised strapping.

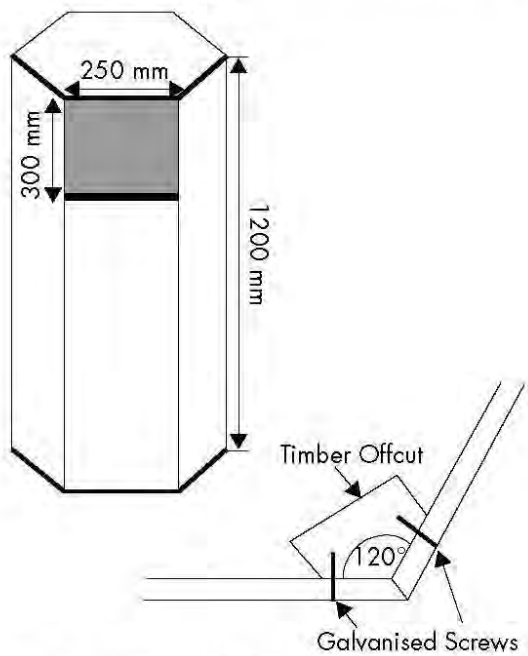

Figure 1. *Constructed owl nesting box.*

Source: Herbert River Catchment Coordinating Committee

Installing an owl nesting box constructed from a hollow log.

FARM FORESTRY

Farm forestry plantations managed for timber production may provide an additional source of future income for canegrowers, using land that is not generally suited for growing cane. Selective harvesting will enable landholders to obtain a direct financial gain from their revegetation areas. However, commercial timber plantings do need to be managed as a crop if the objective is to produce good quality timber. Timber plantations are sometimes difficult to manage and harvest in areas such as riparian zones. In these areas, it is best to establish vegetation that is not used for commercial timber production. Forestry plantations are very well suited to flatter, easy-to-access areas and can be used to provide a valuable buffer between cane-growing land and riparian zones or areas of high conservation value. Some canegrowers have replanted creek banks as a revegetation zone and supplemented this with commercial timber plantings for a 10–20 m strip along the top of the bank. This provides for many riparian zone functions, while also allowing for commercial potential from the less sensitive areas.

In some regions, trees are planted in buffer areas and branches harvested for the cut-foliage market or other alternative income streams. Advice on establishing and managing on-farm forestry plantations, plus the best species to grow, is available from a range of sources, including the Department of Primary Industries. Training programs are available to those interested in learning more about forestry techniques including the Master Tree Growers program.

The main activities in establishing and managing a timber plantation are site preparation, establishment, weed control, pruning, thinning and harvesting. Site preparation, establishment and weed control are similar to those for revegetation sites, though with forestry plantations trees may be planted wider spaced and in rows to allow slashing. The time to produce harvestable timber will vary with region, climate, soil type and tree species. In northern regions, the first harvest is likely to occur at 25 to 35 years for eucalypts and 35 to 45 years for hoop pine. Most of the high-value rainforest timber species take between 40 and 75 years to reach a harvestable size.

WATER QUALITY

Water quality refers to the solutes carried in water and the temperature of the water. These solutes may enter water through natural processes or from human activities. Some natural processes, such as erosion, may be increased by human activities. The diffuse sources of pollution coming from agricultural lands are difficult to measure and to control, particularly those following storm events. Sediment, nutrient and pesticide losses are the major issues of concern from rural lands. Mobile nutrients or pesticides may be transported to streams either through run-off or through deep leaching to groundwaters that discharge into streams. Less mobile pollutants are transported primarily attached to sediments. The scale of effect of these contaminants on aquatic systems depends on their concentration, trends and bioavailability.

Changes in water quality can impact on the aquatic ecosystems within waterways and may also impact on the estuarine and marine systems into which they flow. The removal or degradation of riparian zones and wetland systems has had deleterious effects on water quality.

Management strategies for water quality take into account the environmental values to be protected, the management objectives, performance indicators, monitoring programs and management responses. Guidelines for desired water quality parameters for fresh and marine waters are outlined by the Australia and New Zealand Environment and Conservation Council. Guidelines for aquatic ecosystems, aquaculture, agricultural water use, recreational and aesthetic purposes, and drinking water have been prepared, along with guidelines for monitoring and assessment.

In most cases, discharges from canelands are within water quality guidelines most of the time. Water quality declines after certain events or further downstream. Nutrient losses are the highest above natural levels in the Wet Tropics, the O'Connell River, Pioneer River and Plane Creek catchments. Efficient nutrient and pesticide management, soil conservation measures and riparian management are needed to minimise adverse impacts on water quality.

Impacts on freshwater environments

Stream ecology is dependent on both the quality of water and the quality of the habitat. The habitat quality is influenced predominantly by riparian condition. The quality of the water is influenced by the riparian condition and by the loading of solutes and sediments entering the water in run-off or groundwater.

Nitrogen and phosphorus are generally found naturally in streams at low concentrations. They are essential components of the foodweb. Concentrations of both of these elements can be elevated due to run-off from farming lands. Eutrophication can occur where the balance of the nutrients is altered, leading to algal blooms and excessive growth of water plants and weeds.

Short-term, chronic effects can occur if high levels of insecticide movement enter waterways. Insecticide usage in the sugar industry is relatively low and, as most are buried in the soil, are not very mobile. The long-term effects of trace concentrations of these insecticides and of herbicides are not well known.

Impacts on marine environments

The sugar industry is under particular pressure to minimise its impacts on water quality due to its close proximity to the Great Barrier Reef (GBR). The greatest source of nutrients added to the GBR lagoon is from terrestrial run-off. However, it is thought that these terrestrial inputs are minor relative to the total movement of sediment within the GBR lagoon itself. In the past 150 years, terrestrial run-off has increased four fold. On average, the discharge from all river systems draining into the GBR carries 23 million tonnes of sediment, 77 000 tonnes of nitrogen and 11 000 tonnes of phosphorus each year. The major contributions to this come from grazing, canelands and sewage.

Following flood events, sediment-rich flood plumes extend for many kilometres from a river mouth. Figure 2 illustrates the strong effect of flood events on sediment movement to waterways in the Wet Tropics. These flood events account for most of the water, sediments and nutrients discharged from river systems into the GBR lagoon. Freshwater, sediment and nutrients in these flood plumes may affect the structure and dynamics of benthic populations on near-shore reefs.

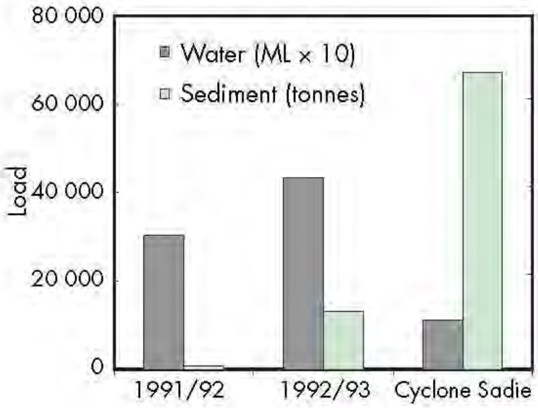

Figure 2. *Comparisons of river discharge and sediment yield in the few days of Cyclone Sadie with the total sediment yield and flow from each of the previous two years. Data are for the South Johnstone River at South Johnstone.*
The catchment area is 399 sq km, and includes 85% rainforest, 6% beef pasture, 5% cane, 2.4% dairy pastures, and 1% bananas.

Source: Hunter, H.M., Walton, R.S. and Russell, D.J. 1996. Contemporary water quality in the Johnstone River catchment. In: Hunter, H.M., Eyles, A.G. and Rayment, G.E. ed. Downstream Effects of Land Use, Queensland Department of Natural Resources, Brisbane, 339-345.

Runaway agricultural inputs have the potential to affect the GBR through elevated phosphorus inputs (weakening coral skeletons), accelerated algal growth from elevated nitrogen and phosphorus levels, or through increased sediment loads that can smother corals, reduce light infiltration and prevent the settlement of coral larvae. These pollutants may also impact on the GBR indirectly through their impacts on the health of the river and estuarine systems themselves and the implications for fisheries resources and habitats.

Current understanding suggests that any adverse impacts of land-use practices on the GBR are limited to near-shore reefs. Studies of chlorophyll A concentrations in waters of the GBR lagoon indicate that no large-scale eutrophication has occurred.

Groundwater

Groundwater includes deep aquifers and shallow, perched watertables. Pollutants may enter these groundwaters through deep leaching. Soil type, rainfall and infiltration characteristics will influence how much is lost to leaching. High nitrate levels have been detected in a small number of bores in canegrowing regions. These bores should be monitored regularly, and fertiliser management practices in farms near these bores adapted to reduce nitrate leaching losses.

The quality of groundwater is important in human health, as many rural households use groundwater for household and drinking supplies. For example, in some areas, bores have nitrate levels above the recommended levels for drinking water, posing a risk particularly for infants. Specialised water filters or rainwater tanks should be used for drinking water in these cases. Contaminated bores should not be used for drinking supplies without treatment.

Some groundwaters may be rendered unsuitable for irrigation due to high salt levels. Bores in salt-water intrusion areas should be regularly tested to determine water salinity levels.

Groundwater systems discharging into streams, freshwater lakes, wetlands, estuaries and marine environments provide a potential pathway for movement of pollutants. Elevated inputs of nutrients or pesticides may, therefore, disturb the ecology of these systems.

Dissolved oxygen

Dissolved oxygen (DO), a measure of the oxygen concentration in water, is an important water-quality parameter that influences the living conditions of all aquatic organisms that require oxygen. It also helps maintain stable chemical conditions within aquatic systems. Urban, industrial and agricultural activities and natural occurrences in catchments can all affect DO in streams and other water bodies. DO reflects the balance between oxygen use and oxygen production and can fluctuate significantly through a 24-hour period. DO levels are influenced by the exchange of oxygen with the air, respiration (use of oxygen), chemical processes and salinity. Less oxygen will remain dissolved in water at higher temperatures.

Many changes to catchments can impact on DO and general water quality. DO fluctuations tend to be more severe in disturbed catchments than undisturbed catchments. Biological oxygen demand (BOD) is a measure of the oxygen used by biological processes in breaking down organic matter and solutes. Management options will reduce impacts on dissolved oxygen. Minimising the movement of nutrients, sediment and organic matter into streams reduces oxygen use by BOD. Sucrose remaining in fields after cane harvest as juice lost from the chopper system and in lost billets can contribute to a high BOD in drainage water. Improving harvesting efficiency and delaying irrigation will reduce the potential for harvesting operations to deplete oxygen levels in waterways. DO can also be depleted by chemical oxygen demand, as occurs where acid-sulfate soils have been disturbed, and consequently oxidised, producing acid drainage water.

Retaining or replanting stream bank vegetation will shade out weeds and maintain stable water temperatures. Water quality, including dissolved oxygen, is strongly linked to healthy riparian vegetation. Farm drainage systems should minimise ponding in paddocks, but low-oxygen groundwater should not be drained. Using tailwater dams, settling ponds or aeration structures can offset increased drainage rates and BOD loads.

Monitoring water quality

Water quality may be monitored either by chemical analysis or biological assessment. Long-term monitoring is important to determine if water quality is declining or improving. These trends may be long-term, as seasonal variations have a strong influence on water quality. Many canegrowers are involved in water quality monitoring through Water-Watch groups or Cane Protection and Productivity Boards (CPPBs). Some monitoring is also undertaken by various government agencies, consultants, sugar mills and for research projects.

Chemical analyses can be carried out either in the laboratory or with test kits for elements, pesticides, or chlorophyll A concentration (an indicator of algal biomass). In-field tests are available for analysing nutrient, sediment and dissolved oxygen concentrations, but are generally less accurate than laboratory tests. Timing of sampling is also critical, as contaminants are likely to move in a peak following a specific event.

A single sample taken either side of this peak or during the middle of the peak would not give an accurate picture of the water quality trend. Intensive sampling by automatic monitoring equipment is used for research purposes but is not economical on a larger scale. 'Grab' samples collected at monthly, or similar, intervals are more commonly used for long-term trend monitoring.

Collecting these samples at a set time of day is recommended, particularly for dissolved oxygen, which fluctuates substantially through the day. The advantages and limitations of any sampling strategy should be considered carefully in light of the objectives of the monitoring program.

Biological assessment is being increasingly used to overcome the difficulties in interpreting the relevance of chemical analyses.

Changes in benthic macroinvertebrate communities are the most commonly used biological indicator to monitor a more integrated view of ecosystem health. As certain species are very sensitive to adverse conditions, their absence indicates a decline in water quality. The low mobility and sensitivity to intermittent pollution and stress extremes make the benthic macroinvertebrates suitable as indicators. Determining the causes of the impacts on water quality is more difficult.

WATER MANAGEMENT

The management of water is a crucial element of canegrowing. Both drainage to remove excess water and, in some regions, irrigation must be well managed. Both have the potential to impact on the environment through hydrological changes or the transport of pollutants.

Irrigation

Recent years have seen considerable public debate over the environmental impacts associated with irrigated agriculture in Australia. While canegrowing regions have not experienced the same degree of problems as have occurred in areas such as the Murray-Darling Basin, potential impacts must be managed. The major concerns arising from irrigation of sugarcane are water loss through run-off or leaching, the potential movement of sediment, nutrients and pesticides in that water, raising or lowering watertables, irrigation-induced salinity, salt water intrusion, and the construction of water infrastructure.

Competition for water use for agricultural, urban and industrial purposes has increased. At the same time, there has been an increase in the recognition of the need for water flows to sustain natural systems. The health of many aquatic systems is dependent not only on a set quantity of water but also on the frequency and intensity of flows. For example, flood events may be important to stream ecology.

The Council of Australian Governments (COAG) Water Reform process is altering legislation to allow for more effective water trading between water users. COAG has also committed to the allocation of water for environmental flows. Improved water-use efficiency and tradeable water rights are two major irrigation responses to this demand for environmental flows.

In Queensland, the Water Allocation and Management Planning (WAMP) process operates on a catchment basis to facilitate agreements over water allocations for competing uses, including environmental flows. WAMPs will soon be in effect for all catchments in Queensland.

Irrigation management

The major potential impact of on-farm irrigation management is water loss, through run-off, deep leaching or evaporation. An understanding of soil type and water-holding capacity and landscape features is critical to achieving efficient irrigation systems.

Any irrigation system can be efficient if it is well managed and is suitably matched to the soil type and landscape. At maximum efficiency, trickle irrigation will have the least impact, because of the evenness of distribution and low application rates. The possibility for trickle irrigation to be used for additional applications, such as fertigation, provides the possibility to further reduce environmental impacts.

Run-off

Run-off from surface irrigation is the most common form of off-site impact associated with irrigation. Run-off can be controlled by closely monitoring cut-off times, blocking the ends of furrows, tailwater retention or adopting irrigation systems with lower run-off risk such as trickle or low-pressure overhead systems. Regular laser levelling of paddocks can significantly reduce run-off from furrow irrigation. By reducing the unevenness in the paddock, levelling helps to ensure that all furrows in a set have a uniform advance time. It is common to find differences of around 25% in the advance time for blocks nearing the end of a cropping cycle. Recently, laser-levelled blocks have a very uniform wetting front and, therefore, their advance times are similar. Run-off from these blocks is regularly less than 3%, whereas the older ratoon blocks may be 8–15%.

Where soils are not suitable for tailwater recycling pits, a system of tailwater retention or blocking the ends of furrows to pond the water at the bottom of cane blocks may be used. However, this practice should be avoided on soils with poor internal drainage or where there is a high risk of waterlogging from seasonal rains.

To prevent the potential risks associated with the movement of soil sediment off-site, broad, flat, well-grassed drains should be used if possible. This type of drain reduces the potential for erosion due to the higher velocities found in steep-sided narrow 'V' drains. One of the most effective means of reducing sediment losses from recently cultivated paddocks is to erect shadecloth weirs, slowing flow and allowing sediment to drop out.

Leaching

While the environmental impacts of the surface run-off are highly visible and for the most part easy to manage, the environmental impacts associated with leaching losses are far harder to measure, quantify and manage. Deep-drainage losses are more insidious in nature, and many years may pass before any problem is apparent. Deep-drainage losses associated with surface irrigation practices have been a contributing factor in rising ground water, increased salinity, and contamination of aquifers with nitrates and pesticides all over the world. Today, more precise methods of analysis have been developed to identify potentially harmful components in these deep-drainage losses. Modern soil moisture monitoring equipment has also been used to identify the flow characteristics of these losses.

From an on-farm management point of view, there are several options available to the grower to reduce these deep-drainage losses and their associated impacts. An understanding of the infiltration characteristics of the soils is needed so as to match the application rates to the infiltration rates. Computer modelling techniques are now available to assess the relative efficiency of an irrigation practice. Using this information, irrigation losses can be reduced by variations in inflows.

Leaching losses under furrow irrigation can be reduced by alternate-furrow irrigation, modifying furrow shape, increasing compaction or surge irrigation. The ultimate aim is to reduce infiltration losses and reduce the risks associated with the various leachates moving below the root zone and impacting on the environment.

Effluent irrigation

Effluent water from urban sources and mills is increasingly being used by canegrowers as a source of irrigation water. The close proximity of canelands to urban centres creates an ideal opportunity for canelands to serve as a biological filter for urban effluent. By using the water for irrigation, it is possible for sewage treatment plants to avoid the high costs of upgrading to a tertiary treatment standard. In this way, canelands can serve as the 'kidneys' for urban centres, while also receiving a valuable irrigation supply.

Groundwater management

Groundwater resources are used in many regions for irrigation and drinking water. For example, the development of the Burdekin region for sugarcane was largely made possible by the presence of abundant, good quality groundwater supplies. In other regions, drainage is used to lower watertables. Management of groundwater resources poses a number of challenges in terms of both quantity and quality.

Excessive extraction may lead to a depletion of groundwater resources, causing problems with irrigation supplies and possible salt-water intrusion in coastal areas, especially in some coastal areas of Mackay, Bundaberg and, to a lesser degree, the Burdekin. Intrusion occurs where groundwater falls below the high-tide level, resulting in inflow of seawater to the aquifer. As a result, the water becomes unsuitable for irrigation. Regional groundwater monitoring and management strategies are needed to minimise this effect. Strategies include conjunctive use, pumping restrictions and sourcing additional water sources.

Drainage

Prolonged periods of waterlogging have adverse impacts on cane growth. The high rainfall experienced in many canegrowing regions makes effective farm drainage a critical component of farm design. The quality and quantity of water discharged from farm drains are important and drainage design may directly impact on both of these. Well-managed drainage systems will provide effective farm drainage and can, in some cases, also provide valuable fisheries habitat. They can also be used to filter run-off waters. Poorly designed drains can exacerbate problems, become a site of erosion, and exaggerate flooding problems or expose acid-sulfate soils.

Drainage is often a highly contentious issue and can lead to intense disputes with neighbouring farmers. Rapid drainage from some farms may cause excessive flooding of areas downstream. Drains shift water from one location to another; they do not reduce the amount of water on the floodplain. If drainage is to avoid imposing detrimental effects on either downstream farms or ecosystems, the drainage capacity should not exceed the ability of natural streams and wetlands to either carry or hold water. Drainage should be designed to remove water as quickly as necessary, rather than as quickly as possible. Effective drainage should be managed on a sub-catchment basis, rather than an individual farm basis.

The waters carried from the farm in drainage systems may be enriched with nutrients, sediments or pesticides that may have adverse impacts downstream. Careful drain design incorporating features such as retention basins and filter strips may help to improve the quality of water leaving the farm and reduce erosion of the drainage system. The drainage system may have more direct impacts on water quality if the drains disturb acid-sulfate soils, have unstable banks, or speed the flow of water. Deep drains that rapidly drain surface water and lower the watertable should be avoided where possible. The draining of groundwater, which is often devoid of oxygen, can have serious impacts on fish in these waterways and can have deleterious effects on wetland systems by altering regional hydrology.

In designing a drainage system, farmers should consider how much drainage is needed to maximise productivity and what type of drainage system is most suitable. The impact of drainage water flowing onto the farm and the impact of drainage discharge water on neighbours, watercourses and wetlands and the effects on water quality should be considered. Drainage design should include retention basins, tailwater recycling pits or artificial lagoons wherever possible. Licences may be required for some works.

SOIL CONSERVATION

Changes in land use since European settlement have led to a significant increase in sediment output. Soil erosion is a double-edged sword—it represents the loss of a most valuable farm resource with costly repair bills where washouts have occurred. In turn, these mobilised sediments cause the degradation of downstream environments where they are deposited. Sediments in waterways cause turbidity, reducing light penetration, and smothering in-stream and estuarine habitats. Figure 3 indicates the impact of land use on sediment yield.

Soil erosion by wind and water has posed a major challenge for the sugar industry in the past, particularly in regions where heavy, intense rainfall is experienced. Many regions where sugarcane is grown frequently receive rainfall in excess of the crop uptake or soil infiltration. Run-off is a significant portion of the water balance in these situations, increasing the risk of erosion. Districts having the highest risk of erosion in Queensland are those around the Cairns, Mackay and Sunshine Coast areas, all areas where sugarcane is grown.

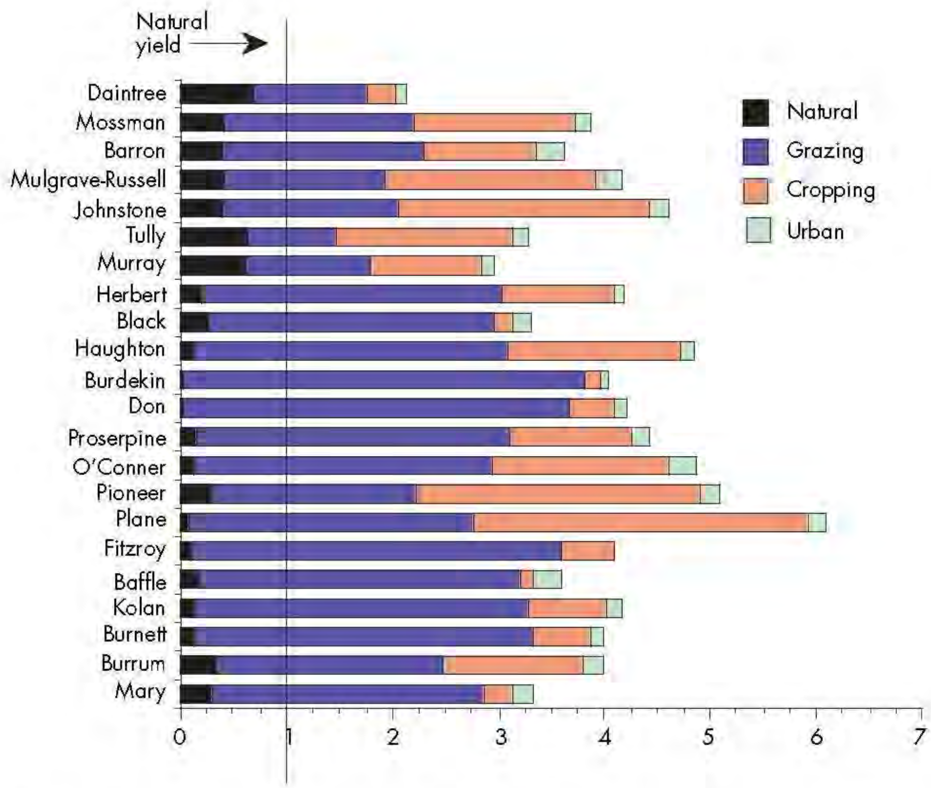

Figure 3. *Relative contributions by present land uses to estimated sediment yields on a catchment basis. Changes are posed relative to a pre-European (natural) sediment yield from the entire catchment of 1.*

Source: Rayment, G.E. and Neil, D.T. 1996. Sources of material in river discharge. In: The Great Barrier Reef—Science, Use and Management. Proceedings of a National Conference, Townsville 25-29 November 1996. (Reef CRC, GBRMPA and James Cook University, Townsville.) 42-58.

Most cane farms are found on alluvial lands with relatively low slopes, where erosion risk is low. Farms on steep slopes, such as around Innisfail, Mackay and Childers, face the significant challenge of managing erosion (Figure 4). The suitability of land for growing cane takes into account erosion risk. During the 1970s, sugarcane growing on highly erodible slopes around Childers and Gin Gin was moved to more suitable soils.

Erosion hazard is increased by high intensity rainfall, as occurs predominantly during storm events prevalent between December and March. Freshly cultivated soils are at high risk, particularly where a heavy rainfall event occurs before the soil has settled (Figure 4). By reducing the number of cultivations undertaken, many growers have lowered the risk of erosion.

Soil loss as high as 380 t/ha has been recorded from cultivated ratoons on steep slopes. Reduced cultivation and green-cane trash-blanketing have significantly reduced the loss of soil from cane blocks. The trash blanket reduces the impact of rain droplets on the soil surface and, by slowing the flow, reduces the erosive forces of overland flow. Erosion risk from fallow lands, plant blocks, drains and headlands, where trash or other cover is not present, remains very high. Under certain conditions, plant cane blocks can also be highly erodible. Research has

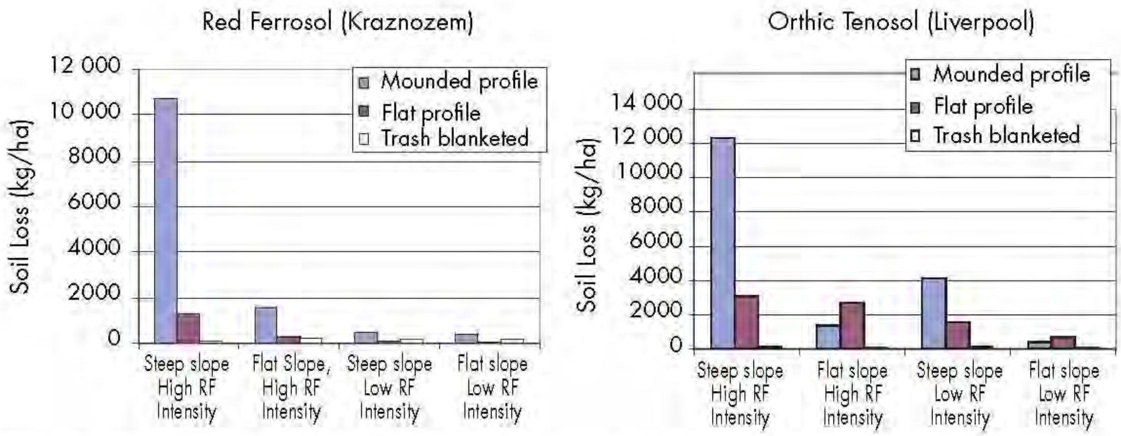

Figure 4. *Soil loss on two soil types following 1 hour simulated rainfall at High (133 mm/h) and Low (70 mm/h) intensities on two slopes.*

Source: J. Reghenzani

indicated that the greatest loss of soil from cane farms under green-cane trash-blanketing now occurs from washouts and slumping of drain banks and headlands.

Minimal tillage techniques and contour planting on steep slopes are particularly important during the erosion-prone plant cycle. Contour banks or whoa-boys have been used to divert water on steep slopes, reducing rill and gully erosion.

To reduce erosion of drains and headlands, farmers should maintain grassed, slashed headlands and use shallow, grassed spoon-shaped drains where possible. Drain banks should be stabilised with suitable batter slopes vegetated with grasses (where they can be slashed), shrubs or trees. Grass will also help to filter sediment during periods of low flow. While wider drains require more land, this can be compensated for in some districts by using drain shoulders as headlands.

Grassed, slashed filter strips approximately 5 m wide can trap up to 70% of sediment from run-off water passing through them. Grassed headlands may serve this role provided that they are not excessively disturbed by traffic operations such as harvesting.

Rock-drop structures such as gabion weirs or rock mattresses can be used in high-flow areas to slow drainage water and diffuse most of the impact, reducing the erosive force and allowing silt to settle out. These can particularly be of benefit to reduce wash where a steep drop-off occurs where a drain enters a creek. Tailwater dams, retention basins or artificial lagoons slow water and reduce erosion and will allow sediments to settle to some degree.

SOIL HEALTH

The farm's soil resource is crucial for sustained cane production. Soil biology, fertility and compaction all influence the 'health' of the soil. Management of these elements is crucial to ensure the soil resource is not degraded. More information is given in the Soil Health chapter.

FALLOW MANAGEMENT

A fallow period between crop cycles provides the soil with a break from continuous sugarcane. The fallow helps break pest, weed and disease cycles, and allows mineralisation of nitrogen and other nutrients that are stored in soil microbes. A break from continuous cropping improves productivity of the plant crop.

Fallow breaks can range in duration depending on the canegrowing region, grower's rotation, cultural practices to help with pest control, and availability of planting contractors. Short fallows usually range from 3-6 months between the ploughout of an old ratoon and the establishment of the plant crop. In some areas, particularly where alternative crops are grown in rotation, the fallow may be up to a year.

A fallow or crop rotation will help control nematodes and diseases like pachymetra and RSD. For nematode and earthpearl control, a break of at least 6 months is recommended. Due to the release of nutrients by microbial activity and mineralisation during the fallow period, plant crops following a fallow break require approximately 40% less nitrogen than for a ratoon crop or replant without a fallow break.

The management of the fallow is important to reduce erosion hazard, control pests, improve soil fertility, or provide an additional income. Fallows may be bare or grassy or an alternative crop may be grown in rotation. Rotation crops may be a green manure or an alternative cash crop. Soybeans, dolichos (lab lab) and cowpeas are commonly grown in cane fallows. They may be incorporated into the soil to provide a high nitrogen source for the next crop and improve soil organic matter, or they may be harvested for grain or seed.

In southern areas, crops including cucurbits, capsicums and tomatoes are commonly grown in rotation with cane. The application of soil ameliorants, fertilisers, fumigation and weed-control measures for small-crop production combined with the benefit of a longer break usually leave the soil in an optimum condition.

Where crops are not grown, a spray-out fallow is recommended rather than a cultivated fallow, as cultivation will increase the risk of erosion and reduce soil structure and organic-matter content. Good weed control during the fallow will help to reduce the bank of weed seeds in the soil, reducing weed growth in the next crop cycle. Volunteer cane should be killed off to reduce the risk of disease such as RSD being carried. Some cover should be maintained to reduce erosion hazard.

SALINITY

Since the 1930s, the salinisation of agricultural lands and waters has emerged as a considerable problem in large areas of Australia. While the problem is not as extensive in canegrowing regions as it is in other parts of the nation, there are areas of canelands affected or with the potential to be affected by salinity. Marine influences affect salinity in the Harwood, Rocky Point, Moreton, Mackay and Burdekin areas and in some parts of far north Queensland. Watertable salting effects occur predominantly in those areas with annual rainfall between 800 and 1200 mm/yr—Maryborough to Bundaberg, Proserpine, Burdekin and the Atherton Tableland. In 1985, 8-20% of farms in the Bundaberg to Maryborough area were affected. In total, 10% of the area under sugarcane may be affected to some degree by salinity.

Salts, predominantly sodium chloride ($NaCl$) in Queensland, are present in many of the soils underlying agricultural areas in Australia. Rising watertables draw these salts to the surface, concentrating them to a degree that they affect plant growth. These watertables rise due to alterations in regional hydrology caused by tree clearing or irrigation.

Recharge areas may be distant from the areas where salt seeps occur, generally found on surrounding hills. As clearing of these areas increases the rate of recharge, the additional water passes down the slope where it may cause seepages at toe slopes or a rise in the watertable lower in the landscape. As this water moves, it brings with it salts that have been stored deep in the soil profile. Irrigation losses to leaching may also cause watertables to rise. Efficient irrigation to reduce leaching losses will reduce the watertable rise in these situations.

Like many other crops, sugarcane is salt sensitive. Both cane yields and sugar quality (ash) are affected by salinity. Current understanding indicates that soil salinity begins to affect plant cane yields at levels of 1.7 dS/m. Beyond this, there is a decline in yield of 5.9% per dS/m. The effect of salinity will vary with the soil clay percentage. Figure 5 illustrates the effect of soil salinity levels on cane productivity. Ratoon cane is regarded as twice as sensitive to salinity as plant cane.

In cropped areas, salinity is marked by stunting, 'fired leaf', scalds and the growth of salt-tolerant weed species. In adjacent, non-cropped areas, potential recharge sites and the presence of salt-tolerant vegetation, such as pigweed, salt couch, samphires and tea tree, are good indicators. Rhodes grass can grow very well on saline soils where the watertable is close to the surface.

Under severe situations, bare scalds form where crops and grasses will not grow. These bare scalds are highly prone to erosion. Saline seeps can affect water quality within streams, which impacts on stream ecology and affects the suitability for irrigation. Groundwaters may also become saline and unsuitable for irrigation.

Electromagnetic induction surveys may be used to assess salinity over a large area. The salinity maps produced may then be used to identify high-risk areas. Using this information, subsequent soil profiles taken to 1.5 m will determine the degree of salinity. Monitoring watertable depth in seepage areas will also help to gain an understanding of the processes involved.

Salt-water intrusion in coastal aquifers also causes a salinity problem in some areas where groundwater extraction has lowered the watertable below sea level. This form of salinity is discussed in the Water Management section.

SOIL ACIDIFICATION

Acid soils occur naturally in humid areas where the acidification of soils (the slow

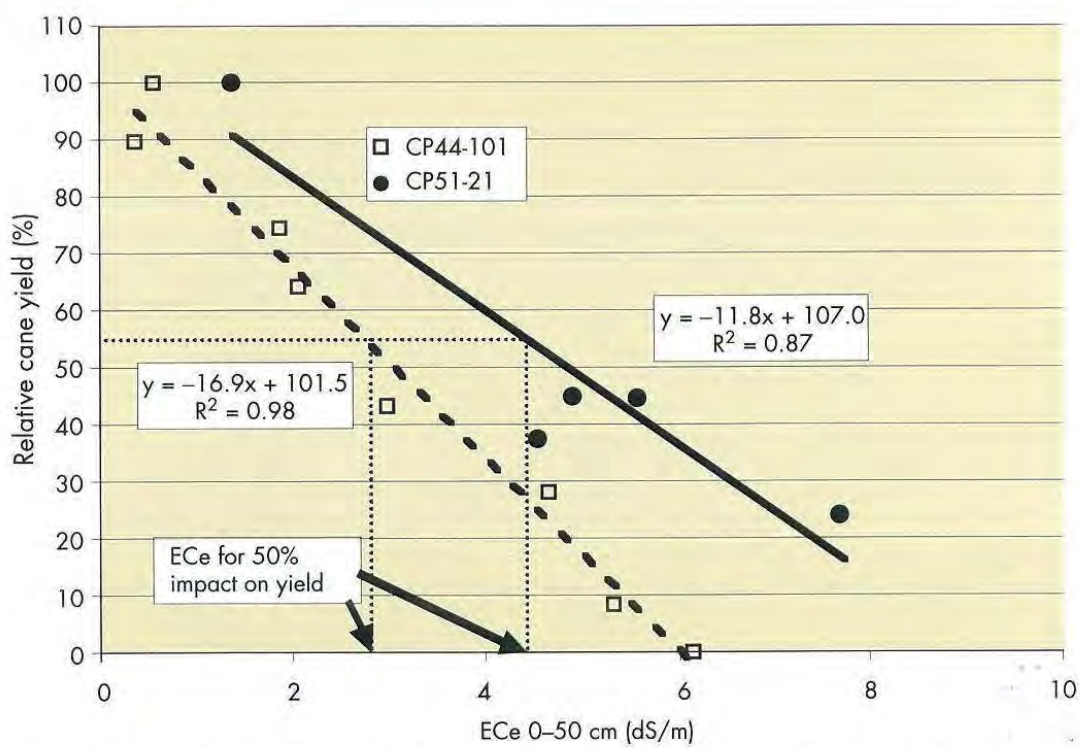

Figure 5. *Soil salinity reduced ratoon yield of CP51-21 and CP44-101, respectively, by 11.8 and 16.9% per unit increase in saturation extract salinity.*
Source: Graham Kingston

decline in pH over time) is a continuing, natural process. In Queensland, more than 2 million hectares of agricultural land are naturally acidic. Almost 90% of canegrowing soils are acidic, and the sugar industry currently applies more than $3.5 million worth of lime (crushed limestone) per year to about 10 000 ha of cane land. Agricultural practices can accelerate the acidification process, and this accelerated acidification has been observed in a number of agricultural systems in Queensland. More than 500 000 ha of agricultural and pastoral land in Queensland have acidified or are at risk of acidification. There are no visible signs of accelerated soil acidification, apart from a slow decline in yields. The development of strongly acidic soils (pH in water <5.5) results in poor plant growth as a consequence of aluminium toxicity, manganese toxicity, deficiencies of calcium, magnesium, phosphorus and molybdenum, and/or reduced microbial activity leading to a reduction in the cycling of nutrients such as nitrogen.

The acidification rate in any agricultural system is dependent on the magnitude and overall balance between the acidifying and alkalising processes. Studies have suggested that about half of the acidification in cane soils is a result of product removal and half due to the use of nitrogenous fertilisers. The extent to which these processes decrease the soil pH depends on the pH buffering capacity of the soil. Soils with high organic and clay contents are better buffered against pH changes compared to sandier soils of lower organic matter content.

Subsoil acidity also occurs both naturally and as a result of management practices. Strongly acidic subsoils are likely to limit or entirely prevent root growth. As a result, water-use efficiency is a major constraint to yield and economic cane production on such soils. Because of the low mobility of typical application rates of lime in most soils, subsoil acidity cannot be easily corrected by conventional incorporation of lime into the plough layer. Even when high rates of lime are applied to the surface, there is little effect on the subsoil in many situations. It is imperative that management practices are designed to minimise or remove the potential for subsoil acidification.

In most agricultural systems, product removal and management practices accelerate soil acidification. Accelerated acidification is demonstrated for sugarcane in Table 2, which shows lower pH values in canegrowing soil compared to undeveloped soil across a fenceline. The removal of large quantities of alkalinity in harvested cane (typically 70–100 t cane/ha) and the input of ammonium-based fertiliser (120–250 kg N/ha/year) are the major contributors to this acidification.

Table 2. The effect of sugarcane production (17-20 years) on soil pH_w (pH_{Ca} in parenthesis) at a site in southeast Queensland.

Depth (mm)	Native rainforest	Sugarcane
0-100	5.50 (4.71)	4.46 (3.82)
100-200	5.17 (4.30)	4.53 (3.83)
200-300	5.00 (4.08)	4.53 (3.86)
300-500	4.88 (3.88)	4.70 (3.95)
500-700	4.59 (3.78)	4.63 (3.83)

Source: Aitken R.L., Moody, P.W., Noble, A.D. and Kingston, G. 1998. Queensland soils—beautiful one day, acidified the next: can we make them perfect again? In: National Soil Acidification Conference Proceedings, Land and Water Resources Research and Development Corporation, Canberra, Australia.

Acidification can be affected by carbon cycle factors, including the removal of alkalinity in harvested products, changes in the level of soil organic matter (increases are acidifying, decreases are alkalising), or addition of imported organic material, which is alkalising. Plant material is alkaline and this alkalinity is derived from the soil. Because of the removal of large quantities of alkalinity in harvested product, an excess of acidity is left in the soil.

The conversion of ammonium, applied as ammonium-based fertiliser, to nitrate in the soil results in the production of acidity. If the nitrate is taken up by the crop, some or all of the acidity produced may be neutralised. However, if the nitrate is leached, an excess of acidity remains and the soil acidifies. Applied nitrate fertilisers have an alkalising effect unless they are leached. The extent of soil acidification resulting from these nitrogen cycling factors depends on the type of fertiliser used and the amount of nitrate leached (Table 3).

Table 3. Lime required (tonnes $CaCO_3$/100 kg N applied) to neutralise the acidifying effects of some nitrogenous fertilisers with different leaching losses of nitrate.

Fertiliser	Nitrate leached		
	Nil	50%	100%
Ammonium sulfate	0.37	0.54	0.71
MAP	0.37	0.54	0.71
DAP	0.18	0.36	0.53
Nitram	0	0.18	0.36
Urea	0	0.18	0.36

Sugarcane is quite tolerant of low soil pH and toxicities of aluminium and manganese. Yield increases from lime application are usually attributed to a response to calcium. Therefore, soils used for sugar production may acidify to low pH values without yield loss, unlike other crops. The areas of acid-sulfate soils which are used for sugarcane production are likely to be the most notable exception to this in that these soils often have a reasonable calcium status but have the potential for pH_w values to decrease markedly below 4. In these circumstances, sugarcane can be adversely affected by aluminium toxicity.

Although sugarcane is tolerant of low pH, it is not a sustainable practice to allow soils to acidify too greatly. Too great a decline in pH will degrade the chemical, physical and biological fertility of the soil, making it unsuitable for the production of other crops. Many fallow crops are more sensitive to acidity than sugarcane and commonly require lime. An additional risk associated with allowing the soil to acidify is that the subsoil will acidify. If this is allowed to occur, it will prove difficult to correct. To arrest the development of subsoil acidity, a pH_w of 5.6 should be maintained in the surface soil. This may be achievable in many mineral soils, but may not be attainable in organic (e.g. peaty gley) soils, where economic correction of a calcium deficiency with lime gives a productivity plateau, yet pH_w may still only be in the range 4.2–4.5.

Liming recommendations have been included in nutrition programs since the late 1970s, to rectify the low calcium levels found on around 30% of canegrowing soils (more information is given in the chapter on nutrition). Management based on the soil calcium criteria will, by default, modify pH, aluminium and manganese levels to some degree, if lime is used as the amendment. Hence, the soil calcium index is useful for ensuring productivity of sugarcane, but pH should also be monitored to guard against pH decline, which will limit chemical, physical and biological fertility of soils.

Attention to pH is essential for preserving the soil resource and the flexibility to grow other crops that have lower tolerance of aluminium and manganese than sugarcane. However, the increasing degradation of chlorpyrifos at soil pH values greater than 6.0 suggests that management of acidic cane soils will require a balance between managing soil acidity and avoiding higher pH values causing enhanced degradation of this insecticide.

The high nitrogen rates used in sugarcane production, together with the greater potential for leaching of nitrogen in tropical and subtropical environments, are major contributors to acidification in canelands. Removal of harvested product contributes to soil acidification and is inevitable. For the system to be sustainable, the alkalinity removed in harvested product needs to be replaced. The impact is usually greatest where a large quantity of material is removed but it is also dependent on the alkalinity of the plant material (Table 4).

Table 4. Some harvested products and the lime required to counter the excess soil acidity remaining after product removal.

Product	Lime equivalent (kg)
10 tonne millable cane	15
1 tonne bananas	5
1000 litres milk	4
1 tonne tobacco leaf	100
1 tonne grass hay	30
1 tonne legume hay	50
1 tonne maize grain	3

Source: Moody, P.W. and Aitken, R.L. 1997. Soil acidification under some tropical agricultural systems. 1. Rates of acidification and contributing factors. Aust. J. Soil Res., 35: 163–173.

Soil acidification may be slowed by reducing nitrogen leaching. However, the comparatively low leaching losses measured on some soils suggest that reducing the rate of acidification under sugarcane will be dependent on further reducing the rate of nigrogen applied and considering the use of nitrate-based fertiliser sources. However, the use of nitrate-based fertilisers is currently limited by economic considerations.

Accelerated soil acidification processes are a serious threat to the long-term sustainability of crop production. Soil acidification can be reduced by matching nitrogen fertiliser inputs to crop demand, using alternative (nitrate) forms of nitrogen fertiliser, adopting efficient irrigation practices to minimise leaching, and making regular applications of lime to counter the acidification inherent in the agricultural system.

SOIL SODICITY

Soils are described as sodic if they have a high proportion of sodium attached to the clay particles. Sodicity can have drastic effects on cane yields, largely due to the low water holding capacity of the soil. The poor structure of these soils also make them prone to erosion. Refer to the Irrigation chapter for more details.

ACID-SULFATE SOILS

Acid-sulfate soils are soils in which large quantities of iron sulfide (pyrite) occur. The conditions necessary for the formation of iron sulfide layers are largely confined to low-lying estuarine areas and these soils occur in low-lying tidal areas, mangrove swamps and the lower parts of coastal river valleys. The formation of pyrite is not an 'overnight process' and much of the pyrite present in acid-sulfate soils in eastern Australia has been formed over the past 5000 to 10 000 years, following the last major sea level rise. When the sea level rose to form estuarine wetlands, sulfate in the sea-water and land sediments containing iron and organic matter provided the ingredients for the formation of iron sulfide in the waterlogged sediments. When present in the soil, the iron sulfides are contained in a layer of waterlogged soil below the watertable.

Problems arise when these soils are drained or disturbed and the iron sulfide is exposed to oxygen in the air. This oxidation produces sulfuric acid which can move through the soil and in run-off, acidifying ground and surface waters. In its natural state, the soil below the watertable where the pyrite occurs is not strongly acidic and often has pH values close to neutral. As long as the pyrite remains below the watertable, and therefore anaerobic, it will remain inert. However, when pyrite is exposed to air, such as in periods of drought, drainage or lowering of the watertable, the pyrite is oxidised to produce sulfuric acid and the pH values may be lower than 3. Extremely large quantities of sulfuric acid may be released into the environment and this will kill both terrestrial and aquatic organisms. Activities such as urban canal development, extractive industries, construction of artificial lakes and agricultural drainage can expose acid-sulfate soils, causing acid drainage. Where cane is grown on acid-sulfate soils, drainage works and deep cultivation may contribute to the release of sulfuric acid to the environment.

Extensive areas of sugarcane production are located in river valleys and coastal flood plains adjacent to estuaries and coastal embayment. Approximately 60% of all New South Wales cane farms have potential acid-sulfate soil within 1.5 m of the surface. In Queensland, detailed mapping has identified 21% or 20 000 ha of caneland in southeast Queensland has potential acid-sulfate soil within 1.5 m of the surface. Smaller areas are thought to exist in central and north Queensland. However, detailed risk mapping has not occurred in those areas.

Acidity produced due to exposure of the pyritic layer may impact on cane growth in some areas. Many of the soils in acid-sulfate soil hazard areas have very low pH values in the surface 300-400 mm (pH 4 to 5.5). However, they have high organic matter levels and are very fertile. As sugarcane is tolerant of these pH values and the associated high levels of aluminium, these soils are highly productive for sugarcane, provided that the watertable is not lowered to expose the sulfidic subsurface material and produce acid. The major impact of exposure of acid-sulfate soil is on the riverine environment. The production and discharge of high levels of acid to waterways following the exposure of acid-sulfate soil can have drastic impacts on fisheries. One of the major impacts may be through the consumption of dissolved oxygen in waterways by chemical processes related to the acid discharge. This can lead to severely depleted dissolved oxygen levels.

Because of the susceptibility of sugarcane to waterlogging, drainage has been important for productivity in the low lying areas where potential acid-sulfate soils are found. In some instances where deep drains were dug, the watertable was lowered resulting in oxidation of pyrite and acid release. Construction and maintenance of the drains has the potential to expose pyrite to oxidation.

The best option for management is to avoid exposing the pyrite. Knowledge of the location and depth of pyrite layers is important in planning drainage works. Shallow, wide drains are recommended to reduce the risk of excavating into the pyritic layer. In maintenance of existing drains, avoid excavating beyond the original drain depth, and use an open (slotted) weed rake rather than a bucket for drain cleaning. A laser-guided excavator for spoil removal or for constructing new drains will help to avoid potential acid-sulfate soil. Laser grading has reduced the requirement for deep drains, thus reducing the risk of acid-sulfate soil exposure. However, activities such as cleaning remaining drains, construction of new drains and other earthworks such as dam construction, water holes, and land grading could risk exposing pyrite to oxidation. Where pyritic soils are disturbed, the use of lime along the disturbed section of drain and on excavated spoil will neutralise any acid hazard produced. The severity of the acid hazard should be determined in advance so that a lime requirement can be determined.

In New South Wales canegrowing areas, acid-sulfate soils are widespread and had posed a considerable concern to the local community. The problem has been addressed through sampling of all cane farms in New South Wales, usually to a depth of 1.5 m, with field and laboratory testing. The landholders were present during the field testing and was able to see the results. Based on this testing, acid-sulfate hazard and drain management plans for each farm have been prepared with liming recommendations to neutralise acid along the drain and in the spoil. Management protocols for acid-sulfate soil and a Best Practice document have been prepared. Both growers and excavator operators are now well aware of these soils and how to avoid and manage them.

In other sections of the industry, the problems of acid-sulfate soils are being addressed by detailed mapping of the severity and distribution of these soils, education and awareness programs, and the development of best practice guidelines.

Natural ecosystems also exist on these soils and can release acidity to aquatic environments. Irrespective of whether the acid-sulfate soil is used for agriculture or supports a natural ecosystem, there is a finite amount of potential acid material present that is decreasing over time. However, it may take many years before this decreases to a level that is no longer a concern. In areas where drains are being filled in, the pyrite has already been exposed and may continue to release acid for a long time even after the watertable has returned.

GREEN-CANE TRASH-BLANKETING

Substantial benefits for both profitability and the environment have been achieved through the widespread adoption of green-cane trash-blanketing (GCTB). This could be claimed to be the most significant change towards sustainability of the industry in recent years.

Until the late 1930s, cane was predominantly hand harvested green. Burning was used on blocks with bad rat infestation to reduce the exposure of cane cutters to the disease *leptospirosis* (Weil's disease), a lethal disease spread through animals such as rats. Labour shortages during World War II led to widespread use of pre-harvest burning to speed harvesting. Rising post-war labour costs saw this practice continue. The early mechanical harvesters of the 1960s were designed for the burnt system and were not well adapted to harvesting green. As a result, pre-harvest burning remained. While this system simplified harvesting, regular cultivation was needed to control weeds and the unprotected, cultivated soils were prone to substantial soil erosion. The introduction of a green-cane harvester in 1976 has since led to a major change in farm management with 70% of the crop (100% in some areas) now harvested green.

In the GCTB system, cane is harvested green and leaf matter ('trash') is retained as a mulch on the soil surface. This practice has involved a change not only in harvesting, but in the whole farming system. In suitable areas, it offers environmental, agronomic, financial and social benefits. While now widespread, it was several years before growers were confident with the new GCTB system.

GCTB provides cost savings for the grower, as fewer production inputs including chemicals, water, machinery and labour are required. Benefits include a significant reduction in soil erosion due to the protection of the trash blanket, increased soil moisture retention and water infiltration (both can be a disadvantage in some areas), weed control, long-term soil structural and nutritional status, reduced smoke and ash fallout in neighbouring towns, no risk of cane loss if rain falls soon after burning, safety, decreased workload, and improved lifestyle.

There are, however, some drawbacks to GCTB. Harvesting costs can be higher, with many of the older mechanical harvesters not able to harvest unburnt cane. New or modified machinery has largely overcome this. Higher levels of extraneous matter in cane supplied to the mill and higher cane loss in harvesting have occurred. Chemical weed control may be needed at later stages of crop growth, requiring specialised equipment for application. Some soil types are difficult to manage under GCTB with increased moisture retention in low-lying, waterlogged soils causing yield loss or poor regrowth of cane (ratooning). There is a risk of accidental fires spreading through the trash and, in the cooler climates of southern areas, the trash blanket can result in poor ratooning.

NUTRIENT MANAGEMENT

Efficient nutrient management is important for both environmental and economic sustainability. The loss of applied nutrients represents an inefficiency in fertiliser management and an environmental hazard. Elevated levels of nutrients in waterways may be one of the most significant challenges for the sustainability of canegrowing. Conversely, insufficient fertiliser application may cause fertility decline as the soil is mined of its nutrients. From a financial perspective, the loss of any nutrient is detrimental. From an ecological perspective, the loss of nitrogen and phosphorus to waterways can impact adversely on aquatic and marine environments. Excessive nitrogen applications can lead to soil acidification and gaseous losses of nitrate contribute to greenhouse gas problems. Excessive nitrate contamination of drinking water supplies poses a health concern.

Under some situations, 14% of applied nitrogen and 17% of applied phosphorus are being lost to waterways. In the Wet Tropics, there are strong seasonal trends in dissolved inorganic nitrogen levels in waterways with peaks of nitrate and ammonium loss at the start of the wet season, remaining high throughout the wet season before declining with the start of dry weather. Dissolved organic nitrogen losses follow no strong seasonal trends. An upward trend in nitrate levels in surface waters has been detected over the past 30 years.

Efficient nutrient management aims to achieve a balance between nutrient inputs and nutrient outputs with minimal losses to the environment. Applied fertilisers account for most (approximately 75%) of the nutrient inputs with lesser amounts coming from irrigation and rainfall. There is also considerable nutrient cycling within the system. Nutrients leave the block in millable cane (major output), gaseous losses, leaching, run-off and denitrification. All of these losses can be managed.

Matching fertiliser rates to crop needs

The crop nutrient demand should be met but not exceeded. Recommended rates and soil and plant analysis should be used to help design a balanced nutrition program. As considerable quantities of nutrients are returned to the soil with mill mud, fertiliser rates (particularly N and P) should be reduced after application of mud, ash and other by-products. Soil type and cane variety should be taken into account in determining fertiliser rates.

A healthier crop will use more nutrients. Farmers should optimise crop nutrient uptake by applying fertiliser when the crop is actively growing and taking measures to reduce factors which stress the crop—acidity, sodicity, waterlogging, moisture stress or pest or disease pressure. More information is given in the chapter on nutrition.

Loss pathways and management options

Volatilisation of nitrogen may pose an environmental concern through the contribution to greenhouse gases, but the major concern from a sustainability perspective is the movement of nutrients to waterways and groundwater by leaching and in run-off.

Some nutrients will bind tightly to soil particles (e.g. phosphorus) and will move mainly attached to sediment. Other nutrients (e.g. nitrogen, potassium) are more mobile and will move more readily through the soil. Management should aim to reduce losses by all pathways. As nutrients are in a balance, if losses are reduced by one pathway, they will generally be increased by another and so, once best application methods are in place, a reduction in rates is needed to minimise total losses.

Leaching losses of 18–56 kg N/ha have been measured in Innisfail. Leaching is influenced by fertiliser rate, placement, timing, rainfall and soil type. Row profile has a considerable impact on leaching losses as demonstrated in Figure 6. Losses are higher under plant cane than ratoons.

Soluble nutrients may also be lost from the block in irrigation tailwater or rainfall run-off. Figure 7 shows some typical nutrient losses through run-off from a furrow-irrigated system. Excessively high losses of nitrate have been measured for up to six irrigations where urea has been surface applied and followed by furrow irrigation prior to incorporation, as shown in Figure 8. Soil conservation

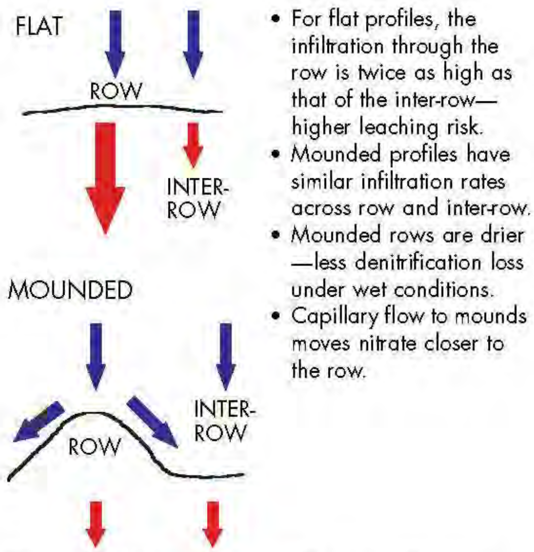

Figure 6. *Effect of row profile on infiltration.*

Source: J. Reghenzani, BSES

measures to slow overland flow and reduce erosion will also reduce run-off losses.

Sustainable nutrient management relies not only on managing fertiliser application and rates but also managing run-off and leaching to ensure that nutrient losses are minimised. Nutrient losses can be reduced by applying fertilisers below the surface wherever possible. If fertilisers are surface applied, they should be incorporated with moderate rainfall or overhead irrigation. Cane should be planted in a mounded soil profile and fertiliser applied in the crest of the mound to reduce leaching losses. Irrigation should be managed to minimise tailwater run-off and leaching losses, and farmers should establish tailwater recycling ponds, retention basins or artificial wetlands. Grassed, slashed filter strips should be maintained to slow run-off and to trap particles. A buffer strip of trees should be maintained along waterways to intercept nutrients at depth and from overland flow.

SUSTAINABLE PESTICIDE USE

Sugarcane pests cause considerable economic loss to the industry—both through the loss of yield and the costs of control. The impacts of these pests are controlled through a range of chemical, mechanical and cultural techniques

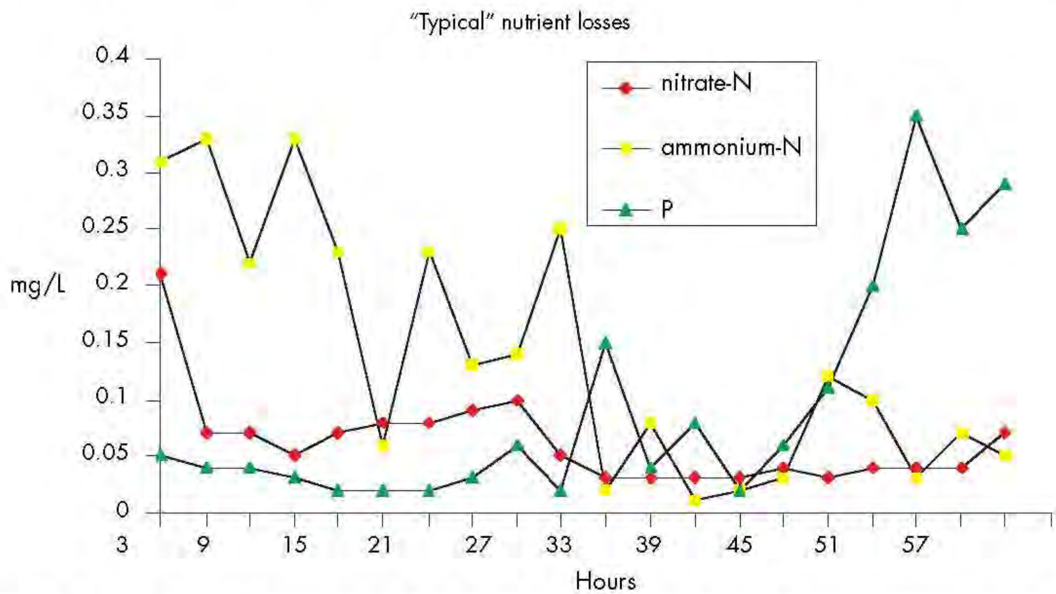

Figure 7. *Nutrient losses measured in whole farm run-off from a furrow irrigated farming system in the Burdekin.*

Source: G. Ham, BSES

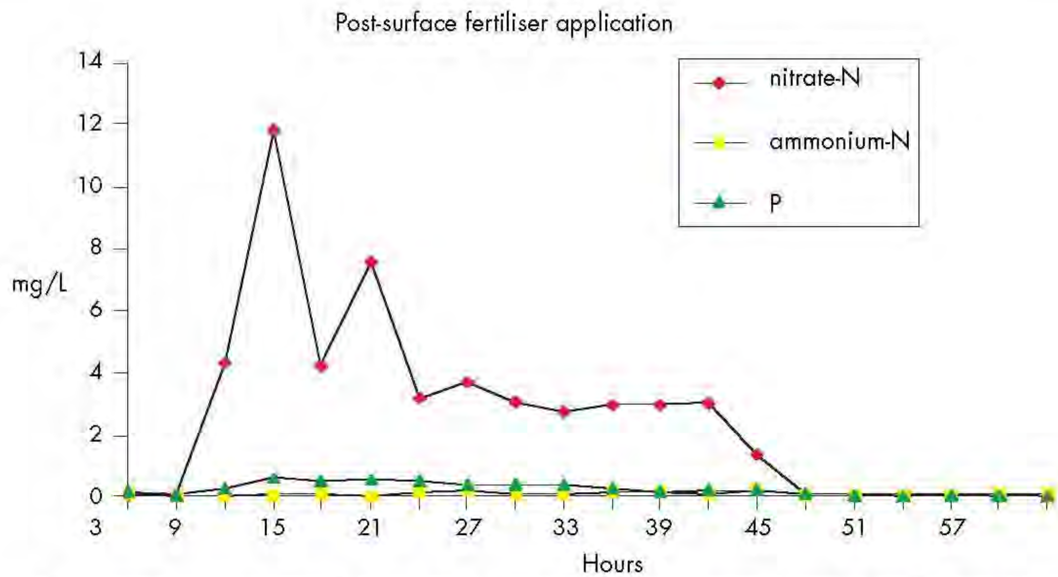

Figure 8. *Nitrogen losses in run-off water from furrow irrigation following surface application of urea.*
Source: G. Ham, BSES

used for their control. While considerable environmental concerns exist over the use of pesticides, they may contribute to the sustainability of the farming system if used appropriately.

The group of agricultural chemicals referred to as pesticides includes insecticides, fungicides and herbicides. The chemical properties of each are quite distinct. These chemicals have played a major part in shaping agricultural systems as we know them today and, in many cases, have reduced the need for regular cultivation. The fate of pesticide residues in the environment and in food products is a concern in many countries. All agricultural industries are facing pressure over their pesticide usage.

Care must be taken in the use of these products to reduce adverse impacts. The loss of pesticide residues to waterways in run-off water and eroded sediments or by leaching to groundwater systems is a concern from an ecological perspective and for the risk posed to human health if waters are used for drinking water. Pesticide residue limits have been set for drinking water on the principles that intake should not be of concern for human health, levels should be as low as can be reasonably achieved if good practices are followed, and there must be analytical methods capable of testing compliance with the standards.

Secondary poisoning of non-target species may also be a risk with some chemicals where the target pest is then preyed on by another animal. Residual pesticides may accumulate up a food chain. For example, the detection of residues in cattle was the major reason for the withdrawal of BHC, heptachlor and dieldrin in the 1980s.

The possible risk of secondary poisoning of owls was a concern with some of the rodenticides formerly used by the cane industry.

A reliance on agricultural chemicals as a sole means of pest control may lead to a number of additional problems. These include pest resistance to the pesticide, the resurgence of the target pest or development of secondary pests, and the enhanced microbial activity in soils speeding pesticide degradation. For these reasons, Integrated

Pest Management (IPM) strategies have become increasingly popular.

Pest-control measures have changed considerably over the years with the phasing out of the more harmful and persistent chemicals such as dieldrin, DDT and heptachlor. Low levels of these superseded organochlorine pesticides are still found in some canegrowing soils. As these residues are mostly found in the upper soil layer, potential exists for these trace chemicals to be transported downstream attached to sediments. However, they have not been detected in near-shore marine sediments. Modern chemicals are far less persistent.

As a general rule, insecticides are more harmful to environmental values than herbicides. Insecticide usage in the sugar industry is relatively small, and more importantly, the products are largely buried, reducing the risk of application to non-target areas. The major insecticide used is chlorpyrifos, a chemical that is essentially immobile in soils. As chlorpyrifos is predominantly buried as a slow controlled-release granule in plant-cane crops, the risk of loss is low provided soil conservation measures are in place to reduce the movement of the sediments to which it binds.

The sugar industry is a major user of herbicides. In the past, cultivation was used as the predominant means for weed control. However, this was costly, time consuming and left soils at high risk of erosion. With the change to green-cane trash-blanketing, mechanical weed control is not possible in ratoon crops. The trash blanket itself suppresses weed growth considerably and is supplemented by herbicidal control, significantly reducing the cost of weed control. In fact, herbicides account for over 90% of the total pesticide usage on cane farms. Atrazine and diuron are the dominant herbicides used in most regions but 2,4-D, glyphosate and ametryn are also used widely (Table 5).

Herbicides are used within the crop and to control weeds around the farm. Weed control, both within and outside of the block, is important to reduce harbourage areas for rats, a major pest of cane. Weeds in waterways are emerging as a major concern and their control is difficult. Herbicides are also used to spray out cane in a fallow block; this leaves the soil undisturbed, and reduces the risk of erosion over the fallow period. In this sense, the use of agricultural chemicals may contribute to the sustainability of the farming system.

Loss of herbicides to waterways from canelands is generally low, with peaks of high loss occurring only occasionally. Acute effects are not expected to occur. However, the long-term effects of low levels of herbicides entering waterways is unknown and concern exists over the possible impacts of diuron on seagrass. Preliminary studies indicate that, even at very low concentrations, they may impact on the photosynthetic ability of seagrass.

Breakdown and loss of pesticides

The environmental fate of a pesticide is influenced by the specific behaviour of that chemical in terms of the rate of degradation by sunlight (photolysis), breakdown in water (hydrolysis), volatility, chemical degradation, soil metabolism, soil persistence, adsorption by clay and organic matter, mobility in soil, and plant uptake. These characteristics vary under different environmental conditions and on different soil types.

The risk period for chemical loss after application varies depending on the chemical and the conditions under which it is applied. For this reason, an understanding of the loss pathways and persistence of each pesticide is important in minimising pesticide loss under any situation.

Leaching

The leaching of pesticides is an important management and environmental issue. Mobile pesticides may be leached to shallow,

Table 5. Estimated annual pesticide usage by the Queensland & New South Wales sugar industries in kg active ingredient/year.

Pesticide	North	Herbert	Burdekin	Central	South	QLD Totals	NSW
Herbicides							
Atrazine	107 594	33 804	46 480	116 011	27 696	331 585	34 776
Diuron	34 264	16 718	7884	108 691	29 889	197 446	6593
2,4-D	50 260	28 237	13 168	41 103	8789	141 557	11 182
Glyphosate	10 267	4388	10 052	53 830	7088	85 625	13 050
Ametryn	8688	2208	11 768	51 113	2205	75 982	1182
Paraquat	12 065	3476	3752	15 345	8167	42 805	6478
Trifluralin	1600	96	3768	10 276	5480	21 220	416
Asulam	1271			4659	12 725	18 655	260
MSMA	3960			5017	1359	10 336	1992
Pendimethalin	976	2760	992	539	627	5894	495
Hexazinone	2054	704		2758	79	5595	23
Ioxynil	27			3328		3355	30
Fluroxypur	1308	560			29	1897	
2,2-DPA				296	130	426	
Dicamba	191				28	219	
Metolachlor	22			26		48	
Diquat					17	17	
Bromacil	9					9	
Picloram				3		3	
Herbicide TOTALS	**234 556**	**92 951**	**97 864**	**412 995**	**104 308**	**942 674**	**76 477**
Insecticides							
Chlorpyrifos	25 653	3104	538	20 967	24 767	74 491	5100
Ethoprophos					4751	4751	
Aldicarb					1582	1582	
Heptachlor	1134					1134	
Diazinon	28					28	
Insecticide TOTALS	**26 815**	**3104**	**538**	**20 967**	**31 100**	**81 986**	**5100**
Rodenticide							
Brodifacoum	8	4		1		13	
Fungicides							
MEMC	724	400	472	378	321	2295	406
Prochloraz	71	99	100	184	177	631	36
Propiconazole	29	19	114	149	41	352	20
Flusilazole	8	14	18	30	15	85	
Fungicide TOTALS	**832**	**532**	**704**	**741**	**554**	**3363**	**462**

Sources: D. Hamilton and G. Haydon (1996) Pesticides and fertilisers in the Queensland sugar industry—estimates of usage and likely environmental fate. Project ICM-R&D.94.01 Final Report. DPI, Indooroopilly. Volume 1: Pesticides and D. Hamilton and G. Haydon (1997) Pesticides and Fertilisers in the New South Wales Sugar Industry—estimate of usage and likely environmental fate Project: RSC-DH/GH.96.01, Final Report: November 1997, Volume 1: Pesticides

perched watertables, from where they flow to waterways or they may leach to groundwater systems. Pesticides can be very persistent in groundwater, which poses issues for human health where the groundwater is used for drinking water.

The solubility of a chemical and how strongly it adheres to soil particles will affect its risk of leaching. It is possible for a chemical to be highly soluble but not readily leached. With the exception of cracking clays, leaching tends to decrease as the clay or organic matter content of soil increases.

Run-off

Run-off water from cane blocks generally contains extremely low levels of pesticides. However, pulses of high levels of herbicide loss have been detected in run-off water after certain events. In particular, peaks of high levels of atrazine and diuron have been measured in run-off water, as demonstrated in Figure 9.

In some cases, these have occurred from irrigation tailwater or low rainfall events, indicating that there is a possibility to reduce these losses through improved management techniques.

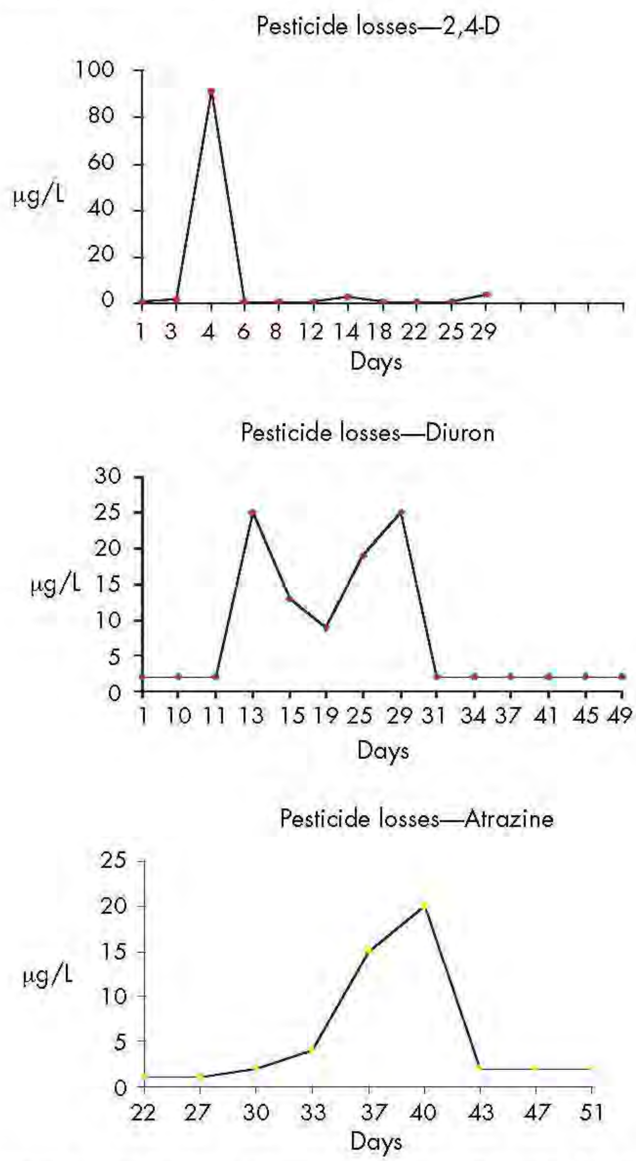

Figure 9. *Losses of selected herbicides from a furrow irrigated field in the Burdekin Region.*
Source: G. Ham

Soil movement

Some chemicals, such as the residual herbicides and the insecticide chlorpyrifos, bind tightly to soil particles. The major risk of these compounds moving downstream is by the erosion of the sediments to which they are attached. Practices to reduce soil erosion and trap sediments will lower the risk of these chemicals entering waterways. Under a GCTB system, supported by tailwater dams or retention basins, there is minimal risk of these chemicals being transported off-farm.

Chemical breakdown

Pesticides are degraded by reacting with water (hydrolysis). The rate of this degradation varies depending on the properties of the chemical and the pH of the water. Pesticides also vary in their rate of breakdown by sunlight—information specific to the product is provided on the label. Pesticides left in the soil will also degrade, independently of these abiotic processes, with soil bacteria and fungi working to degrade some pesticides. This metabolic breakdown occurs quickly in warm moist conditions. The pH of the soil can affect the rate of breakdown of herbicides and insecticides.

In some cases, the chemical breakdown products may be more persistent, more mobile and more toxic than the original compound. These breakdown products may, therefore, also pose an environmental risk. The loss pathways of the degradation products may be quite different from those of the original chemical.

Volatilisation

Volatilisation or evaporation from soil, plant and water surfaces to the air is the major loss process for some herbicides. The degree of volatilisation depends on temperature, wind speed, soil moisture levels, the vapour pressure of the pesticide and the degree of binding to plant or soil surfaces. Vapour pressure is a measure of how easily a pesticide can be converted into a gas. This varies greatly between different chemicals.

Volatilisation is greater under higher temperatures. Surface temperatures of most Queensland soils can reach 50-60°C in summer so temperature can be a significant factor. To reduce the effects of volatilisation, farmers should avoid spraying onto hot, dry soils, avoid spraying atrazine, diuron, ametryn, pendimethalin or trifluralin onto unshaded soil if possible, and incorporate or irrigate as soon as possible if needed.

Drift

The risk of pesticide drift is generally greatest where aerial application is used. Vapour drift is a significant loss pathway for highly volatile herbicides such as 2,4-D. Chemical drift may impact on neighbouring crops, urban areas or on native vegetation and waterways. All care should be taken to minimise drift, particularly when spraying close to houses or sensitive crops.

The risk of spray or vapour drift may be reduced by selecting products that are less likely to vaporise, spraying only under light wind conditions, and paying attention to droplet size, application pressure, boom height and nozzle selection.

Minimising the impacts of chemical usage

Appropriate application techniques should be used to reduce the potential for off-site impacts of chemical usage to people, other crops, or the environment. Particular care must be taken when near susceptible crops (e.g. care must be taken when using 2,4-D adjacent to vegetable growers) or aquatic environments (e.g. the use of atrazine in areas adjacent to creeks, rivers or wetlands is not recommended).

An understanding of how herbicides break down is vitally important, as it will enable strategies to be used to minimise the effect of management and environmental factors and maximise the effectiveness of the product used.

Applying herbicides at the correct plant stage and environmental conditions will maximise effectiveness with minimal chemical requirement.

Chemicals with low toxicity or those that are not toxic to non-target organisms should be used wherever possible. Volatile products should be avoided where an effective, less volatile product is available (e.g. avoid 2,4-D esters and use 2,4-D amines instead).

Application techniques are also important. The label should be read before use and the withholding period noted. Equipment must be calibrated before use, be pressure checked according to specification, have nozzles cleared, and be spraying uniformly. Minimise release height so that the risk of drift will be reduced. The nozzles and pressures should be selected to create a suitable droplet size to maximise efficiency and minimise drift.

Spraying should not occur when thermal inversion conditions exist, or in high wind speeds. When possible, spray when the temperature is below 32°C and the relative humidity is high.

Neighbours who might be affected should be notified. Be aware of susceptible crops and areas.

Integrated pest management

Integrated Pest Management (IPM) uses an understanding of a pest's biology and habits to effectively use a combination of different control measures. Best use is made of natural controls that are already present, particularly biological controls, and additional control measures are used only in a strategic manner when it is economic to do so. By using pesticides at the most effective times and in combination with other measures, IPM can reduce the overall usage of pesticides—reducing risks to the environment from excess chemical usage. The likelihood of resistance developing is also reduced and the pest can be more effectively controlled in the longer term. In this way, IPM is providing for more sustainable and more cost-effective weed and pest control strategies.

The concepts of IPM can be applied to any kind of pest—vertebrates, invertebrates, plants, bacteria, fungi or viruses. For example, based on knowledge of the lifecycle of the cane rat, the IPM program for rat control in sugarcane deals with weed control in the crop, management of adjacent harbourage areas, monitoring for the presence or absence of rats, and strategic baiting. Knowledge of the pest is critical for conducting baiting of rodent populations. IPM strategies are the most effective means for control of the major pests of sugarcane, the greyback canegrub, and other canegrubs.

Green-cane trash-blanketing is essentially a form of integrated weed management. The trash acts as a mulch, suppressing the germination and growth of weeds. The plant-cane cycle is currently the most sensitive to weed competition, due to the bare soil. Minimum-tillage planting, where the trash is retained into the new crop cycle, or the use of cover crops, which may be planted directly into and provide a surface mulch, could further reduce weed growth and the need for chemical control.

More information is given in the chapters on disease, pest and weed management.

HEAVY METALS

Heavy metals include arsenic, cadmium, copper, chromium, mercury, lead, nickel, selenium and zinc. Some of these elements may be in elevated levels in soils as a result of farming or industrial practices or they may naturally occur at high levels in some soils. Heavy metal concentrations in canegrowing soils are, on average, within typical ranges for agricultural soils. Differences that do exist within regions are generally related to the geological and fertiliser-use histories.

Mercury

Mercury typically occurs naturally in the environment at very low levels. Mercury is not an essential biological element and is a neurotoxin and enzyme deactivator. At elevated levels, it is one of the most toxic trace elements. In the 1950s, neurological disorders and deaths occurred following the release and accumulation of methyl mercury compounds from factories in Japan. Similar pollution events in Sweden and Canada focused attention on mercury accumulation in marine sediments. Subsequent studies have found mercury to be bio-concentrated enormously in fish and crabs. Inorganic mercury is converted by bacteria to forms of mercury that are very toxic and rapidly absorbed by aquatic creatures.

Studies of marine sediment cores off the north Queensland coast have identified low background levels of mercury. A sharp increase in levels in one core is believed to be linked to mercury use in gold mining activities in the Charters Towers and Ravenswood area between 1870 and 1890. Dated sediment cores in the Herbert estuary show excess (contaminant) mercury being supplied from about 1950 to the present day, indicating that human activities are increasing the concentration of mercury entering the marine environment. Concentrations of excess mercury in the sediment are still very low by comparison to European and North American pollution problems. Sediment movement from canelands treated with mercurial fungicides may be one source of this additional mercury.

Fungicides are used in sugarcane in planting operations to prevent the rot of cane setts from pineapple disease. Since the 1940s some of these fungicides (Shirtan® or Aretan®) have contained mercury in the form of methoxyethylmercuric chloride. Mercurial products have been phased out of use in other agricultural industries in Australia. In the past 10 years, non-mercurial fungicides have become available for cane planting and are frequently used. However, many canegrowers regard the mercurial fungicides to be more effective in preventing pineapple disease and in stimulating germination.

Because mercury binds tightly to soil particles, leaching is unlikely to occur. The highest mercury pollution risk is the movement of mercury-enriched sediments by erosion. Soil conservation measures will minimise the risk of mercury entering waterways and marine environments. Fungicides are applied to the plant crop, the highest risk period for in-field erosion. Minimum-tillage techniques and suitable timing of planting will help to minimise soil loss.

Contact with mercury products can cause skin to blister, similar to a second degree burn. When using mercurial fungicides, exposure to mercury should be minimised by wearing protective clothing such as gloves, overalls, hat and faceshield. Avoid breathing the vapours when adding the chemical to the dip or spray tank and if a spill does occur, wash it off immediately.

Cadmium

Cadmium levels in many canegrowing soils have been elevated by the use of cadmium-rich superphosphate fertilisers. This does not pose a concern for cane production. However, on some farms, cadmium concentrations are raised sufficiently to be of concern if alternative crops where soil contamination is a concern, such as peanuts, were to be grown and harvested.

WASTE MANAGEMENT

In addition to using appropriate land management practices, other areas of the farm enterprise need to be managed appropriately to reduce environmental impacts. The appropriate management of waste is a critical component of an environmental management system for any business. Appropriate disposal or re-use of wastes will avoid contaminants and rubbish entering waterways or building up in soils. Major wastes from cane farming operations are packaging (chemical drums and bags, fertiliser bags), oils, oil filters, batteries and tyres from tractors and harvesters. Many of these can now be commercially recycled. Local councils or CANEGROWERS offices can advise of appropriate disposal sites for regulated wastes.

The need for storage or disposal of agricultural chemicals can be reduced by planning chemical usage so that only just enough product is brought onto the farm. Check the label and Material Safety Data Sheet (MSDS) for the correct method of disposal for any chemical. Some products are now available in refillable containers or granulated form, reducing the problem with container disposal. Recycling facilities are available in most regions for chemical containers. Before taking containers to a recycling or disposal facility, triple rinse all empty containers, and return washings to the spray vat or container for inclusion in the next application procedure.

Oils and oil filters from farm machinery need to be disposed of appropriately. Check to determine whether an oil collection service is available. It may be most economical to share a collection tank with neighbouring farms. The treatment of farm machinery with used oil is discouraged. If it is done, ensure it is undertaken in a bunded area well away from creeks and drainage lines.

BY-PRODUCTS

The sugar industry has a long history of recycling the by-products of sugar production. Very little waste is produced from sugar milling as by-products are used as resources. This practice of recycling contributes significantly to the overall sustainability of the whole industry, provided care is taken in the use of these products.

Bagasse

Bagasse, the fibre from sugarcane, is burnt to provide power to operate sugar mills. There now exist possibilities for excess power to be sold commercially through electricity networks as 'green' power. The ash remaining from the burning of bagasse is used, either alone or combined with filter mud, as a fertiliser and soil ameliorant. Bagasse may also be used as a compost or to make particle board or paper.

Filter mud and ash

As cane juice is clarified and filtered at the mill, filter mud is separated from it. This mud comprises the soil that enters the mill in the cane supply (which can be a considerable component, particularly during wet harvests), together with organic materials (sugar and bagasse) and the lime that is used in the mill's clarification process.

Filter mud is spread on canelands, either alone or mixed with mill ash, as a soil ameliorant and fertiliser. As a general rule, 75% by weight of mud is water and some dryland growers have been known to use mud as a moisture source. The high water content also adds considerably to the cost of transport. Due to transport costs, mud/ash is usually distributed on those farms close to the mill. This may have implications for long-term sustainability, as the mud taken from around the district is concentrated on those farms closer to the mill.

The organic matter and calcium contained in mud/ash improve soil structure and water-holding capacity. The nutritional status of mud is also substantial. Growers often apply mud or mud/ash as a soil ameliorant without fully appreciating the nutritional value. Application of mud/ash without adjusting fertiliser rates mean an over application of some nutrients.

Some mills dispose of ash separately from mud. Ash is beneficial in the treatment of sodic soils. It should be worked in as deeply as possible to improve the soil physical condition, water penetration and aeration. Ash can also be beneficial on heavy clay soils.

More information on the use of mud/ash is given in the chapter on nutrition.

Molasses and dunder

Molasses is sold as a dietary supplement for cattle or distilled to produce ethanol or rum. A by-product of the distillation process, dunder, is now used as a potassium-rich fertiliser. This liquid fertiliser may be applied directly or blended with nitrogen to provide a liquid one-shot fertiliser. Dunder has a very high biological oxygen demand and care should be taken to avoid run-off to waterways. Prior to its use as a fertiliser, disposal of dunder had been a major environmental concern. Improved distillery processes to produce biodunder and its use as a fertiliser is a sustainable reuse of a by-product.

Mill effluent

Mill effluent is made up primarily of the water boiled from cane juice in making raw sugar. Each million tonnes of cane crushed at the mill contains about 700 ML of water. Some of this is lost to evaporation in the factory and from storage dams. The remainder is available for irrigation of cane.

The nutrient content of mill effluent can be highly variable. Mill effluents may be quite alkaline and may increase soil pH somewhat but not to a degree to cause concern for soil structure. Potassium levels are generally high and application of potassium fertiliser should be reduced where mill effluent is used for irrigation.

Analysis of the effluent water and soil tests are recommended to help refine the nutrition program to cater for the nutrients in the effluent water.

Cane trash

The collection of cane tops and trash has been developed as a profitable business venture in some areas. In cooler, low lying areas, such as are commonly found around the Rocky Point area, trash blanketing is not a viable option. However, community pressure to reduce cane firing meant that an alternative needed to be found. The close proximity to urban areas opened a market for garden mulch. Cane is now harvested green and the trash raked and baled. The trash is then sold as bales or shredded and packaged to a refined garden mulch.

Cane tops and trash are sometimes baled to provide feed for cattle during times of drought. Care must be taken to ensure that this trash does not contain pesticide residues that render it unsuitable for stock feed. Residues of some superseded pesticides, such as dieldrin and BHC, are still a concern in some areas.

AIR QUALITY

Air quality is predominantly affected by the concentration of pollutants in the troposphere, the layer of atmosphere up to 15 km from the Earth's surface. Suspended particles, nitrogen oxides, volatile organic compounds, sulfur dioxide and carbon monoxide are the main pollutants of concern for Queensland's air quality.

The most significant impact of canegrowing on air quality comes from the pre- and post-harvest burning of cane and trash. Ash fallout (commonly dubbed 'black snow') has been a regular feature of the harvest season in canegrowing regions but has been reduced with the change to green-cane trash-blanketing. The emissions of smoke and ash from cane fires, both before and after harvest, are a major social concern and pose a risk of possible health problems. Ash emitted from cane fires is considered a nuisance when it falls in residential areas. However, people living in canegrowing districts tend to be more tolerant of these problems, due to the contribution of the sugar industry to the local economy.

Drift from chemical spray applications also impacts on air quality and is a concern for many people. All practical measures should be taken to minimise pesticide drift.

NOISE

Excessive noise levels may be regarded as an environmental nuisance if they impact on the quality of life. In Queensland, noise complaints are managed by the local government, the Environment Protection Agency and the Police Service. Regulations related to noise have been introduced (*Environmental Protection Act 1994, Environmental Protection Regulation 1998* and *Environmental Protection (Noise) Policy 1997*) with the aim of achieving noise levels that are acceptable for most people.

These regulations are predominantly related to urban situations.

Noise concerns may be expressed where residential areas are close to sugarcane farming and transport operations. Most notable are transport and harvesting operations, particularly in areas with 24-hour harvesting. Disputes and complaints can be minimised by harvesting those blocks furthest from residential areas during late night and early morning activities.

CLIMATE CHANGE

Greenhouse effect

The Earth's surface is warmed by sunlight passing through the atmosphere. Heat is then reflected and released from land and oceans in the form of infra-red radiation. Some of this radiated heat is trapped by water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other trace gases that make up the Earth's atmosphere. This trapping of heat by atmospheric gases is known as the 'greenhouse effect'. These heat-trapping gases play an important role in regulating the temperature of the Earth's surface and atmosphere—without them the Earth's surface would be about 33°C colder than it is today.

Industrialisation, land-use change (including agricultural expansion), energy demands (and fossil fuels) and population increase over the past 200 years have increased the concentrations of many greenhouse gases. Today, the concentration of greenhouse gases is 28% greater than in the 18th century. Without controls, greenhouse gases will increase over the next 50–100 years to have a heat trapping effect equivalent to double the pre-industrial levels.

As the concentrations of greenhouse gases in the Earth's atmosphere increase, the amount of heat retained will also increase, leading to a warming of the lower atmosphere. By the year 2100, it is estimated that average world temperatures will be 0.8 to 4.5°C warmer than they are now. Changes in climate and weather are expected worldwide. Some areas will experience more rain and storms and others will have less. With the warming of the Earth's surface, sea levels are predicted to rise by 0.13–1.1 m above 1990 levels by the end of the 21st century. These changes will affect water resources, agriculture, natural environments, coastal management and urban areas.

As the impacts of elevated levels of greenhouse gases are not confined to national boundaries, a global response is needed. Australia is a party to the 1992 United Nations' Framework Convention on Climate Change and the subsequent 1997 Kyoto Protocol. Australia has committed to a reduction in the growth of greenhouse gas emissions. A National Greenhouse Gas Inventory is prepared annually, outlining greenhouse budgets from Australia's land uses and industries.

In 1997, Australia's net greenhouse gas emissions, excluding land clearing, were estimated to be equivalent to 431 Mt CO_2, an increase of 11% from 1990s 389 Mt. This increase in total emissions comprised a 16.5% increase in CO_2, 1.9% increase in CH_4, 15.7% increase in N_2O and a drop of over 70% in PFC. Agriculture contributes a total of 22% of net greenhouse-gas emissions.

Land clearing is believed to contribute 13% of Australia's total emissions, though these releases have decreased. Vegetation is important in reducing greenhouse gas emissions as plants take in carbon dioxide and store carbon in trees, shrubs and soils. This carbon is rapidly lost when forests are cleared.

Carbon dioxide

The majority of the increase in carbon dioxide in the atmosphere comes from the burning of fossil fuels such as oil, coal and natural gas. Each year, human activities worldwide are believed to add some 26 000 Mt of carbon dioxide to our atmosphere. Carbon dioxide is emitted during the burning of sugarcane and through organic-matter breakdown processes in both trash-blanketed and bare soils. However, the sugarcane crop is a significant carbon sink. That is, it has the ability to efficiently fix carbon. Crop uptake (estimated to be 13.4 Mt CO_2-C/yr in 1994) exceeds the total CO_2 emitted during sugarcane production.

Methane

Methane is formed when organic materials are broken down in the absence of oxygen. About 50% of Australia's methane emissions come from livestock, produced by bacteria that break down cellulose in the stomachs of sheep and cattle. An additional 31% of methane emissions arise from other agricultural activities. Methane is also released from microbial activity in waterlogged soils, burning vegetation, coal mines and natural gas fields.

Methane is emitted during the smouldering phase after sugarcane is burnt. However, trash-blanketed soils are a significant sink for atmospheric methane, consuming far more than is released in burning. As the majority of soils are now trash blanketed, sugarcane fields are regarded as net consumers of methane.

Nitrous oxide

Nitrous oxide is an important greenhouse gas as it does not break down easily, with an atmospheric lifetime of 150 years. Nitrous oxide emissions from the agricultural sector are predominantly released from the tillage of land for crop production. Biomass burning, nitrogen fertiliser and management of animal wastes also contribute.

Sugarcane is estimated to contribute approximately 1.1% (10 800 tonnes) of Australia's total agricultural emissions of nitrous oxide. About 90% of these emissions are derived from the soil by nitrification and denitrification. The large proportion of this has been linked to gaseous nitrogen losses from denitrification following fertiliser application. On-farm management practices can be adapted to minimise the direct emissions of nitrous oxide into the atmosphere by matching nitrogen rates to crop requirements by soil and plant testing, and applying nitrogen fertiliser to the crop more frequently in smaller amounts. Nitrogen inhibitors may be used to maintain nitrogenous fertilisers in the ammonium form. However, this is not economic. Minimal tillage and green-cane trash-blanketing (N_2O emissions from burnt lands are almost 60% higher than those with trash blankets) will also help reduce nitrous oxide emissions.

Sugarcane—source or sink?

Overall, the canegrowing sector of the Australian sugar industry is considered to be a significant sink of the greenhouse gases carbon dioxide and methane. However, it does emit the more potent greenhouse gas nitrous oxide. Taking into account the milling sector, sugar production rates as a greenhouse neutral activity. That is, the greenhouse gas emissions from the crop and during milling operations are balanced by the CO_2 fixed by the crop and methane consumed by the trash blanket.

To calculate a total budget for the industry, the emissions from fuel use in machinery, transport and shipping and the effects of land clearing should also be considered. Through cogeneration, the sugar industry has the opportunity to contribute to a reduction in net greenhouse gases by providing a renewable energy source. Currently mills produce power for their own use through the combustion of bagasse. Many of these produce additional power that is sold to energy corporations. Opportunity exists to provide greater amounts of this renewable energy to the community by increasing the efficiency of mill power plants and supplementing with alternative fibre wastes.

Ozone depletion

Another element affecting climate change is ozone—a gas that acts as a barrier preventing the majority of ultra-violet (UV) radiation from reaching the Earth's surface. Ozone (O_3)

is a form of oxygen found in the stratosphere (the upper atmosphere 15-50 km above the Earth's surface). It occurs in small amounts throughout the stratosphere but is most concentrated around 35 km elevation—this is known as the ozone layer. This layer of ozone screens out approximately 90% of UVB radiation.

Ozone also occurs naturally in minute amounts in the troposphere closer to Earth, and is also produced as a pollutant in smog in this lower atmosphere. Ozone is essential in the upper atmosphere, but at elevated levels in the lower atmosphere, it is a highly corrosive gas, toxic to most organisms. It is also a minor greenhouse gas.

In the stratosphere, ozone is constantly being formed in small amounts by the action of sunlight on oxygen. However, natural processes are in play to break down ozone and the natural balance of ozone breakdown and formation keeps the total amount of ozone at a constant level. However, human activity has disturbed this natural balance. Certain substances manufactured synthetically or as an indirect result of human activity destroy ozone far more quickly than it is formed. Many of these ozone-depleting substances, usually containing chlorine or bromine, have been banned. It may take many years for these substances to reach the ozone layer, but once there, their impacts are severe. The most abundant are the chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). Ozone-depleting substances of concern for agriculture are methyl bromide and nitrous oxides. Methyl bromide is rarely used in sugarcane production, but may be used on some cane farms as a soil fumigant prior to small-crop production. Nitrous oxide is more of a concern for the industry, as this may be produced from the application of nitrogenous fertilisers. As discussed in the previous section, sugarcane growing contributes approximately 1.1% of Australia's total agricultural emissions of nitrous oxide. Good farm management can reduce these.

The depletion of ozone in the stratosphere will increase the levels of UVB reaching the Earth's surface. Even a 1% increase in the depletion of ozone in the upper atmosphere causes a measurable increase in UVB. Excessive exposure to UVB has harmful effects on human health, animals and plants. The 'ozone hole' over Antarctica is an area covering approximately 26 million square kilometres where the concentration of ozone gas in the stratosphere is substantially depleted. Excessive UVB is measured in areas under these ozone holes.

MARKET POTENTIAL

Environmental management standards are becoming an increasingly strong driver in international trade. Australian agriculture has built on its reputation as a clean, green producer of high quality, safe food. Markets are now beginning to demand this standard. Premiums may develop for foods or fibres that have been produced according to good environmental standards. A market for organically produced foods currently exists and is growing. Conversely, food safety, environmental and health concerns are forming the basis for barriers to trade. International treaties on the environment have been developed, and Australia is signatory to many of these. However, implementation of such treaties can be difficult. Trade often becomes the tool used in ensuring these treaties are followed.

Consumers are increasingly demanding that foods are produced to high quality, safety and environmental standards. This demand for 'safe food' is a strong market driver that has led to various quality assurance and accreditation schemes coming into place in a number of agricultural commodities in Australia.

Organic production

Organically produced food and fibre products are grown without the use of pesticides, inorganic fertilisers or transgenic organisms and are produced, harvested, handled and transported without risk of contamination by chemicals, fumigation or irradiation. Organic certification can be provided in Australia by one of seven, internationally recognised bodies.

To obtain certification, there must be no use of restricted materials for at least three years. It takes 12–24 months to gain certification and audits are then undertaken every 12 months.

The demand for organically produced food products has increased rapidly and continues to do so, particularly in Europe and Japan. Studies indicate that the demand is driven largely by concern over food safety and genetic modification. While food safety may be less of a concern for a refined product such as sugar, the demand for organic sugar may be driven more by the manufactured foods market seeking organic labelling. Premiums for organically produced food products are generally 20–40% higher than conventionally produced products. Premiums have been up to 200% higher when there is a scarcity.

Organic production is a long-term commitment. Options for soil fertility and weed-control measures must be considered carefully and problems with isolation of products in mills must be addressed.

Environmental accreditation

Quality and safety standards are increasingly being demanded from food producers. Environmental concerns have the ability to influence international trade. While current schemes are primarily food-safety based, it is possible that a similar standard may be demanded for environmental accreditation in the future.

Since 1993, the European Union, through their Eco-Management and Audit Scheme (EMAS), has established a register of companies that have achieved environmental standards and are working towards on-going improvement. EMAS recognition can be used in restricting trade.

The International Standards for environmental management systems, environmental auditing, environmental labelling and life cycle assessment (ISO 14000 family of standards) are the major international recognition of Environmental Management Systems (EMS). This standard has been applied to agricultural systems in Australia and New Zealand.

The basic principle of an EMS is based around situation analysis and on-going improvement. A review of current practices is undertaken, plans made for improvement, changes implemented and then audited.

Quality assurance (QA) has been applied to many production sectors, including agriculture, and has gained widespread consumer recognition. HACCP (Hazard Analysis Critical Control Point) schemes are being adopted by the fresh fruit and vegetable sector in response to food safety concerns. Major retail chains have signed agreements with fruit and vegetable producers for produce to be grown and handled to agreed standards.

The possibility exists for the sugar industry to develop an environmental accreditation program based on the Code of Practice for Sustainable Cane Growing.

An auditing system and a process for assessment and on-going improvement across all production sectors would be central to such a program.

Good record keeping is essential for any quality, safety or environmental accreditation system. Many businesses have indicated a benefit from the adoption of an environmental management system that is often related back to the improvement in record keeping and the assessment of 'normal' practices.

Environmental accreditation may be the future for canegrowers to ensure their farming practices are sustainable and to retain access to international markets that are demanding demonstrated environmental care and food safety standards.

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