Soil Erosion, Scientists and the Development of Conservation Tillage Techniques in the Queensland Sugar Industry, 1935–1995

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ABSTRACT

Soil erosion throughout Queensland's sugar cane producing lands emerged as a significant problem in the 1930s. Poor farming techniques such as leaving fallow land or fields with young crops bare during the wetter summer months and cultivating sloping land were blamed for this environmental problem. Drawing upon archival documents, government reports and published accounts of agricultural scientists, this paper aims to document how officers of the Queensland Bureau of Sugar Experiment Stations and the Soil Conservation Branch of the Queensland Department of Agriculture and Stock (later Primary Industries) tried developing soil conservation methods suited to land cropped with sugar cane. The conclusion from the historical analysis is that many Queensland canegrowers before 1980 were very slow to adopt the soil conservation methods advocated by the agricultural scientists, even though they acknowledged that soil erosion was a problem. This reluctance to 'save the land' changed during the 1980s following the emergence of an agricultural practice known as trash blanketing. The ease of its implementation and associated reduction in tillage costs contributed to its rapid uptake.

KEYWORDS

Queensland, soil erosion, sugar cane, contour farming, trash blanketing

INTRODUCTION

Soil erosion has long been associated with the pursuit of cane growing. By the 1660s, twenty years after the commencement of sugar cane cultivation on Barba-

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dos, soil erosion was contributing to declining sugar cane yields. By 1710, much of the island had temporarily been abandoned for cane cultivation because of soil loss. Loss of soil in hilly cane growing areas throughout Jamaica and St Kitts is mentioned in contemporary accounts during the eighteenth century. Nearby on Cuba, declining yields during the mid-nineteenth century were caused by the 'disappearance into the sea' of thousands of tons of soil through erosion. In South Africa's sugar growing regions, the 'menace of soil erosion' was reported in the late 1940s as becoming 'a matter of importance to all farmers'.[1]

In Queensland's sugar cane growing lands, soil erosion is not mentioned in the official documents until the 1930s, almost seventy years after the establishment of the industry in the 1860s. Its presence, however, probably occurred long before the State's agricultural officers became concerned enough to mention the problem. This paper sets out to provide the context surrounding the recognition of this problem in the 1930s and to explain the location and extent of this soil loss throughout Queensland's sugar cane growing districts after 1945. Attempts to slow this soil loss are also considered, although the analysis will highlight that the techniques recommended to reduce soil erosion (i.e. contour tillage, terraces and grassed waterways) were only slowly adopted, with many canegrowers continuing to suffer soil loss either knowingly or unwittingly.

The relationship between soil erosion, conservation efforts and small European canegrowers is particularly interesting for three main reasons. First, the topic has not been considered previously, with the historical accounts of the Queensland sugar industry failing to mention soil erosion, probably because most focus upon the period prior to 1930 and deal mainly with the issue of the industry's labour supply.[2] Historical studies dealing with more recent developments in the Queensland sugar industry have concentrated on documenting the introduction of mechanical harvesting, not the land management practices adopted by Queensland's canegrowers.[3] Therefore, this paper aims to redress this omission in the historiography of the Australian sugar industry. Second, the paper will highlight that many Queensland canegrowers between 1930 and 1980 employed agricultural practices that were environmentally unsound (e.g. leaving fields fallow during the summer rainy season; planting in furrows aligned downslope; cultivating land with slopes of greater than ten per cent). Third, the analysis will illustrate how the transfer of models from other crops and physical environments is not always successful or possible. The agricultural scientists and extension officers were restricted in the types of soil conservation techniques that they could recommend to Queensland canegrowers. Sugar cane in Queensland is cultivated as an intensive monoculture in high rainfall localities and the farmers lacked alternative suitable crops that were as profitable as sugar cane. Soil conservation methods appropriate for lighter rainfall areas which were cropped with mixtures of cereals, legumes and grasses could not be easily adopted in Queensland's sugar producing lands.

I begin this account by briefly providing an overview of the Queensland sugar industry. The second section contains information on how farming practices contributed to soil erosion in Queensland's sugar cane producing lands. Details about the extent of soil loss throughout Queensland's sugar cane producing lands are presented in the third section of this article, although the discussion will show that the figures on the magnitude of the problem need to be interpreted with caution. In the fourth section, the conservation tillage techniques developed by the agricultural scientists are outlined. Information about the adoption of these techniques by Queensland canegrowers is provided in the final section, although it will be highlighted that the State's canegrowers were slow to adopt the practices that saved their soil until the 1980s.

THE QUEENSLAND SUGAR INDUSTRY

The Queensland sugar industry was established in the 1860s, almost two hundred years after other colonial sugar industries were founded in the Caribbean, Louisiana and Brazil. Initially, the Queensland sugar industry mirrored the established production model, being based on plantations, although the field workers were indentured Melanesians or Asians, not slaves. The practice of recruiting Melanesians for the Queensland sugar industry became known as 'blackbirding' and was increasingly opposed by sections of the Australian community after 1880. This opposition to the employment of non-European workers in the Queensland sugar industry and the implementation of the White Australia Policy after 1900 led to a transformation in its production structure during the 1890s and 1900s. Large numbers of small, European-owned family farms supplying sugar cane to cooperative or proprietary central sugar mills took the place of plantations.[4] This arrangement still existed in the early 1990s, with the basis of the Queensland sugar industry being approximately 6,300 farms, most of which were cultivated with between 30 and 90 hectares of cane, and 25 mills.

Growth in the area under sugar cane cultivation was steady between 1860 and 1920, followed by a particularly large expansion in the 1920s. During this period, sugar cane cultivation spread across generally well-watered fertile alluvial coastal plains, containing some sloping terrain, and the eight main non-contiguous sugar cane growing districts were established (Figure 1). Expansion in the area cropped with sugar cane slowed during the 1930s, due to fears about overproduction and some attempts at regulating growth (see below). Growth resumed after World War Two as new farms in existing sugar cane growing localities were settled by eligible ex-servicemen. A further expansion was sanctioned by the Queensland Government in the early 1950s, leading to the area under sugar cane increasing substantially during the 1960s (see Figure 2), although its cultivation did not spread to any new districts in Queensland. Between 1970 and 1995, the Queensland sugar industry continued to expand.[5] Essentially, however, this

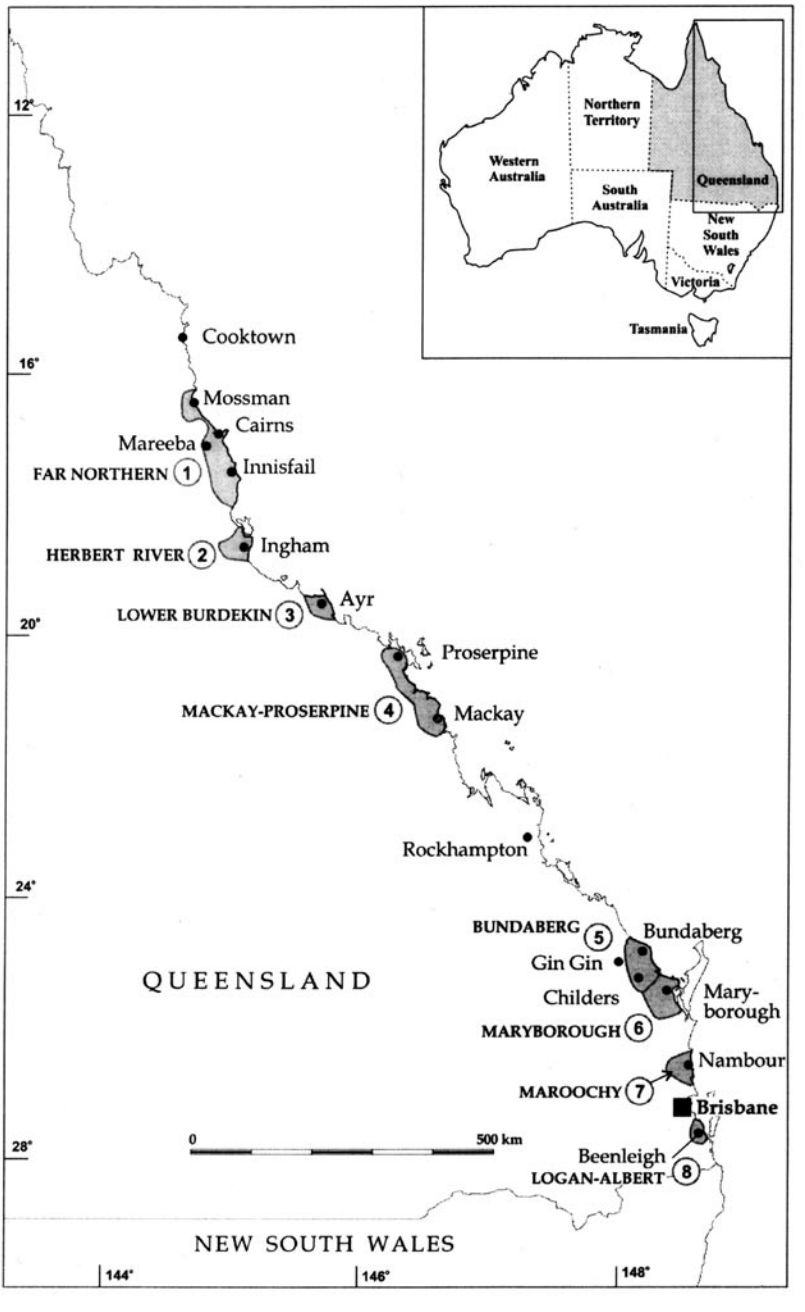

FIGURE 1. Sugar cane growing regions of Queensland in 1995.

expansion was a 'filling in' process, making use of previously uncultivated land in most mill areas. Unfortunately, the most suitable land for cane growing was already in use, so the land occupied by this expansion, particularly in northern cane growing districts, was either sloping or poorly drained.[6]

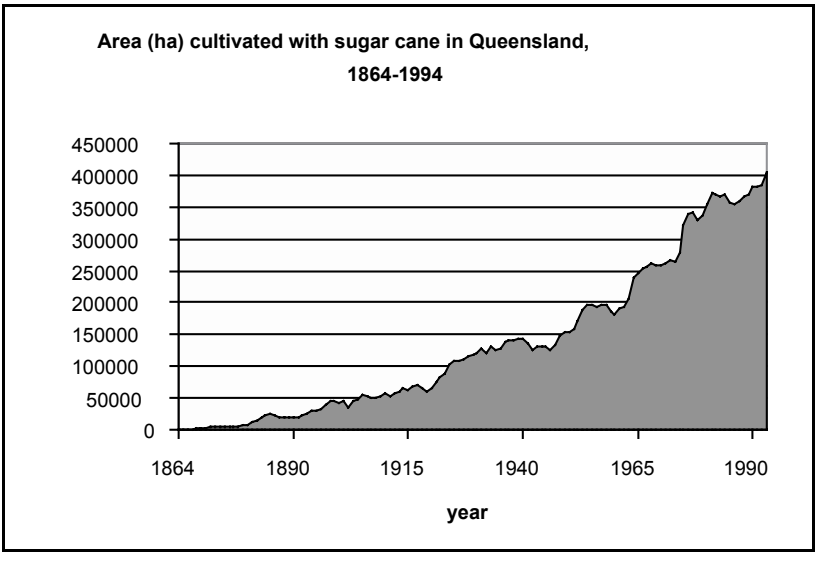

FIGURE 2. The area cultivated with sugar cane in Queensland, 1864–1994.

Source: Assembled from figures published in the *Statistics of the Colony of Queensland* and the *Australian Yearbook*

Another distinguishing feature of the Queensland sugar industry, until quite recently, was the high degree of regulation over all aspects of production. During the early 1910s, tensions developed between canegrowers and millers over the prices paid for cane and the inclination of some canegrowers to send their cane to different mills each year. Legislation was introduced in 1915 (and subsequently amended several times over the next fifty years) to create the Central Cane Prices Board. This organisation controlled the areas of land on which individual farmers grew sugar cane or the location of land 'assigned' to cane cultivation. By 1930, Queensland canegrowers were granted an entitlement which allowed them to deliver to a mill for payment, cane grown on a number of hectares of a specific amount of land assigned to an individual mill (i.e. an assignment). After 1929, millers operated under what became known as the Peak Year Scheme, and were allocated a set tonnage of raw sugar they could produce each year. The price canegrowers received for their cane and the price millers received for their

sugar was determined by legislation. The domestic market was protected by a ban on imports of sugar and all sugar produced by the mills was compulsorily acquired by the Queensland Sugar Board, which handled the marketing of sugar domestically and overseas. Removal of many of these regulatory controls has occurred during the 1990s and early 2000s.[7]

CAUSES OF SOIL EROSION IN QUEENSLAND'S CANE GROWING LANDS

Soil erosion is the loosening and removal of soil from its previous resting place, through the agency of wind and water. Wind erosion is usually experienced in drier regions. The topsoil becomes loose and powdery and the wind carries it away. Sugar cane cultivation, however, is mostly concentrated in high-rainfall localities, so water erosion is more a problem. Rainfall causes two types of erosion: sheet and gully. The latter is the most easily discernable form of erosion and is commonly found on sloping land: generally the steeper the slope the more frequent the gullies. These gullies occur in two forms. The commoner is a complex of small gullies (sometimes known as rills or grooves) that can be crossed and reclaimed with the usual farm implements. The other type of gully has deep and steep sides, often one to three metres in depth (see Figure 3). Such gullies are difficult to reclaim with ordinary farm machinery, but are usually

FIGURE 3. Serious gully erosion on a cane farm at Childers, 1950.
Source: Vallance 1950: 28.

rare.[8] In contrast, sheet erosion is not easily detected. When heavy rain falls on unprotected soil, absorption takes place at a rate governed by the soil type, its structure and texture and existing level of soil moisture. As soil becomes saturated or when the rate of precipitation exceeds that of absorption, free water develops on the surface. When free surface water develops on even gently sloping land, it moves towards lower levels at a speed dependent upon the slope gradient. Soil particles dislodged by the raindrops are carried away suspended in the moving water. The result is the loss of finer soil particles, often over the entire field, and its effects often pass unnoticed until gullying may commence.[9]

Soil erosion is caused when farmers cultivate inappropriate locations. The steepness or gradient of the land has a very direct influence on the degree of erosion present. Land with a slope greater than ten per cent is very difficult to cultivate. In the Isis district (near Childers), J.L. Tardent, a local forester, calculated in 1938 that 80 per cent of the area planted in the district was located on slopes between 6 and 20 per cent, and that damage from erosion reached an 'alarming total'.[10] In 1945, an investigation into soil erosion in Queensland cane growing regions found that slopes with angles of 25 degrees in the Mackay district were being cultivated and the resulting erosion was 'very far advanced'. The Queensland Bureau of Investigation which surveyed soil erosion in Queensland during 1946, concluded that the 'cultivation of slopes of from 15 to 20 per cent is not uncommon, while in some instances slopes exceeding 25 per cent have been used for the production of sugar cane'.[11]

Soil erosion can also be caused when farmers employ incorrect farming techniques. Agricultural practices used by Queensland canegrowers had improved between 1890 and 1920, with some canegrowers now resting parts of their farms under soil enriching leguminous crops, improving on-farm drainage and arresting soil deterioration by applying both natural and artificial manures.[12] However, contour tillage appears to have been unknown in Queensland sugar cane growing districts before 1945 (or present but not recorded in any official documents), and the long straight drills went up and down hills with no thought given to how excess water might form channels seeking lower levels. Land was often left fallow during summer months and fields with young crops suffered from heavy falls of rain; scouring and small rills can occur on land with even a slight slope. In 1939, Charles Young, the General Manager of the Fairymead Sugar Company Ltd., for example, told a Royal Commission on Sugar Peaks and other Cognate Matters, that the organisation he represented had been forced to throw out of cultivation 260 acres (105 hectares) 'largely on account of soil erosion whilst it was fallow'.[13] In addition, historically fields with ratoon sugar cane crops (i.e. cane regrowth from the stalks left in the ground after a crop has been harvested) in Queensland were often exposed to summer rains. The conservation of trash (i.e. cane tops and leaves or the residue left after harvesting) was not commonly employed in the Queensland sugar industry and even less so after 1930 due to the introduction of widespread pre-harvest burning of

crops. This practice was adopted as a health precaution to reduce the incidence of Weil's disease amongst cane cutters, thereby avoiding strike action by cane cutters, and post-harvest burning of crop residues because of the concerns that this material harboured pests and disease.[14]

Queensland's regulated system of sugar cane production compounded the above poor practices. As mentioned above, Queensland's canegrowers after 1930 had an assignment or an entitlement that allowed them to deliver to a mill for payment cane grown on a number of hectares situated within the boundaries of a designated block of land assigned to a particular mill. Farmers were expected to produce a crop of cane every year, although until 1965 they were restricted to harvesting no more than 75 per cent of their assigned area, thereby ensuring annually that a quarter of the assignment was rested and cropped with soil-regenerating cover crops.[15] Moreover, canegrowers could not easily get permission to change assignments, even within existing farm boundaries. Such arrangements caused the continued use of eroded and eroding lands.[16] The Queensland government in the 1970s recognised that this undesirable feature of Queensland's regulated system of sugar production was contributing to soil erosion in at least the Isis district. Working in conjunction with all sectors of the sugar industry in the Isis district, the Queensland government assisted seventy canegrowers farming sloping land to move their assignments to more level farms created from vacant Crown land or areas surrendered from local State Forests.[17]

OFFICIAL CONCERN ABOUT SOIL EROSION THROUGHOUT QUEENSLAND'S CANE GROWING LANDS

Soil erosion was noted in other parts of Australia long before its presence was recorded in the sugar cane growing lands of Queensland. Wind erosion and drifting sand dunes emerged as a concern in the semi-arid, lighter soils districts of South Australia and Victoria during the late nineteenth century. By the late 1920s and early 1930s, residents of Sydney were increasingly complaining about the heavy dust storms hitting their city. Widespread use of bare fallow practices in the drier parts of Australia's wheat zone was leading to the creation of Australia's own dustbowl. In wetter areas, agricultural scientists reported that heavy summer rainstorms contributed to severe sheet and gully erosion throughout the wheat growing areas.[18] Thus, reports of soil erosion in Queensland's cane growing regions in the late 1930s were part of an Australian-wide concern for the loss of soil and form part of an intensified worldwide concern for soil erosion that arose following the creation of the 'Dust Bowl' in the southern Great Plains of the United States in the early 1930s.

The loss of Australia's soil became the topic of several books during the 1930s and 1940s. Amongst these publications was the now classic work *Soil Erosion in Australia and New Zealand* by James Macdonald Holmes, which included a

map that categorised the seriousness of soil erosion in Australia. The sugar cane growing lands of Queensland were identified as suffering the greatest risk of sheet erosion and gullying, although Holmes did not specifically mention soil loss throughout these districts in his text.[19] Moreover, as soil loss grew widespread, governments in Australia began to take the problem more seriously. New South Wales led the way, forming a government committee in 1933 to monitor the problem and in 1938 a soil conservation service was created to survey the extent of the problem and begin ameliorative action. In South Australia, a Soil Conservation Committee had prepared maps on the extent of soil erosion in the State by 1937 and had commenced promoting better farming techniques. Victoria was slower to respond, despite the evidence of widespread wind erosion in the Mallee region during the early 1930s. A government committee to investigate the matter was established in 1936, but a State-wide survey of the problem did not commence until a Soil Conservation Board was formed in 1940.[20]

Loss of soil throughout Queensland's cropping lands, especially on the Darling Downs, was recognised as a problem in the early 1930s. In 1935, A.F. Skinner, a cadet in the Agriculture Branch of the Queensland Department of Agriculture and Stock, surveyed and constructed a contour bank over 25 hectares of land on the northern outskirts of Toowoomba. This first government soil conservation work done in Queensland encouraged several farmers on the Darling Downs to install contour banks on their properties. This interest in soil conservation was halted by World War Two, when all work was directed towards the production of food and fibre. Soil conservation work resumed in 1947 when Jasper Ladewig was appointed a Soil Conservation Officer in the Queensland Department of Agriculture and Stock, thus creating the nucleus of a soil conservation service in Queensland. Eventually legislation was introduced in 1951, requiring the Queensland Department of Agriculture and Stock to assess the extent of soil erosion throughout the State and to assist landholders with the reduction of the extent of soil loss. Under this legislation districts could be declared areas of soil erosion hazard.[21]

The first official report about soil erosion in Queensland's cane growing lands that could be found in the extant records was made in 1938 by J. L. Tardent, who estimated that 800 ha in the Isis district once grew sugar cane but 'are absolutely derelict land now or carry very poor crops'. He attributed this situation to the extensive soil loss occurring in the district. Interestingly, Edward Knox Junior, the General Manager of the Colonial Sugar Refining Company – Australia's largest sugar miller and refiner – had hinted at this problem much earlier. In 1899, he visited one of the firm's Queensland sugar mills at Isis, near Childers. As part of this visit, he toured the district, inspecting the farms of those European settlers who supplied the Isis Sugar Mill with sugar cane. In his report to the Company's Board of Directors, Knox expressed concern at what he had witnessed, writing, 'already some drawbacks are showing themselves. Many

of the hills are very steep and in course of time trouble will be caused through the soil being washed into the gullies in heavy rains'.[22]

On the eve of World War Two, Dr Henry William (Bill) Kerr and Arthur Bell from the Queensland Bureau of Sugar Experiment Stations (hereafter BSES) wrote, 'many fields of valuable land are being rapidly deprived of their fertile surface soils'. They singled out the Isis and South Johnstone (near Innisfail) districts as the two Queensland sugar cane producing regions suffering the most soil erosion.[23] World War Two interrupted any official action to deal with the issue of soil loss. However, in March 1945, the Queensland Cane Growers' Council asked the Prime Minister of Australia to survey the extent of the problem in Queensland. The Commonwealth Government acceded to this request. During the latter months of 1945, officers from the Division of Soils, Council for Scientific and Industrial Research, and the BSES, toured half the sugar producing regions of Queensland, with the focus of their investigations being northern localities. The report provided a qualitative assessment of the extent of the problem. Serious field erosion was reported from all districts visited, except Ingham, with the deep red soils found in the Isis and South Johnstone districts being the worst affected.

The first quantitative estimate of the extent of the cultivated areas needing soil erosion measures in the sugar cane producing lands in Queensland are attached as an appendix to a letter from the Hon. Frank Nicklin, Premier of Queensland, to Hon. Robert Menzies, Prime Minister of Australia in 1959. The author of these figures is not stated and the archival document provides no clue as to why they were assembled. Clearly, these figures need to be interpreted cautiously, as there is no explanation as to what criteria were used to determine which cane growing lands needed soil conservation measures. No definition was provided as to what constituted a soil conservation measure (i.e. contour banks or reducing the amount of bare fallow land). With these caveats in mind, the figures suggested that overall, approximately 31 000 ha in sugar producing shires in Queensland or nearly a third of the cultivated land in these shires required some soil conservation measures. Local authorities in the Maryborough district suffered the greatest amount of soil erosion, with between 60 and 80 per cent of the cultivated area experiencing some form of soil loss. Between 20 and 30 per cent of the cultivated area in a group of mostly southern Queensland shires around Bundaberg and Nambour needed soil conservation measures. In these districts, sugar cane growing was often conducted on hilly land. Around 10 per cent of the cultivated areas in the remaining shires needed soil conservation measures. In the Mackay and Innisfail districts, soil erosion occurred because of the extensive cultivation of sugar cane on sloping land.[24]

As the above expansions progressed, the presence of soil erosion in Queensland's sugar cane producing lands continued to be mentioned in official publications produced by the Queensland Department of Primary Industries.[25] By 1975, the Isis and Gin Gin districts, two of southern Queensland's sugar cane growing

districts, had been declared areas of soil erosion hazard. In addition, local Shire and River Trust Engineers began expressing concern that soil eroding from sugar cane growing lands was contributing to siltation in the lower reaches of the major rivers along the Queensland coast and exacerbating flooding hazards and negating drainage improvements undertaken in flood-prone areas.[26] This perceived worsening soil erosion problem in Queensland's sugar cane growing lands led to the Queensland Department of Primary Industries commencing investigations into quantifying how much soil was being lost from sloping paddocks cultivated with sugar cane. The first of these studies conducted in the Mackay district during the wet seasons of 1976/77 and 1977/78 concluded that losses approximately equivalent to 42 to 227 tonnes/ha per year were occurring on paddocks with slopes of between six and eight per cent. These amounts were extremely high, as maximum losses of 12.5 tonnes/ha per year were considered acceptable.[27] Further studies during the early 1980s investigated the magnitude of soil loss on cane paddocks under conventional cultivation in Far North Queensland. Average annual losses were calculated to be 150 tonnes/ha, with a range of annual measurement being 70–500 tonnes/ha.[28] With the loss of these amounts of soil, it was not surprising that local Shire and River Trust engineers were expressing concern about river siltation.

As the above studies were being undertaken, the Division of Land Utilisation of the Queensland Department of Primary Industries also completed a series of studies on land suitability for sugar cane cultivation throughout Queensland.[29] As part of these investigations, details on the extent of eroded cane land throughout Queensland were gathered from soil conservation staff. Again these figures need to be interpreted cautiously, as no explanation was presented outlining what criteria were used to determine eroded land. With this caveat in mind, the figures suggested that in 1983 approximately 107 900 ha or a third of Queensland's assigned sugar cane producing lands were eroded or eroding. This overall figure is much the same as that calculated in 1958, with the most widespread erosion continuing to be concentrated in the Isis/Maryborough and Bundaberg districts. However, the 1983 figures suggest higher levels of erosion in the Northern and Mackay districts compared to the 1958 figures. Such an assessment would seem plausible, given that sugar cane cultivation had spread onto more marginal lands during the 1970s and early 1980s expansions.

Since the above figures were published, major changes have occurred in the on-farm land management practices employed by many Queensland canegrowers. Green cane harvesting, trash blanketing and minimum tillage practices have become widely used throughout some sugar cane producing districts (see below). These new practices have clearly reduced soil erosion, but concerns remain over the vulnerability of soil to erosion during the planting phase or in districts with a low level of trash blanketing (e.g. Burdekin).[30] Recently claims have been made that soil erosion remains a major problem throughout the sugar cane growing lands of Queensland, although none of these authors provide any

evidence to support their claims other than references to the studies done at Mackay and Innisfail in the late 1970s and early 1980s.[31] Moreover, inquiries associated with the research for this paper have led to the conclusion that after 1983 the collection of figures on the extent of cane growing lands requiring soil conservation measures was sporadic and had ceased altogether by the early 1990s. Any figures collected during the 1980s probably remain with the government agencies and are unpublished. Thus, the safest conclusion that can be drawn from these inquires is that the extent of cane growing lands requiring soil conservation measures in Queensland's cane producing lands in the mid 1990s was unknown.

PREVENTING EROSION

Measures to reduce soil loss fall into three broad categories (Table 1). The first category incorporates mechanical field methods such as contour tillage, terracing and waterways, which are all used to either reduce the velocity of the flow of water across the soil surface or convey water at a non-erosive velocity to a suitable disposal point. Practices to manage the soil more effectively make up the second category. These measures maintain soil structure, allow infiltration and reduce surface runoff. Conventional tillage techniques often pulverise the soil near the surface, creating a compacted layer at plough depth and thereby reducing infiltration and increasing runoff. To lessen these effects, tillage operations are restricted by reducing their number and carrying out as many operations (e.g. fertilising, weed control) as possible in one pass. The aim is to concentrate these activities on the rows where the plant grows and leaving the inter-rows untilled. In addition, a reduction in runoff can be achieved by increasing the rate of subsurface water movement by installing mole drains and the breakup of compacted sub-surface layers by subsoiling. The third category includes those agronomic measures using plant cover to reduce erosion. Generally row crops (under which erosion is higher) and cover crops are cultivated either simultaneously or consecutively in rotation. Bare fields during the fallow period are also avoided by the use of cover crops or mulching.

Some of the above techniques such as crop rotation, contour tillage and terracing have a long history, being employed by the ancient Peruvians or used by the farmers in Ancient Italy.[32] Subsequently they have been modified, refined and used in many environments around the world. In contrast, a form of terracing known as 'cane-hole agriculture', was only developed in the early eighteenth century and specifically designed to arrest soil erosion in areas cultivated with sugar cane in the Caribbean. Its development occurred in response to the emergence of soil deterioration and soil loss on the sugar cane growing lands throughout the Caribbean during the late seventeenth century. The former could be ameliorated by the commencement of general manuring using appropri-

TABLE 1. Practices used for soil conservation

Category	Practice	Description
Mechanical means	Terracing	Large earth embankments constructed across slopes to intercept surface runoff and to convey it to an outlet at a non-erosive velocity.
	Contour bunds	Small earth banks, mostly hand-constructed, thrown across slopes to act as a barrier to surface runoff.
	Contour tillage	Completing ploughing, planting and cultivation on the contour, instead of furrows aligned downslope.
	Waterways	Structures designed to convey runoff at a non-erosive velocity to a suitable disposal point. They include grass waterways, diversion channels and terrace channels.
	Stabilsation structures	Small dams are built across gullies to trap sediment and slow surface runoff. They can be used in gully reclamation and gully erosion control.
Soil management	Improved drainage	Increasing the rate of subsurface water movement by installing mole drains or the breakup of compacted sub-surface layers by subsoiling. Such practices reduce the amount of surface runoff.
	Minimum tillage	Concentrating the number of operations (e.g. fertilising; weed control) as much as possible in one pass and/or by restricting them to the row where the plant grows.
Agronomic measures	Crop rotation	Alternating row crops with legumes and/or grasses. Erosion under row crops is counteracted by low rates under other crops.
	Cover crops	Growing cover crops (often legumes) during fallow periods or as ground protection under trees.
	Strip cropping	Combining row crops and protection effective crops in alternating strips aligned on the contour. Erosion is limited to the row crops and the soil removed from these is trapped in the next strip downslope.
	Mulching	Covering the soil with crop residues (e.g. straw; maize stalks; palm fronds; standing stubble) to protect if from raindrop impact and to reduce the velocity of runoff and wind.

Source: Morgan 1979: 57–66.

ate materials produced on individual estates by means of the farm dung, trash, megass (i.e. the final crushed sugar cane fibre remaining after milling) when not consumed in the mill furnaces and unused molasses. The adoption of manuring

techniques, however, did not stop soil loss, especially in localities where cane was cultivated on sloping land. The sugar cane planters realised that planting cane in trenches or furrows aligned downslope contributed to soil erosion, and as such sought an alternative system of planting.[33]

The essential feature of cane-hole agriculture involved the slaves using hand hoes to systematically subdivide the fields into squares approximately 1.5 metres in size. Within each square, a 'hole' or depression measuring approximately 0.5 metre to 1 metre long and 12.5 cm to 15 cm deep was dug, with the slaves raising the soil along the tops and sides of the depression into ridges known respectively as saddles and banks. Once excavated, the holes remained unused until planted with cane, but the presence in the landscape of a system of two-directional ridges prevented or contained any downslope loss of soil. The cane was eventually planted in the depressions packed with manure. As the cane plants grew taller they provided protection for the soil, thereby easing the threat of soil erosion. Cane holes were also advantageous, preserving more soil moisture than trenches. Cane-hole agriculture, however, was very labour intensive, with such work being regarded as the 'most taxing of all on sugar estates'.[34]

Galloway claims that cane-hole agriculture never spread very widely throughout the West Indies, and it was abandoned increasingly after 1850 in favour of plough agriculture, except on Barbados where the practice still existed in the 1970s. Soil loss throughout the West Indies was minimised increasingly by mulching using trash or the erection of contour bunds.[35] In Australia during the late nineteenth century, a variation of cane-hole agriculture was mentioned as being used by a few sugar cane planters, who were observed planting cane into holes about eighteen inches square and eight inches deep. However, this practice was never widespread, despite a plentiful supply of indentured labour being available to allow the sculpturing of the fields into squares, saddles and banks. Instead, the majority of sugar cane planters and the small canegrowers that took their place mostly practised plough agriculture, with apparent little regard for the slope of the land or the orientation of the furrows. Moreover, as mentioned above, mulching using trash was not an established practice.[36]

Thus, when Dr H. W. (Bill) Kerr, Director of the BSES, began considering ways to reduce soil erosion in Queensland's cane growing lands in the mid-1930s, he was faced with several challenges. First, he could not easily recommend cane-hole agriculture, one of the traditional methods used to reduce soil loss in other sugar cane growing countries. There was very limited experience of its adoption in Australia. In addition, soil loss in Queensland's cane growing lands had to be reduced on small family farms where a minimum amount of labour was employed to complete fieldwork. The canegrowers would have been loathe to return to a time-consuming, labour-demanding arrangement involving the creation of squares with hoes, when they were now using gasoline powered tractors and ploughs. Second, he could not recommend three of the agronomic practices listed in Table 1. Queensland canegrowers, because of legislative re-

quirements, could not alternate sugar cane with other row or tree crops every few years, nor easily engage in strip cropping. Moreover, even if no legislative restriction upon the cultivation of other crops existed, there was the difficulty of finding a profitable alternative crop to grow on these farms. Rubber, rice, cotton, tea, coffee and bananas had all been tried in Queensland's coastal districts during the late nineteenth century, but all had proved unprofitable, except in the Innisfail region where a small banana industry co-existed alongside sugar cane cultivation. Mulching using the trash to protect the soil was also not an option as it was increasingly being burnt because of associated health and industrial concerns. Moreover, it was highly unlikely Kerr would be able to convince the authorities to reverse this practice on environmental grounds, even though officers from the BSES recognised that destroying trash was short-sighted and that its use was the best means available for restoring soil humus and fertility and protecting the soil from erosion. Third, cane growing in Queensland was being conducted on slopes over 10 per cent. According to world authorities on soil conservation, such land should have been used only for grazing or forestry. However, sugar cane cultivation could not be easily stopped on this land, so the agricultural scientists were required to develop erosion control methods suited to such steep gradients.[37]

Kerr's initial advice to Queensland canegrowers on soil erosion occurred in 1936, when he suggested a combination of some techniques mentioned in Table 2. First, he urged canegrowers to practise better soil management on their properties. The absorptive capacity of the soil could be improved by sub-drainage. Providing channels through which the water could pass was achievable by deep ploughing, subsoiling or growing deep-rooted crops (e.g. lucerne) on the land when it was not cultivated with cane. Second, mechanical measures should be adopted. The rows of cane needed to follow the contour or run parallel to the slope, avoiding the long straight drills that went up and down hills. When this method proved not adequate or suitable, the farmers should establish contour banks or terraces and grassed waterways on their land. Fields could be crossed by broad, shallow waterways following the contour, which were flanked on the down-hill by mounds or ridges of earth. The contour banks diverted run-off water to larger outlet channels before it had time to obtain sufficient velocity to erode the soil from the cultivated areas between the terraces. Finally, during the fallowing of land, the field should be protected by a green manure crop or a trash blanket.[38]

Kerr's advice was not supported by the results from any field experiments under Queensland conditions and the outbreak of World War Two curtailed any further investigations into this matter. However in 1945, C. Stephens from the Division of Soils, Council for Scientific and Industrial Research, alerted the BSES to potential difficulties in using terraces. He suggested that the contour banks used in the American soil conservation programs would not cope with the huge volume of water that accompanied such high intensity rainfall in Queens-

land and they would be seriously damaged.[39] Thus, immediately following the conclusion of World War Two, Norman King and L.G. Vallance of the BSES and the cotton expert W.G. Wells met with Isis canegrowers in September 1945 and agreed to show farmers how they could reduce soil loss on their properties. During the wet season of 1946–47, L.G. Vallance conducted a soil erosion control experiment in the Isis district. The trial was placed on a slope having a maximum gradient of 16 per cent. Part of the paddock was terraced with contour banks, and all the run-off was diverted by waterways into one main outlet. A considerable amount of soil movement occurred and the diversion waterways became almost completely silted up, but the contour banks had stopped the formation of deep gullies that were noticeable in nearby fields that were unprotected by contour banks.[40]

As the above experiments progressed, P.A. Yeomans, an Australian mining engineer who owned a small property near Sydney, was developing his Keyline planting method. This approach aimed to increase both the depth and fertility of the soil by remoulding the landscape, firstly by a proper assessment of the natural resources on a particular property, and secondly by special methods of planning design based on water control and land management. At the heart of this method was the Keyline, a very specific contour line that occurs in all valley and ridge topography. This contour line delineates the transition areas above which all contour tillage must proceed up the slope and below which all contour tillage must proceed down the slope. Terraces and waterways are established to channel run off water into a series of farm dams, thereby drought-proofing properties.[41] To improve soil infiltration, the ground is contour ripped parallel to the terraces.

Armed with the details gained from the earliest experiments in the Isis district and the approach adopted by Yeomans, the BSES scientists designed further trials during the early 1950s in order to refine the advice they provided to canegrowers. Contour banks were built on additional cane growing paddocks in the Isis district, using the Keyline method, although elements of the approach such as contour ripping and on-farm dams were omitted. The main aim of these trials was to determine the spacing of the terraces on sloping land. Canegrowers had expressed dissatisfaction with placing contour banks every 100 feet apart, as they did not deal adequately with the large amount of run-off. By the late 1950s, the BSES scientists had concluded that contour banks placed at distances between 70 and 90 feet apart achieved a greater reduction in the velocity of the flowing water on cane paddocks. In addition, they had evidence that the contour banks had restricted water flow across fields and increased water penetration, as there had been improved growth in the cane rows adjacent to the banks.[42]

The knowledge gained from these layouts contributed to a greater understanding of the problem as it applied to sugar cane growing conditions, especially on very steep land. Equipped with this information, a succession of BSES officers over the next two decades promoted soil conservation measures throughout

Queensland cane growing regions. To slow the flow of water across their properties, canegrowers were urged to adopt one or more of the following measures: contour tillage (later known as contour row direction); erecting contour banks; encircling their fields on sloping land with grassed waterways or ditches to divert water away from paddocks; and the building of stabilisation structures across gullies to prevent their extension. Canegrowers were also urged to minimise the duration of the bare fallow during the summer season of high rainfall by planting a summer cover crop.[43]

The above efforts were supported by other organisations. From the early 1950s onwards, the Colonial Sugar Refining Company Ltd. (later changed its name to CSR Ltd.), Australia's largest sugar miller and refiner, conducted its own trials in the Innisfail area to determine the effectiveness of contour banks in slowing soil loss. Results from these trials convinced CSR that contour banks were an effective way to reduce soil loss, so the firm urged its canegrowers who cultivated sloping land in the Innisfail district to build contour banks and cover fallow paddocks with green manure crops.[44] The Queensland Department of Agriculture and Stock (later the Department of Primary Industries) also turned its attention to soil loss in the sugar cane growing lands. Soil conservation officers were appointed at Bundaberg and Mackay in 1955 and 1967 respectively and a soil conservation unit was established in 1980 at the South Johnstone Research Station, near Innisfail, in order to tackle the loss of soil in northern cane growing regions. By 1983, eleven field officers and five technical support staff were employed to service the State's cane producing areas.[45] A map of part of a canegrower's property modified in 1976 to reduce soil erosion following advice from Mackay officers of the Queensland Soil Conservation Branch is shown in Figure 4.

During the late 1970s and early 1980s, Queensland canegrowers were being provided with increasingly more refined advice on ways to reduce soil erosion. The suitability of land for cane growing was being determined via land resource surveys. In some instances, such as the expansion of cane growing to the Julatten district (near Mareeba) in the early 1980s, official confirmation of assigned areas was made conditional on satisfactory soil conservation measures being established from the outset. In addition, canegrowers were urged to complete plough out-replant operations or the replanting of fallow land early to ensure an adequate crop cover by the rainy season. Contour banks, diversion waterways and contour row direction continued to be promoted. However, the old layouts with sharp corners and many short rows were being superceded by layouts that contained slighter curves, parallel banks and fewer short rows.[46] A comparison between the layout of a property in the Bundaberg region showing contour banks following the exact grade line, and many short rows (top map) and the parallel layout approach, with fewer short rows (bottom map) is shown in Figure 5. The parallel layout approach is also illustrated in Figure 6.

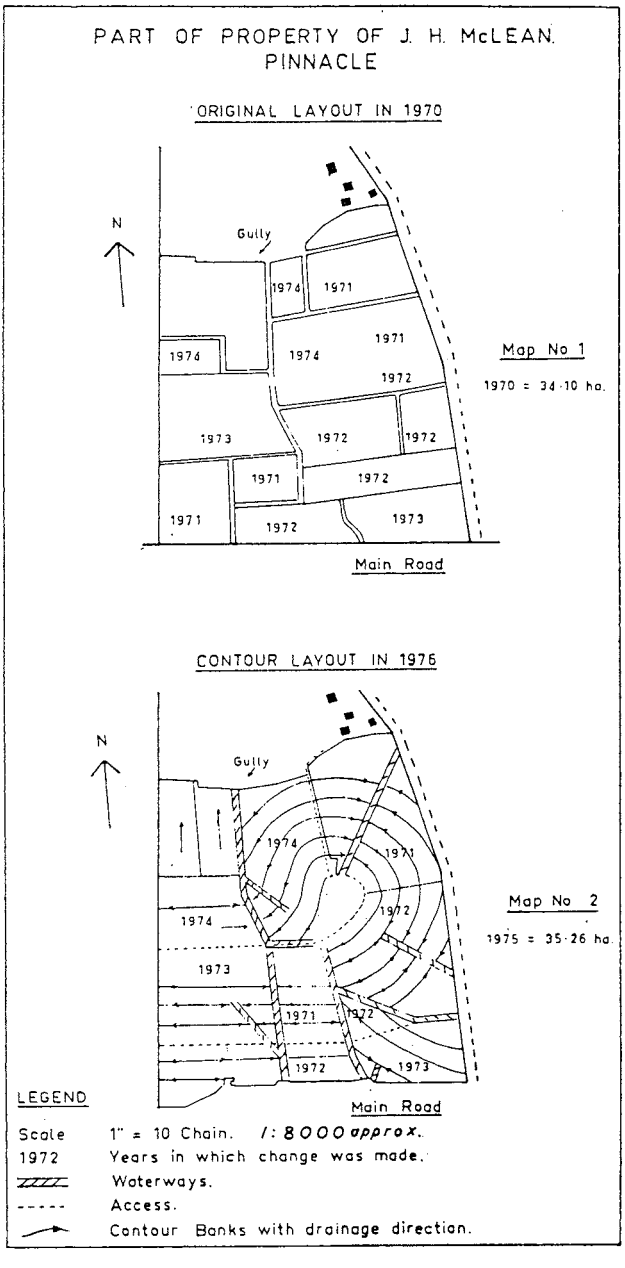

FIGURE 4. A comparison between the layout of a farm in the Mackay district before and after contour banks had been established in 1976.

Source: Veurman 1977: 584.

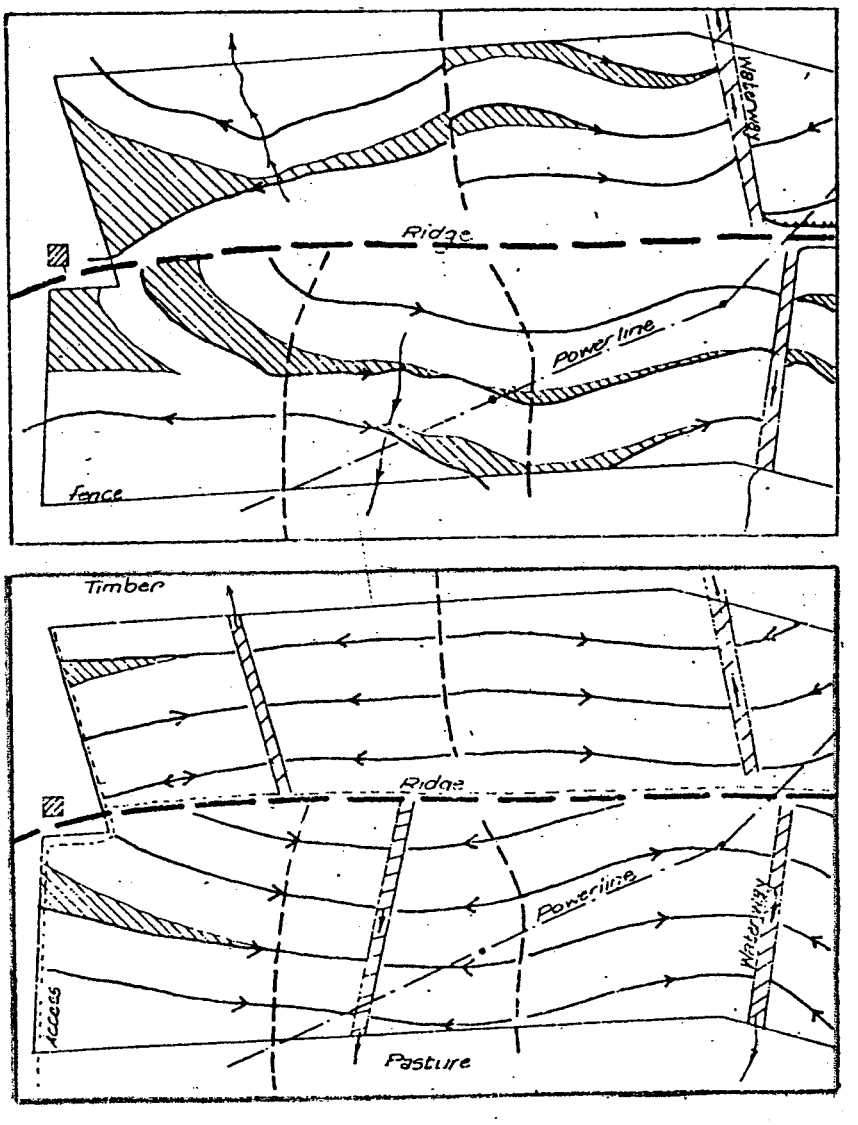

FIGURE 5. A comparison between the layout of a property in the Bundaberg region showing contour banks following the exact grade line (top map) and the parallel layout approach (bottom map). The shaded areas indicate short rows. The parallel layout approach eliminates the many short rows making the design more acceptable to mechanical harvesting.

Source: Pink 1975: 19.

FIGURE 6. Parallel contour banks protecting the land from erosion and providing long runs for mechanical harvesters on a cane farm in the Nambour district, 1976.

Source: *The Cane Growers' Quarterly Bulletin*, Vol. 39, No. 3 (January 1976), p. 77.

Despite the above changes, N. Dawson, R. Berndt and B. Venz, officers from the Queensland Department of Primary Industries, expressed concern in 1983 that the efforts by the State's canegrowers to reduce soil erosion were not quick enough. They claimed that the adoption of soil conservation measures did not keep up with the rate of development of erosion prone land in Queensland's sugar cane producing districts, let alone make inroads into the 100,000 ha of existing land cropped with cane that had untreated erosion problems. In the absence of any further expansion in cane growing, the canegrowers would take 40–50 years to treat all the eroding land. The Queensland sugar industry could not rely on additional Department of Primary Industry staff to hasten the implementation of these measures.[47] The solution: some major change to the current soil conservation programs in sugar cane producing lands was needed if these lands were to be stabilised within a reasonable time. That change was to be green cane harvesting (i.e. harvesting cane without prior burning), trash blanketing and minimum tillage techniques.

Before 1930, cane crops in Australia were mostly unburnt before manual harvesting. However, as mentioned above, pre-harvest burning of cane became standard practice in Queensland during the 1930s. After the introduction of mechanical harvesting in the 1960s, the health reason for the pre-harvest burning of cane crops vanished as workers were no longer exposed to Weil's disease. Yet the practice continued as pre-harvest burning reduced the amount of trash, as the earliest machines struggled to handle large amounts of trash. In addition, any trash generated during harvest was often raked into heaps by the canegrow-

ers and burnt, thereby depriving canegrowers of vital mulch that could protect their paddocks from erosion.[48]

Interest in green cane harvesting re-surfaced in the mid-1970s because of the disruptions to the 1973 and 1975 harvest seasons by prolonged periods of wet weather. By 1979 green cane harvesting entirely had been adopted by at least six harvesting groups in North Queensland.[49] Green cane harvesting produced larger amounts of trash than burnt cane harvesting and not all canegrowers were inclined to burn this trash, allowing it to cover their fields. Thus, trials in North Queensland were initiated by the BSES in 1977 to identify any unexpected problems associated with trash retention. These and subsequent trials during the 1980s and early 1990s, including those conducted by CSR Ltd., confirmed that trash blanketing caused no agronomic problems such as reduced ratoon growth, reduced yields or an increased incidence of diseases.[50] In 1982, the Queensland Department of Primary Industries and BSES also commenced trials to determine the effectiveness of trash retention as a method of reducing soil erosion. These studies concluded that average annual soil loss over the period 1982–1987 was 5 t/ha under a green cane harvest with 100 per cent of the trash retained as a blanket cover. If no trash blanketing was practised, the soil losses grew to 15 t/ha. Thus, trash blanketing or trash blanketing and no tillage provided a substantial soil conservation measure regardless of soil type. These results were confirmed when additional studies into the magnitude of soil loss in sloping sugar cane land under conventional cultivation and various no-tillage operations were completed by the Queensland Department of Primary Industries in the early 1990s.[51]

As a result of these trials, canegrowers now had a soil conservation measure that did not solely involve contour tillage and/or building contour banks and ditches. Moreover, trash blanketing reduced weed growth. Therefore, the amount of chemicals applied to control weeds could be reduced and canegrowers did not have to make frequent passes over the paddocks for weed control, thereby reducing fuel bills and the wear and tear on cultivation implements and tractors. Hence, substantial savings on cultivation costs could be achieved if trash blanketing and minimum tillage were adopted.[52] In addition, canegrowers adopting such practices would be perceived as displaying a concern for the environment, as they demonstrated a reduction in both soil erosion and chemical use.

ADOPTING SOIL CONSERVATION MEASURES

Information on soil conservation measures practised in Queensland's cane growing lands before 1945 is not extensive. During the 1930s, some Italian farmers in the Finch Hatton district, near Mackay, were observed to have stone pitched the heads of gullies on their farms to stop them from getting any larger. Dams built across gullies to check the loss of soil from cultivated fields by causing

silting of channels were also observed in the Childers and Innisfail district in the early 1940s. Dr H. Kerr, however, noted in 1936 that contour banks had not been constructed in any Queensland cane growing areas.[53] This fragmentary evidence suggests that the use of soil conservation measures was probably not widespread in Queensland sugar cane producing districts before 1945.

Attitudes to soil conservation methods amongst Queensland canegrowers changed only slowly after World War Two. In 1947, W. Sloan of the BSES noted, 'too many farmers still plant and cultivate up and down the slopes'.[54] In the Isis district where erosion was particularly severe, some canegrowers established contour banks on their farms. Yet R. Moller of the BSES observed that in 1958 only a 'small minority of farmers' had adopted soil erosion measures throughout the Isis district. He expressed concern that erosion control practices were not implemented until gully erosion had become quite serious.[55] In 1957, A.R. Taylor of the South Johnstone Cane Pest and Disease Control Board observed the sporadic use of contour ploughing and stone walls in the South Johnstone district. However, he also noted that tragically no attempt had been made to halt erosion on numerous farms and fields throughout the district. Taylor was particularly scathing of the State's canegrowers, claiming that despite repeated warnings about the need for soil conservation measures the 'subject seldom progresses beyond the discussion stage with the average Queensland cane farmer'.[56]

Soil conservation measures such as contour tillage and/or the building of contour banks were still not being widely used in many cane growing districts during the early 1970s (see Table 2). The Queensland Department of Primary Industries during its compilation of the Sarina Shire Handbook summarised the general attitude amongst local canegrowers: 'acceptance of soil conservation practices in sugar cane is very recent'.[57] Moreover in 1970, some of the severest soil erosion in the State's cane growing districts still occurred in the Isis district, but only 23 canegrowers or nine per cent of the district's canegrowers used soil conservation measures. The Isis Land Use Committee noted forlornly that if the number of canegrowers adopting soil conservation measures doubled from six per year 'it would be about twenty years before an acceptable level of soil conservation would be applied over the whole district'.[58]

By the early 1980s, BSES officers reported that some canegrowers farming sloping land had constructed head ditches to prevent excess water flowing onto their fields, but except in a few instances, further control measures had not been implemented. Similar observations were made by northern soil conservation officers who noted that in North Queensland 'little adoption of the more traditional soil conservation methods had been achieved'.[59] In 1986, for example, only 1,300 ha had been treated with soil conservation measures throughout the Innisfail district. This amount was a tiny fraction of out of a possible 23,000 ha with a slope above 3 per cent requiring contouring. In contrast, adoption of soil conservation methods amongst Maryborough, Childers and Bundaberg canegrowers had improved by the mid-1980s, with the local soil conservation

TABLE 2. Extent of soil conservation measures in selected Queensland cane-growing shires, 1970-1976

Shire	Year of survey	Details about soil erosion and conservation measures	Source
Ayr	1973	'soil erosion is not a major hazard; very little soil conservation measures adopted'	Finlay & Cribb 1973: 4-11
Burrum	1971	'of the area of 20,800 acres under cultivation in 1969 approximately 14,500 acres are requiring intensive soil conservation measures; from January 1967 until May 1970 approximately 600 acres of agricultural land has been protected against erosion'	Middleton 1970: 4-3
Douglas	1974	'conservation measures are not practised widely'	Middleton & Barnes 1974: 4-3
Gooburrum	1971	'approx. 750 acres has been protected'	Hawley 1971: 4-8
Hinchinbrook	1975	'Shire not subjected to significant erosion'	Seton 1975: 4-3
Kolan	1972	'sheet, rill and gully erosion have taken a heavy toll of the limited land resources'	Hawley 1972: 4-10
Maroochy	1976	'about 20 % of cultivated area suffers from erosion; no control measures have been adopted as yet'	Butcher *et. al* 1976: 66
Mirani	1971	'23,000 acres require intensive soil conservation measures, but only 194 acres protected by soil conservation structures'	Everett 1971: 4-2
Pioneer	1971	'72 farmers employ soil conservation practices; area of land protected totals 1180 acres'	Filet, 1971(a): 4-2
Proserpine	1973	'about 800 ha need soil conservation measures; very little work has been carried out to date'	Cribb 1973: 4-1
Sarina	1971	'only 1.6 % of the area requiring protection (26,000 acres) had been treated'	Filet 1971(b): 4-2
Tiaro	1973	'soil conservation measures have been taken on a few farms; more needs to be done'	Beal 1973: 4-3
Woongarra	1975	'199 ha of land have been protected with contour banks, and 351 ha have been treated with simple conservation measures'	Adams 1975: 4-3

Sources: Based upon the authors mentioned in the table. See reference list for full details.

officer estimating that a third of the existing cultivated land in 1987 was protected by soil conservation measures.[60]

Assessing the reasons for why there was such slow acceptance by some Queensland canegrowers of the facts about soil erosion and solutions to the problems is difficult. The agricultural scientists and extension officers have left many opinions in the literature about why the State's canegrowers continued to engage in such exploitive mismanagement of the soil. These opinions are not confirmed or refuted by the views from canegrowers due to the absence of detailed oral histories. Nevertheless, sixty canegrowers were surveyed at Innisfail in 1982 about soil erosion on their properties, so some information from the canegrowers' perspective can be presented in this narrative.

Acceptance that soil loss needed to be reduced required canegrowers to make two confessions: that a problem existed; and that this problem existed because of poor agricultural practices adopted currently or in the past. W. Sloan of the BSES claimed in 1947 that many canegrowers were still not fully 'cognisant of the dangers of soil erosion' or that they did not understand that a problem existed.[61] However, there is a contrasting view. In 1946, C.K. Simpson, the Technical Field Officer at Goondi Mill, noted that the local canegrowers knew about the dangers of soil erosion, but were 'apt to consider soil erosion was something that nothing can be done about.' The survey of Innisfail canegrowers in 1982 confirmed that they recognised erosion as a problem on their farms, but it was rated as a lesser problem than rising production costs and declining prices of sugar.[62] Thus, this fragmentary evidence suggests that some Queensland canegrowers knew that soil loss was a problem, but were slow to respond for other reasons.

Three reasons have been put forward in the literature to explain the slow uptake of soil conservation measures by Queensland's canegrowers. The first factor was that the loss of topsoil by soil erosion, except in the most extreme instances, had not transferred into lost productivity. The State's canegrowers reaped the benefits of scientific advances in other areas. Improvements in plant breeding provided them with sucrose-rich cane varieties suited to each district and the threat of diseases and pests were reduced by the BSES control programs. Greater use of fertilisers, including the addition of approximately 200 kg of nitrogen per hectare by the 1970s, reduced soil deterioration.[63] Moreover, in some cane growing districts, the eroding soils had sufficient depth to permit repeated turning up of a fresh layer for cultivation. Yet in the Mackay district by the early 1970s, so much topsoil had been removed that farmers were reduced to using the subsoil. [64]

The second reason advanced for the slow uptake of soil conservation measures was the perceived disadvantages of contour tillage and terraces. Canegrowers, including those surveyed at Innisfail in 1982, claimed that a great number of short rows almost always occurred between the contour banks at frequent intervals along their length. Such short rows were difficult to cultivate and became less acceptable following the widespread adoption of mechanical harvesting in the

1960s. Field layouts had to be designed to allow the use of heavy mechanical harvesters requiring well-defined turning points. In addition, contour banks absorbed an appreciable amount of scarce tillable land on their assignments, they became places where weeds and grasses accumulated, they silted up every few years and difficulties arose using traveling irrigators (i.e. large pieces of machinery that move across fields spraying water) on non-straight layouts.[65]

A third factor was the lack of equipment and staff with expertise. In 1959, R. Moller claimed that the construction of soil conservation measures in the Isis district was hindered because earth-moving equipment was not readily available for hire. Even when earth moving equipment became more readily available, the Queensland Department of Primary Industries admitted in 1983 that canegrowers wishing to implement soil conservation measures were hindered by the following factors: lack of suitable topographic information about their properties; the ratoon system which inhibited implementation across an entire property as part of the farm is always under a crop; and a restricted implementation period (i.e. April to September). Under these constraints, soil conservation officers in cane producing districts had only been able to plan and survey soil conservation measures on approximately 250 ha per man-year. In contrast, rates of 7000 ha per man had been achieved in extensive grain cropping lands of central Queensland. [66]

As a few innovative canegrowers began using trash blanketing in the late 1970s, M. Sallaway of the Queensland Department of Primary Industries noted that the largest problem with the general acceptance of trash retention may be 'with the outlook of individuals'.[67] Sallway hinted at the innate conservatism of Queensland's canegrowers when it came to changing their land management practices. Yet the successful implementation of trash retention and minimum tillage techniques by these canegrowers and improvements in the green cane capability of harvesters accelerated the adoption of green cane harvesting. Furthermore, the slump in world sugar prices in the early 1980s encouraged more canegrowers to reduce their cultivation costs, achievable by adopting trash blanketing and reduced tillage.[68] Hence, by 1996, half the entire Queensland crop was produced using green harvesting, although its adoption was initially greater in cane growing districts north of Townsville. South of Townsville, the adoption of green cane harvesting has been much slower, although had increased substantially by 2001 (See Table 3). In the Burdekin region, the thick trash blanket posed difficulties for irrigation, while the rationing of cane under the colder conditions of southern Queensland presents significant problems. In addition, by 1991, an estimated 80 per cent of the sloping land (> 2 per cent) in Far North Queensland was being farmed with trash blanketing and zero tillage methods.[69] Thus, despite the different rates of adoption based upon latitude, the acceptance of trash retention and minimum tillage with its soil erosion reduction characteristics has occurred much faster than the implementation of traditional soil conservation measures.

Unexpected environmental consequences, other than reduced erosion, have also emerged following the adoption of green cane harvesting and trash blanket-

TABLE 3. Percentage of green cane harvesting in Australian cane producing regions, 1985 to 2001

Region	1985	1987	1989	1990	1992	1994	2001
Northern*	21	45	68	73	79	88	94
Burdekin	0	0	0	5	4	3	5
Central	0	0	11	12	12	27	87
South	0	0	18	15	17	24	58

* Sugar cane growing districts north of Townsville include Mossman, Cairns, Innisfail, Tully and Ingham.

Source: Prove and Hicks 1991: 69; Woods *et al*. 1997: 481; & personal communication, BSES Ltd.

ing. Some Queensland canegrowers have commenced reporting their general pleasure with the positive effect on soil conditions due to trash retention. The most apparent effects on the soil condition noted by canegrowers included improved soil structure, more earthworms and less damage by machinery wheel tracks following cultivation and harvesting. More wildlife on farms has also been observed following the cessation of cane burning. In addition, canegrowers in the Herbert River, Bundaberg and Mackay districts using trash blanketing have reported improved yields (i.e. tonnes of cane per hectare and tonnes of sugar per hectare).[70]

CONCLUSION

Soil erosion throughout parts of Queensland's sugar cane producing lands was first acknowledged as a significant problem by officials from the industry in the 1930s. By the early 1980s, at least a third of the assigned area cultivated with sugar cane in Queensland was identified as suffering some form of erosion, with the Isis (Childers), Bundaberg and Mackay districts being the worst affected. The discussion in this paper has highlighted that soil loss existed so long because many Queensland canegrowers between 1930 and 1980 employed exploitive land management techniques. They persisted in cultivating sloping land without adopting soil conservation techniques such as contour tillage, terraces and diversion waterways. Declining productivity which may have prompted more Queensland canegrowers to adopt soil conservation techniques did not emerge. The State's canegrowers reaped the benefits from improvements in plant breeding which provided them with sucrose-rich cane varieties suited to each district and the threat of diseases and pests was reduced by the BSES control programs. Soil

deterioration was reduced by greater use of fertilisers. Together these measures maintained yields, masking the deleterious effects of any soil loss.

The analysis in this paper has also illustrated that the transfer of models from other crops and physical environments is not always successful. Sugar cane in Queensland was cultivated as an intensive monoculture in high rainfall localities under a highly regulated system of production. Queensland canegrowers, because of legislative requirements, could not alternate sugar cane with other row or tree crops every few years, nor easily engage in strip cropping to slow the velocity of water across their fields. Moreover, even if no legislative restriction upon the cultivation of other crops existed, repeated efforts had failed to find a profitable alternative crop to grow on these farms. Mulching using the trash to protect the soil was also not an option as it was initially burnt because of associated health and industrial concerns, and later to facilitate mechanical harvesting. The officials promoting soil conservation could only mostly recommend mechanical methods such as contour tillage, contour banks and waterways. However, even when modified to take into account the higher amounts of rainfall in tropical and semi-tropical districts, Queensland's canegrowers were reluctant to adopt these measures claiming that they hindered mechanical harvesting and irrigation and that the banks absorbed too much scarce, tillable land on their assignments.

Finally, the BSES and Queensland Government's soil conservation policies did not readily exacerbate soil erosion in the sugar growing lands of Queensland. However, due to the reluctance of the canegrowers to adopt the soil conservation measures recommended, they did little to ameliorate its effects between 1930 and 1980. The few techniques recommended can be categorised as top-down approaches, promoted by BSES scientists and agricultural extension officers from the Queensland Department of Primary Industries. Success in reducing soil loss only followed the introduction of green cane harvesting and trash blanketing in the 1980s, a bottom-up solution aimed not at reducing soil erosion, but eliminating delays in harvesting due to prolonged periods of wet weather which precluded pre-harvest burning of the crops to be harvested. Nevertheless, many canegrowers willingly adopted the practices promoted by the harvest operators (and eventually the BSES officials), partially because of the ease of implementation, but also due to the associated reduction in tillage costs and improved yields that followed their use. In doing so, they ensured that the State's sugar cane industry in the 1990s finally commenced using more sustainable land management practices, instead of persisting with the exploitive land management practices of the past decades.

NOTES

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[1] Watts 1987: 222, 397 and 438; Richardson 1992: 30–31; Fraginals 1976: 92; Mechanisation Committee of the South African Sugar Association 1949: 9.

[2] The main studies include Easterby 1932; Lowndes 1956; Saunders, 1982; Graves 1988; and Graves 1993.

[3] See and Crouch 1963; Department of Labour and National Service 1970; Willis 1972; Burrows and Shlomowitz 1992; Kerr and Blyth 1993.

[4] These changes are discussed fully in Griggs 1997 and Griggs 2000.

[5] For overviews of the pre-1945 expansions in the Queensland sugar industry see Graves 1988: 144–54; Graves 1993: 11–19; and Shlomowitz 1979: 100–110; for details on more recent expansions in the Queensland sugar industry see Courtenay 1982: 129–31 and Robinson 1995: 217–18.

[6] Wilson, Wissemann and Dwyer 1982: 1; Prove 1991: 29.

[7] Graves 1988: 144–9; deregulation is discussed by Robinson 1995.

[8] Kerr 1936: 26.

[9] King, Mungomery and Hughes 1956: 221.

[10] J. Tardent, 1938. 'Soil erosion in Queensland', p. 12. Queensland Forestry Files, SRS 5213/1, Box 12, Item 65: Soil Erosion, 1935–1966, Queensland State Archives, Brisbane, Queensland (hereafter QSA).

[11] Stephens 1945: 3; Kemp 1947:651.

[12] For a full account see Griggs 2004.

[13] Charles Young, 1939. 'Evidence' in Minutes of Evidence before the Royal Commission on Sugar Peaks Scheme and Cognate Matters, p. 97. In Colonial Sugar Refining Company Records (hereafter CSRR), Z/109, Box 48, Noel Butlin Archives Centre, Canberra (hereafter NBAC).

[14] Kerr 1940: 222; King, Mungomery and Hughes 1956: 48, 50 and 219; Penrose 1998: 134–5.

[15] This limit was relaxed for the 1964 season and extended to 85 % and removed entirely in 1975.

[16] Stephens 1945: 6; Vallance 1947: 120; Isis Land Use Committee 1971: 4-2; Industry Commission 1992: 37–8.

[17] Isis Land Use Committee 1971: 7-3 and 7-4; Kerr 1996: 136–7.

[18] For more detailed discussions see Bolton 1981: 138–40; McTainish and Leys 1993: 193–200 and Williams 1974: 303–5.

[19] See for example Alldis 1937; Ratcliffe 1938; Bank of New South Wales 1939; Pick 1942; and Holmes 1946: 28.

[20] Williams 1974: 305–6; Soil Conservation Authority, Victoria 1953: 6–9.

[21] Skerman, Fisher and Lloyd 1988: 207–9.

[22] J. Tardent, 1938. 'Soil erosion in Queensland', p. 12. In Queensland Forestry Files, SRS 5213/1, Box 12, Item 65: Soil Erosion, 1935-196612, QSA ; Edward W. Knox,

'Notes on a visit to the Isis district, 21 July 1899', pp. 1–2, in 'Memoranda and Reports for the Board of Directors 1887–1899', CSRR, 142/2753, NBAC.

[23] Kerr and Bell 1939: 109.

[24] Figures calculated from statistics provided in an Appendix attached to a letter from Hon. Frank Nicklin, Premier of Queensland to the Hon. Robert Menzies, Prime Minister of Australia, 30 July 1959. Queensland Department of Co-ordinator General Files, SRS1043/1, Box 718, Item 2158: Soil erosion and conservation flood mitigation; QSA.

[25] For example see Everett 1971: 4-2; Filet 1971a: 4-2; Adams 1975: 4-2.

[26] Capelin and Prove 1983: 88.

[27] Sallaway 1979b: 130; Sallaway 1981.

[28] Capelin and Prove 1983; Prove and Hicks 1991: 68.

[29] See for example Anon 1974; Capelin 1979; Holz, 1979; and Holz and Shields, 1985.

[30] Commonwealth Scientific and Industrial Research Organisation 2002: 27.

[31] Johnson *et al*. 1998: 98; Johnson and Bellamy 2000: 165.

[32] Bennett 1939: 32–3 and 48.

[33] Watts 1987: 399–401 and 435; Ormrod 1979: 160–2.

[34] Watts 1987: 403–4.

[35] Galloway 1989: 102; Watts 1987: 512 and 547; Davy 1851: 116.

[36] For planting methods in the nineteenth century Australian sugar industry see Griggs 2004: 6–8.

[37] For views on the use of trash see King 1934: 127–8, Kerr and Bell 1939: 114 and Kerr 1940: 222; opinions on the cultivation of steeply sloping land are found in Moller 1958: 93 and Moller 1959: 89.

[38] Kerr 1936: 28–33.

[39] Stephens 1945: 6.

[40] Kerr 1996: 133; Vallance 1947: 121–6.

[41] For an abbreviated account of this method see Holmes 1946: 138–9; for more details see Yeomans 1965.

[42] Kerr 1996: 134; Smith 1955: 103; Moller 1958: 94–5.

[43] Taylor 1957; King 1958: 28; Moller 1958; Rosser 1961; Linedale 1970; Wright 1970.

[44] For examples of this advice see CSR Ltd., 'Agricultural Circulars for Goondi Mill, 1951 to 1970', in CSRR, N 126/131, NBAC.

[45] Smith 1955: 103; Amiet and Jones 1970:153; Dawson *et al*. 1983: 50; Prove 1991: 31.

[46] See for example Veurman 1975: 94; Capelin 1979; Capelin and Prove 1983: 89–90; Holz 1979; and Holz and Shields 1985.

[47] Dawson *et al*. 1983: 50.

[48] King, Mungomery and Hughes 1965: 128–9.

[49] Baxter 1983: 33; Ridge *et al*. 1979: 89.

[50] Matthews and Makepeace 1981; Ridge *et al*. 1979; Hardman *et al*. 1985; Wood 1991; Dick 1993.

[51] Bureau of Sugar Experiment Stations 1984; Prove *et al*. 1986: 79; Prove and Hicks 1991: 68–9; Prove, Doogan and Truong 1995.

[52] Mackson 1983: 22–3; Prove *et al*. 1986: 81.

[53] Stephens 1945: 3; Kerr 1991: 66; C. Simpson, Technical Field Officer, Goondi Mill, to General Manager, CSR Ltd., Sydney, 9 October 1946, Letter No. 255N, re: visit of Mr Skinner, Queensland Lands Department, CSRR, N/126/131, NBAC; Kerr 1936: 33.

[54] Sloan 1947: 160.

[55] Moller 1958: 93; Kerr 1996: 134–5.

[56] Taylor 1957: 149.

[57] Filet 1971b: 4-2.

[58] Isis Land Use Committee 1970: 7-3.

[59] Matthews and Makepeace 1981: 43; Wilson, Wissemann and Dwyer 1982: 5; Prove and Hicks 1991: 69.

[60] Prove, Truong and Evans 1986: 78; *Australian Canegrower*, vol. 9, 10 (October 1987): 26

[61] C. Simpson, Technical Field Officer, Goondi Mill, to General Manager, CSR Ltd., Sydney, 27 November 1946, Letter No. 258, re: soil erosion, CSRR, N126/131, NBAC; Sloan 1947: 157.

[62] Wilson, Wissemann and Dwyer 1982: 11.

[63] Sloan 1947: 157; Prove 1991: 31; Hogarth and Allsopp 2000: 162–5.

[64] Veurman 1977: 582

[65] Smith 1955: 104; Moller 1958: 94; Wright 1970: 138; Sypkens 1970: 137; Amiet and Jones 1970: 152; Veurman 1977: 582; Wilson, Wissemann and Dwyer 1982: 9 and 13; Klein 1984: 4–5.

[66] Moller 1959: 90; Dawson *et al*. 1983: 50.

[67] Sallaway 1979a: 133.

[68] Wood 1991: 71.

[69] Quabba 2000: 160; Prove and Hicks 1991: 70.

[70] Gutteridge, Haskins and Davey 1996: 112; Kalpana 1996:96; Quabba 2000: 160; Chapman, Larsen and Jackson, 2001

ARCHIVAL SOURCES

Noel Butlin Archives Centre, Australian National University, Canberra

Colonial Sugar Refining Company Records (CSRR):

Agricultural Circulars for Goondi Mill, 1951 – 1970, CSRR, N 126/ 131.

Simpson, C., Technical Field Officer, Goondi Mill, to General Manager, CSR Ltd., Sydney, 9 October 1946, Letter No. 255N, re: visit of Mr Skinner, Queensland Lands Department, CSRR, N 126/131.

Simpson, C., Technical Field Officer, Goondi Mill, to General Manager, CSR Ltd., Sydney, 27 November 1946, Letter No. 258, re: soil erosion, CSRR, N126/131.

Knox, Edward W., ‘Notes on a visit to the Isis district, 21 July 1899’, in ‘Memoranda

and Reports for the Board of Directors 1887–1899', CSRR, 142/2753.

Young, Charles 1939. 'Evidence' in 'Minutes of Evidence before the Royal Commission on Sugar Peaks Scheme and Cognate Matters', pp. 96–8, in CSRR, Z/109, Box 48.

Queensland State Archives, Brisbane, Queensland (QSA):

Tardent, J. 1938. 'Soil erosion in Queensland'. *Queensland* Forestry Files, SRS 5213/1, Box 12, Item 65: Soil Erosion, 1935–1966.

Nicklin, Frank. Letter to the Hon. Robert Menzies, Prime Minister of Australia, 30 July 1959. Department of Co-ordinator General Files, SRS1043/1, Box 718, Item 2158: Soil erosion and conservation flood mitigation.

REFERENCES

Adams, N. 1975. *Woongarra Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Alldis, V. 1937. *Soil Erosion*. Young, New South Wales: Witness Press.

Amiet, P. and Jones, H. 1970. 'Soil conservation in relation to canegrowing'. *Proceedings of the Queensland Society of Sugar Cane Technologists*, 47–52.

Anon. 1974. *Moreton Region Non-urban Land Suitability Study*. Division Land Utilisation Technical Bulletin No. 11. Brisbane: Queensland Department of Primary Industries.

Bank of New South Wales. 1939. *Conserve your Soil: A Simple Guide to Soil Erosion*. Sydney: Bank of New South Wales.

Baxter, B. 1983. 'Green cane harvest review'. *Australian Canegrower*, February, 32–5.

Beachey, R.W. 1957. The *British West Indies Sugar Industry in the Late Nineteenth Century*. Oxford: Blackwell.

Beal, D. 1973. *Tiaro Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Bennett, Hugh. 1939. *Soil Conservation*. New York and London: McGraw-Hill Book Company Inc.

Bolton, G. 1981. *Soil and Spoilers. Australians Make Their Environment 1788–1980*. Sydney: George Allen & Unwin.

Bureau of Sugar Experiment Stations. 1984. 'A review of results of trials with trash management for soil conservation'. *Proceedings of the Australian Society of Sugar Cane Technologists*, 6: 101–6.

Burrows, Geoff and Shlomowitz, Ralph. 1992. 'The lag in mechanisation of the sugar cane harvest: some comparative perspectives'. *Agricultural History*, 66: 61–75.

Butcher, F., Parsons, R. and Beal, D. 1976. *Maroochy Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Capelin, M. 1979. *Moreton Mill Area – A Sugar Cane Land Suitability Study*. Division Land Utilisation Technical Bulletin No. 37. Brisbane: Queensland Department of Primary Industries.

Capelin, M. and Prove, B. 1983. 'Soil conservation problems of the humid tropics of

North Queensland'. *Proceedings of the Australian Society of Sugar Cane Technologists*, 5: 87–93.

Chapman, L., Larsen, P. and Jackson, J. 2001. 'Trash conservation increases cane yield in the Mackay district'. *Proceedings of the Australian Society of Sugar Cane Technologists*, 23: 176–84.

Commonwealth Scientific and Industrial Research Organisation. 2002. *Unlocking Success Through Change and Innovation: Options to Improve the Profitability and Environmental Performance of the Australian Sugar Industry*. Submission to the Independent Assessment of the Australian Sugar Industry, Townsville, 5 April. Website, http://www.affa.gov.au/corporate_docs/publications/pdf/sugar_assessment/csiro.pdf. Accessed 15 October 2004.

Courtenay, Philip. 1982. *Northern Australia. Patterns and Problems of Tropical Development in an Advanced Country*. Melbourne: Longman Cheshire.

Cribb, I. 1973. *Proserpine Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Davy, John. 1851. *The West Indies Before and Since Slave Emancipation*. London: W. & F. Cash.

Dawson, N., Berndt, R. and Venz, B. 1983. 'Land use planning – Queensland canelands'. *Proceedings of the Australian Society of Sugar Cane Technologists*, 5: 43–52.

Department of Labour and National Service, Australia. 1970. *Men and Machines in Sugar Cane Harvesting*, Employment and Technology Series No. 7. Melbourne: Department of Labour and National Service, Australia.

Dick, R. 1993. 'Minimum tillage agriculture in southern Queensland'. *Proceedings of the Australian Society of Sugar Cane Technologists*, 15: 312–15.

Easterby, H. 1932. *The Queensland Sugar Industry: An Historical Review*. Brisbane: Government Printer.

Everett, M. 1971. *Mirani Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Filet, C. 1971a. *Pioneer Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Filet, C. 1971b. *Sarina Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Finlay, M. and Cribb, I. 1973. *Ayr Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Fraginals, M. 1976. *The Sugar Mill: The Socioeconomic Complex of Sugar in Cuba, 1760–1860*. New York and London: Monthly Review Press.

Galloway, J.H. 1989. *The Sugar Cane Industry. An Historical Geography from its Origins to 1914*. Cambridge: Cambridge University Press.

Graves, Adrian. *Cane and Labour. The Political Economy of the Queensland Sugar Industry 1862–1906*. Edinburgh: Edinburgh University Press, 1993.

Graves, Adrian. 'Crisis and change in the Australian sugar industry, 1914–1939' in Bill Albert and Adrian Graves (eds), *The World Sugar Economy in War and Depression 1914–1940*, pp. 142–56. London: Routledge, 1988.

Griggs, Peter. 1997. 'The origins and early development of the small cane farming system in Queensland, 1870–1915'. *Journal of Historical Geography*, 23 (1): 46–61.

Griggs, Peter. 2000. 'Sugar plantations in Queensland, 1864–1912: origins, characteristics, distribution and decline'. *Agricultural History*, 74 (3): 609–47.

Griggs, Peter. 2004. 'Improving agricultural practices. Science and the Australian sugarcane grower, 1864–1915'. *Agricultural History*, 78 (1): 1–33.

Gutteridge Haskins and Davey Pty Ltd. 1996. *Environmental Audit of the Queensland Canegrowing Industry. Report to CANEGROWERS*. Brisbane: Gutteridge Haskins and Davey Pty Ltd.

Hardman, J., Tilley, L. and Glanville, T. 1985. 'Agronomic and economic aspects of various farming systems for sugarcane in the Bundaberg district'. *Proceedings of the Australian Society of Sugar Cane Technologists*, 7: 147–53.

Hawley, G. 1971. *Gooburrum Shire Handbook*, Queensland Department of Primary Industries.

Hawley, G. 1972. *Kolan Shire Handbook*. Brisbane: Queensland Department of Primary Industries, Brisbane.

Hogarth, M. and Allsopp, P. 2000. *Manual of Cane Growing*. Brisbane: Queensland Bureau of Sugar Experiment Stations.

Holmes, J.M. 1946. *Soil Erosion in Australia and New Zealand*. Sydney: Angus and Robertson.

Holz, G. 1979. *Rocky Point – A Sugar Cane Land Suitability Study*. Division Land Utilisation Technical Bulletin No. 38. Brisbane: Queensland Department of Primary Industries.

Holz, G. and Shields, P. 1985. *Mackay Sugar Cane Land Suitability Study*. 2 vols. Brisbane: Queensland Department of Primary Industries.

Industry Commission. 1992. *The Australian Sugar Industry*. Canberra: Australian Government Publishing Service.

Isis Land Use Committee. 1971. *Report on a Land Use Study of the Isis District*. Brisbane: Queensland Department of Primary Industries.

Johnson, Andrew, McDonald, Geoffrey, Shrubsole, Dan and Walker, Dan 1998. 'Natural Resource Use and Management in the Australian Sugar Industry: Current Practice and Opportunities for Improved Policy, Planning and Management'. *Australian Journal of Environmental Management,* 5: 97–108.

Johnson, Andrew and Bellamy, Jennifer 2000. 'Managing for ecological sustainability: Moving from rhetoric to practice in the Australian sugar industry'. In Peter Hale, Anita Petrie, Damian Moloney and Paul Sattler (eds), *Management for Sustainable Ecosystems*, pp. 163–74. Brisbane: Centre for Conservation Biology, The University of Queensland.

Kalpana, Parthasarathy, 1996. 'Economics of sustainable sugarcane production: the case of Bundaberg'. Master of Agricultural Economics Studies, University of Queensland, Brisbane.

Kemp, J. 1947. 'Annual Report of the Bureau of Investigation for 1946'. *Queensland Parliamentary Papers*, 2 (1947–48): 639–60.

Kerr, H. 1936. 'Soil erosion'. *The Cane Growers' Quarterly Bulletin*, 4 (1): 26–33.

Kerr, H. 1940.'Some agricultural problems of the Mackay district'. *Proceedings of the Queensland Society of Sugar Cane Technologists*, 221–3.

Kerr, H. and Bell, A. 1939. *The Queensland Agricultural and Pastoral Handbook. Vol.*

4: Sugar Cane and its Culture. Brisbane: Queensland Government.

Kerr, John. 1991. *Top Mill in the Valley. Cattle Creek Sugar Mill, Finch Hatton, 1906–1990*. Mackay: Mackay Sugar Cooperative Association Limited.

Kerr, John 1996. *Only Room for One. A History of Sugar in the Isis District*. Childers: Isis Central Sugar Mill Company Limited.

Kerr, W. and Blyth, K. 1993. *They're All Half Crazy. 100 Years of Mechanical Cane Harvesting*. Brisbane: Canegrowers.

Klein, J. 1984. *Erosion Awareness Survey. Hummock Area, Bundaberg*. Project Report Q084010. Brisbane: Queensland Department of Primary Industries.

King, Norman 1934. 'Trash conservation'. *The Cane Growers' Quarterly Bulletin*, 1 (1): 126–32.

King, Norman 1958. *Annual Report of the Queensland Bureau of Sugar Experiment Stations*. Brisbane: Queensland Department of Primary Industries.

King, Norman, Mungomery, Reginald and Hughes, Cecil 1956. *Manual of Cane-Growing*. Sydney: Angus and Robertson.

King, Norman, Mungomery, Reginald and Hughes, Cecil 1965. *Manual of Cane-Growing*. Revised edition , 1956; rpt. Sydney: Angus and Robertson

Linedale, T. 1970. 'Combating erosion in the Moreton area'. *The Cane Growers' Quarterly Bulletin*, 39 (3): 77–9.

Lowndes, A. (ed). 1956. *South Pacific Enterprise: The Colonial Sugar Refining Co. Ltd*. Sydney: Angus and Robertson.

Mackson, J. 1983. 'Trash retention: dollars in your pocket?'. *Australian Canegrower*, December, 22–4.

Matthews, A. and Makepeace, P. 1981. 'A new slant on soil erosion control'. *The Cane Growers Quarterly Bulletin*, 45 (No. 2): 43–7.

Middleton, B. 1970. *Burrum Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Middleton, B. and Barnes, L. 1974. *Douglas Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

McTainish, G. and Leys, J. 1993. 'Soil erosion by wind' in McTainsh, G. and Boughton, W. (eds), *Land Degradation Processes in Australia*, pp. 188–233, Melbourne: Longman Cheshire.

Mechanization Committee of the South African Sugar Association. 1949. *Mechanisation on South African Farms. Report No. 2*. Supplement to *The South African Sugar Journal*, January 1949. 18 pp. booklet.

Moller, R. 1958. 'Soil conservation in the Childers Area'. *The Cane Growers Quarterly Bulletin*, 21 (3): 93–6.

Moller, R. 1959. 'Soil conservation in the Isis Area'. *Proceedings of the Queensland Society of Sugar Cane Technologists*, 89–91.

Morgan, R. 1979. *Soil Erosion*. London: Longman Group Limited.

Ormrod, Richard. 1979. 'The evolution of soil management practices in early Jamaican sugar planting'. *Journal of Historical Geography*, 5, 2: 157–70.

Penrose, B. 1998. 'Medical experts and occupational illness: Weil's disease in North Queensland, 1933–1936'. *Labour History*, 75: 125–43.

Pick, Jock. 1942. *Australia's Dying Heart: Soil Erosion in the Inland*. Melbourne: Melbourne University Press, 1942.

Pink, H. 1975. 'Protecting the soil in new cane areas'. *Producers' Review*, 65 (12): 19–22.

Prove, Brian 1991. 'A study of the hydrological and erosional processes under sugar cane culture on the Wet Tropics coast of northeastern Australia'. Unpublished PhD thesis, James Cook University.

Prove, B., Truong, P. and Evans, D. 1986. 'Strategies for controlling caneland erosion in the Wet Tropical Coast of Queensland'. *Proceedings of the Australian Society of Sugar Cane Technologists*. 8: 77–84.

Prove, B. and Hicks, W. 1991. 'Soil and nutrient movements from rural lands of North Queensland'. In David Yellowlees (ed.), *Land Use Patterns and Nutrient Loading of the Great Barrier Reef*, pp. 67–76. Townsville: Sir George Fisher Centre for Tropical Marine Studies, James Cook University.

Prove, B., Doogan, V. and Truong, P. 1995. 'Nature and magnitude of soil erosion in sugarcane land on the wet tropical coast of north-eastern Queensland'. *Australian Journal of Experimental Agriculture*. 35: 641–9.

Quabba, Ray 2000. 'Achieving ESD as a cane grower'. In P. Hale, A. Petrie, D. Moloney and P. Sattler (eds), *Management for Sustainable Ecosystems*, pp. 159–62. Brisbane: Centre for Conservation Biology, The University of Queensland.

Ratcliffe, F. 1938. *Flying Fox and Drifting Sand: The Adventures of a Biologist in Australia*. London: Chatto and Windus.

Richardson, Bonham. *The Caribbean in the Wider World, 1492–1992. A Regional Geography*. Cambridge: Cambridge University Press, 1992.

Ridge, D., Hurney, A. and Chandler, K. 1979. 'Trash disposal after green cane harvesting'. *Proceedings of the Australian Society of Sugar Cane Technologists*, 1: 89–92.

Robinson, Guy 1995. 'Deregulation and restructuring in the Australian cane sugar industry'. *Australian Geographical Studies*, 33 (2): 212–27.

Rosser, J. 1961. 'Mackay growers use contour banks to control erosion'. *The Cane Growers' Quarterly Bulletin*, 25 (1): 13–16 & 21–3.

Sallaway, M. 1979a 'Trash retention as a soil conservation technique'. *Proceedings of the Australian Society of Sugar Cane Technologists*, 1: 133–7.

Sallaway, M. 1979b. 'Soil erosion studies in the Mackay district'. *Proceedings of the Australian Society of Sugar Cane Technologists*, 1: 125–32.

Sallaway, M. 1981. 'Soil erosion processes in Mackay Canelands'. Unpublished Master of Philosophy thesis, Griffith University, Brisbane.

Saunders, Kay. 1982. *Workers in Bondage. The Origins and Basis of Unfree Labour in Queensland 1824–1916*. Brisbane: The University of Queensland Press.

See, J. and Crouch, H. 1963. 'Mechanisation of Sugar Cane Harvesting'. *Australian Department of Labour and National Service Personnel Practice Bulletin*, 40–48.

Seton, D. 1975. *Hinchinbrook Shire Handbook*. Brisbane: Queensland Department of Primary Industries.

Shlomowitz, Ralph. 1979. 'The search for institutional equilibrium in Queensland's sugar industry 1884–1913'. *Australian Economic History Review*, 19 (2): 91–122.

Sloan, W. 1947. 'Some aspects of the problem of soil erosion control in Queensland cane fields'. *The Cane Growers' Quarterly Bulletin*, 10 (4): 155–61.

Skerman, P., Fisher, A. and Lloyd, P. 1988. *Guiding Queensland Agriculture 1887–1987*. Brisbane: Queensland Department of Primary Industries.

Smith, N. 1955. 'Combatting the soil erosion problem in the Childers area'. *The Cane Growers' Quarterly Bulletin*, 18 (3): 103–4.

Soil Conservation Authority, Victoria. 1953. *The Soil Conservation Authority, Victoria, Australia: A Brief History of Victorian Erosion Control*. Melbourne: Victorian Soil Conservation Authority.

Sypkens, E. 1970. 'Are short rows necessary in contoured canefields'. *The Cane Growers' Quarterly Bulletin*, 23 (4): 137–41.

Stephens, C. 1945. *The Nature and Incidence of Soil Erosion on the Sugar Cane Fields of Queensland*. Divisional Report No. 20 of 1945, Division of Soils, Council for Scientific and Industrial Research.

Taylor, A. 1957. 'Attempts at soil conservation on South Johnstone farms'. *Proceedings of the Queensland Society of Sugar Cane Technologists*, 149–53.

Vallance, L. 1947. 'A soil erosion control experiment in the Isis district'. *The Cane Growers' Quarterly Bulletin*, 10 (3): 118–28.

Vallance, L. 1950. 'The History of Sugar Soils Investigations and Agricultural Research'. In Queensland Bureau of Sugar Experiment Stations, *Fifty Years of Scientific Progress: A Historical Review of the Half Century Since the Foundation of the Bureau of Sugar Experiment Stations*, pp. 21–37. Brisbane: Queensland Government Printer.

Veurman, J. 1975. 'Contours protect threatened soil'. *Producers' Review*, 65 (4): 94–5.

Veurman, J. 1977. 'Soil conservation in the central cane district'. *Queensland Agricultural District*, 103 (6): 579–87.

Watts, D. 1987. *The West Indies: Patterns of Development, Culture and Environmental Change since 1492*. Cambridge: Cambridge University Press.

Williams, Michael. 1974. *The Making of the South Australian Landscape*. London: Acdemic Press.

Willis, G. 1972. *The Harvesting and Transport of Sugar Cane in Australia*. Department of Geography Monograph Series, No. 3. Townsville: James Cook University of North Queensland.

Wilson, T., Wissemann, A. and Dwyer, G. 1982. *Report on the Soil Conservation Practices and Related Attitudes of Innisfail Canegrowers*. Project report No. Q082015. Brisbane: Queensland Department of Primary Industries.

Wood, Andrew 1991. 'Management of crop residues following green harvesting of sugarcane in north Queensland'. *Soil and Tillage Research*, 20 (1): 69–85.

Woods, E., Cox, P. and Norrish, S. 1997. 'Doing things differently: the R, D & E revolution?' In Keating, Brian and Wilson, J. (eds), *Intensive Sugarcane Production: Meeting the Challenges Beyond 2000*, pp. 469–90. Wallingford, UK: CAB International.

Wright, J. 1970. 'Is soil erosion a problem on the farm?'. *The Cane Growers' Quarterly Bulletin*, 23 (4): 134–6.

Yeomans, Percival. 1965. *Water for Every Farm*. Sydney: Murray Books.