Optimum land use in the Moreton canegrowing area: An application of spatial analysis using linear programming

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The long term use of agricultural land suitable for growing sugarcane in south east Queensland has been studied to assist in planning for the future stability of the sugar industry in a rapidly developing coastal area.

A geographic information system was used for the storage and manipulation of land resource information and linear programming was used to determine the optimum location of canegrowing activities in the Moreton Mill area. The results of the analysis were interpreted with the aid of mapping software from a geographic information system's package (GIS). They display some of the theoretically expected characteristics of an optimally located agricultural industry.

The analysis has shown that the data from existing land use studies can be used for detailed economic analysis and that modern information handling techniques, including databases and spatial technology, are beneficial in analysing and interpreting results.

The location of land required for the continued viability of the existing sugar mill at Nambour has been assessed and the study has provided local planning authorities and the sugar industry with information for the formulation of strategic plans and policies for the canegrowing area concerned.

Development and conservation of agricultural land

There is growing concern within the community about land conservation issues. The traditional view that land in Australia is almost a limitless resource is far from correct, especially in parts of the country where rapid population growth and competition from other industries is eroding the land base of important agricultural industries.

For the sugar industry in Queensland, the loss of farm land is more significant than for any other major agricultural industry. Local processing of cane is essential and much of the land suitable for sugarcane production is located on the high rainfall strip where the fastest growing population centres are located.

There is a long-term need to protect valuable agricultural land, given the continuing importance of agricultural production in the Australian economy. Over 80 per cent of raw sugar produced in Queensland is exported and canegrowers and raw sugar millers have demonstrated, over a long period of time dominated by low world sugar prices, that they can compete effectively in the market with other, heavily subsidised producers.

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Coleman and Edwards (1991) state that only 2 per cent of the land in Queensland is suitable for canegrowing. Currently, 1.6 per cent of the area of the state is planted to sugarcane and most of that lies along the coastal strip.

The loss of assigned caneland in each canegrowing district over the 10 year period, 1980 to 1989 is presented in Table 1. The most severely affected canegrowing areas have been the Mossman-Cairns area, Mackay, southern Queensland, and northern New South Wales.

Table 1: Sugarcane land transferred to other uses

Canegrowing area	Caneland rezoned or resumed	Caneland converted to other farm uses	Caneland transferred to new areas
Mossman-Cairns	2 306	534	549
Wet tropical coast	73	2 300	105
Herbert River district	0	533	508
Burdekin	50	405	435
Mackay	879	3 537	3 312
Bundaberg-Maryborough	224	3 958	3 161
Nambour-Rocky Point	254	695	135
New South Wales	690	1 781	2 080
Total	**4 497**	**13 743**	**10 285**

Source: Coleman and Edwards (1991, p 18)

By 1990, 28 525 ha, nearly 10 per cent of the total area growing cane in Australia ten years earlier, had been converted to urban or other agricultural uses. Nearly 4 000 hectares of caneland had been rezoned, 615 has had been resumed or purchased by government bodies for roads, railways, schools, etc. and 13 743 ha had been converted to other agricultural uses, mainly rural residential blocks and hobby farms. Canegrowing ceased on another 10 285 hectares of land within existing mill areas but the owners transferred their entitlements to grow cane to another part of the same canegrowing district. In many of these cases, productive land, close to the mill was taken out of production to be replaced by more marginal land located at a much greater distance from the factory. Coleman and Edwards (1991) reported that these new areas to which cane growing entitlements had been transferred were between 20 and 80 kilometres from the mill.

At the local level, the extent to which town economies depend on the sugar industry tends to be underrated. In canegrowing areas, people connected directly and indirectly with the industry may comprise half the population. Closure of the raw sugar mill, as a result of its having become unviable, would have significant social and economic effects on urban centres such as Murwillumbah, Nambour, Proserpine, Gordonvale, and Mossman. In all of these cases, strong local pressure exists to convert canegrowing land to other uses (Coleman and Edwards 1991).

In 1991, the Queensland Government produced a policy document on the development and conservation of agricultural land (Planning Bulletin No. 1/91, 1991). This bulletin sets out the government's policy and it is designed to provide guidance to local authorities on conserving and developing good quality agricultural land when carrying out their town planning duties.

There is a large body of literature on land economics and the market place is the proper way to decide appropriate forms of land use. If agricultural land use cannot generate as large a stream of benefits for the community as some alternative use, can there be any real argument about preservation of such land for agriculture? However, many of the decisions taken by individual landowners to sell their land on the edge of expanding urban areas for housing development or for hobby farms seem to be the result of undervaluing the benefits from future streams of income if the land continues to be used for agriculture. Also, there seems to be a tendency to overvalue the benefits accruing to the community, and ignore the fact that most of the benefits accrue to individual landowners, when rural land is converted to urban use. Furthermore, extra costs that the community, especially in future generations, might have to bear through this conversion, are ignored.

Information to support or deny the contention that the loss of agricultural land is a serious economic problem for the community is urgently required. A notable recent contribution to this serious lack of information was made by Wills (1992). One approach to providing some such information has been developed through the combination of appropriate economic analysis and computerised mapping technology.

With the widespread availability of geographic information system's software, it is a pertinent time to review regional economics theory in the hope that researchers and practitioners without a background in economics or regional science, who use the technology now readily available to them, will use it with a proper understanding of the problems they address.

Regional science and location theory

Mankind's adaption to and interaction with the physical environment suggests that a comprehensive theory of economic activity should embrace both space and time dimensions.

The world, each of its major meaningful divisions, and each of its larger nations may be viewed as a system of regions (Isard 1960, p 122).

Time is a significant variable for conventional economists. It was often ignored in the past although most studies now explicitly try to incorporate it. Even more basic than time is the spatial and regional framework that is often used for regional analysis (Isard 1960, p 122). Isard considered that two-dimensional space considerations were much harder to deal with than time. Time is open-ended and infinite while economic space is not. Frequently, economic analyses are conducted in terms of a single spatial dimension and location is described by position along a line. While this is a useful analytical device that may give acceptable results when the second spatial dimension does not matter, two dimensional location is important in much of the analysis that is of interest to agricultural scientists. Soil type and climatic attributes are two important factors that condition agricultural production and these are affected by fixed positions on a map.

In the preface to *Location and space economy* Isard (1956 p vii) proposed that the theory of regional economic development should be testable, for example against the background of historic development in many regions of the world, and therefore should offer an explanation for this development. Ideally, its conceptual framework should enable one to anticipate the course of future developments, given certain premises and judgments.

General equilibrium theory

Palender, writing in 1935, regarded the Walras-Pareto-Cassel theory on general equilibrium as meaningful only for locational analysis of an economic district where transport costs were zero, capital and labour were freely mobile, and technical conditions of production were uniform throughout the region. He regarded the region as being compressed into a point location although he conceded that a somewhat closer approximation to reality was achieved by removing some simplifying assumptions.

General equilibrium theory depends on the principle of pure competition but this proposition is difficult to sustain when space considerations, and thus transport costs, are introduced.

If the various locations in a region are treated as different markets to relax the assumption about compressing each region into a single point, the necessary condition of a large number of buyers and sellers for each commodity cannot be fulfilled. Either the region is viewed as representing one market with different prices for a given commodity at various places within the region (signifying a non-uniform product) or a uniform product in an imperfect market is assumed. In this case, individuals are considered to be in a monopoly situation in accordance with the advantages of their respective location. Neither case can be regarded as pure competition.

"Everybody is a spatial monopolist in a neighbourhood that may sometimes be quite large" (Beckmann (1984, p 33).

Lösch developed a highly simplified model of a space economy operating under conditions of monopolistic competition (Isard 1956, p 48). Lösch studied the location problem in relation to the production of industrial goods but considered the location of production for agricultural products could also be analysed. Significant criticisms of the Lösch model were documented by Isard (1956, p 48). Relaxation of Lösch's simple assumptions about uniformity of the area under consideration to allow inequalities in resources, or an uneven and discontinuous spread of population, or other types of local differences, makes the model less attractive.

Isard (1956, p 49), considered that from a functional point of view, it was better to describe the solution to regional problems as seeking a set of substitution points in respect to inputs, and outputs (costs including transport, and revenues) which would equate the various spatial parameters. Such a model would not require absolute spatial coordinates, as Lösch's model did and would be better able to cope with other considerations.

Harris (1984) noted that the maximisation of expected utility was a fundamental paradigm in decision-making. It is assumed that utility is maximised by individuals but in actual practice, the utility maximiser is more frequently a household or family, or even a larger social or economic group. Even within households, there are complex interpersonal relationships which control the process of substitution between inputs and establish the trade-off relationships between alternative courses of action, especially in relation to location. Such a decision-making situation is far from being purely economic.

The factors that influence group decision-making - earning capacity, cultural background, education, training, aptitude, physical and psychological endurance, are particularly sensitive to spacio-temporal distributions and are hence important for spatial analysis (Harris 1984, p 91). Also, social goals, such as quality of life, social stability, and preservation of the environment, are affected by economic events but they cannot be measured entirely in monetary values. These factors lead to substantial problems when using economic models to represent real situations and to reach optimum positions in regard to community objectives.

Harris (1984) noted that "the use of economic models (for regional analysis) is convenient and intellectually appealing because the economic paradigm is well developed. However, he considered that the economic approach captured too narrow a segment of the world and must be extended". GIS technology now enables us to do that and to display more of the interactions that might affect economic performance at the regional level.

Regional development

Mankind's reaction with the environment, the constant modification of the constraints and scarcities which it imposes, and the incessant development of techniques that revalue resources and cause certain natural features to be less restrictive and others more productive is the essential essence of economic development.

The economics of spatial relationships are centred on spatial interaction. Such interaction involves movement of either information, commodities, or people between two locations (at least). This interaction is of interest if it creates benefits but it is also likely to create costs. Spatial interaction can be crudely defined as what it costs to produce something plus what it costs to transport it to another location.

Regional planning aims to bring about changes in spatial and economic structures to achieve a harmonious adjustment to social, economic and cultural needs of society (Nijkamp 1984, p 267). Therefore, regional policy should aim to create conditions for a healthy economic strucuture by simulating economic development, by eliminating constraints to growth, and by modifying less desirable development tendencies. Nijkamp (1984) outlined several theories which might explain differences in regional growth.

One theory that he described, **regional development potential theory**, assumes that regional disparities are the result of long-run developments and not short-term cyclical fluctuations, thus putting emphasis on capacity and the supply side. A region is considered too small in comparison with the total outside economy to exert significant influence on prices, resource supplies, etc. Demand for regional products is also given and the question of dealing with regional disparities is essentially a comparative allocation problem - what share of total demand can be obtained by successive regions in an open spatial system?

This largely explains the degree to which regions succeed in utilising their productive capacity. Regional development potential depends on availability of natural resources and the availability of mobile factors of production, particularly labour, and capital for new investment.

Geographic Information Systems (GIS) technology

GIS technology combines the power of a relational database with the capacity to display things spatially.

"GIS technology is less than 20 years old but it is emerging as one of the fastest growing application areas for interactive computer graphics. Once limited to users who could afford expensive systems requiring expert staff, GIS technology is experiencing a surge of acceptance. This is due to advances in software, powerful microcomputers to act as workstations, and growing user interest. Users in industry, research, and in government are finding that GIS technology has made it possible to condense tasks that once took months into a job that just takes a few minutes.

"One of the advantages of a GIS is the ability to extract stored information in any combination and in various formats. Through the use of GIS technology, those responsible for managing infrastructure can access a vast amount of useful information". It sounds like something from an advertising brochure but it is in fact part of a serious commentary about the use of geographic information systems in the sugar industry (McKenzie 1990).

GIS packages come in a wide variety of prices and can be supported by an equally wide variety of computer hardware. Versions for DOS, Unix, and Macintosh operating systems are available and the popularity of PC based versions is putting this technology into the hands of a lot of users who in the past would have not had this capability.

One of the most popular packages sold 100 copies in the first six months after its introduction into Australia about three years ago and another 400 copies in the next year. The fast growth of the geographic information system market is dependent on the popularity of the personal computer.

GIS software is mostly used as a long-term planning tool in mining, land management, forestry and urban development. To use GIS technology properly, organisations have to develop detailed databases of information which may take many years, and can be expensive in the use of resources, to establish.

With the widespread commercial availability of geographic information systems software, it is important that a wider cross-section of users have an appreciation of the basic elements of location economics. Methods of regional analysis need to be better understood by agricultural economists and other users if the potential of this technology to improve economic performance is to be realised.

Graphic data analysis

The definitions of GIS are as disparate as the vendors who sell the software and the academics who write about it. Essentially, a GIS is "computer-based technology used to capture, edit, store, retrieve, analyse, and display spatial data". Reduced to its simplest form, it means that you can draw maps on a computer screen quickly and shade the various areas that are of interest for some reason. GIS technology will not allow us to do anything that we cannot do already but it will enable it to be done much more efficiently.

The advantage of a GIS package over conventional database technology is the relative ease with which the locatio of features meeting certain criteria can be plotted and illustrated. Researchers will no longer have to visualise where features such as low or high yielding farm paddocks are situated: they, and the factors likely to contribute to productivity, can all be readily incorporated into one graphic display. The facility of being able to display information spatially will provide research scientists with another boost to their interpretive capacity similar to that which was experienced when an earlier generation of computer graphics allowed us to display two-dimensional, graphical relationships so readily.

One of the most desirable features of the spatial technology approach is the ability to integrate data from a wide variety of sources. Geographic information from satellites, printed maps, aerial photographs, and files of descriptive records can be stored in appropriate computer files as a database. Overlays of information such as property boundaries, natural land features, service and transport networks, land use patterns, productivity information, demographic data, etc can also be displayed.

There are essentially two types of basic data contained in the database associated with any GIS - spatial and non-spatial information. Spatial or locational data represents objects that have physical dimensions such as landscape features that can be represented on a map. Farm paddocks (polygons), roads and trainlines, irrigation channels, drainage ditches (lines) and bores, dams, houses, watering points, irrigation pumps (points) are some examples of the spatial information that could be of interest to agricultural economists. Labels attached to this spatial data represent the non-spatial or attribute information that is also stored in the database. For example, an irrigation pipeline may have attributes such as type of material, diameter, capacity, or a farm paddock could be described in terms of soil type, crop history, yield potential.

Both types of information are normally stored in conventional computer databases and so can be stored, searched, sorted, selected and reported in the manner of conventional database files. The new feature of a GIS package is that the result of these searches can be illustrated spatially. Most GIS software has an inbuilt database but because of the large amounts of information to be stored, a relational database management system (RDMS) using one of the later generation databases such as dBaseIV, INGRES, or ORACLE, is normally required. One of the advantages of using a separate proprietary database is that such a database may be used already, for example, for storing farm productivity information, so it is a simple matter to add the additional spatial information required for a GIS.

Application of spatial technology to a regional land allocation problem

A regional analysis of some aspects of cane production in the Moreton Mill area in southern Queensland is described. The study was an attempt to determine the optimum utilisation of canegrowing land in the mill area by linear programming analysis. The results were interpreted with the aid of a GIS software package.

The Moreton canegrowing area

The Moreton Central Sugar Mill at Nambour is one of the smaller mills in Queensland. Like other canegrowing areas along the Queensland coast, it faces problems in regard to availability of suitable land for continued expansion and economic operation. The area of land suitable for canegrowing is diminishing rapidly as it is diverted to competing uses.

The majority of the land assigned for canegrowing in the Moreton Mill area is located on the alluvial plains and coastal depositional areas that surround the Maroochy River system although the mill area in total now extends from Eumundi and Doonan in the north to the Mooloolah River west of Caloundra in the south. Historically, it was situated entirely within the Maroochy and Noosa Shires although there is now a small area of cane being grown in Caloundra City (formerly Landsborough Shire) as well.

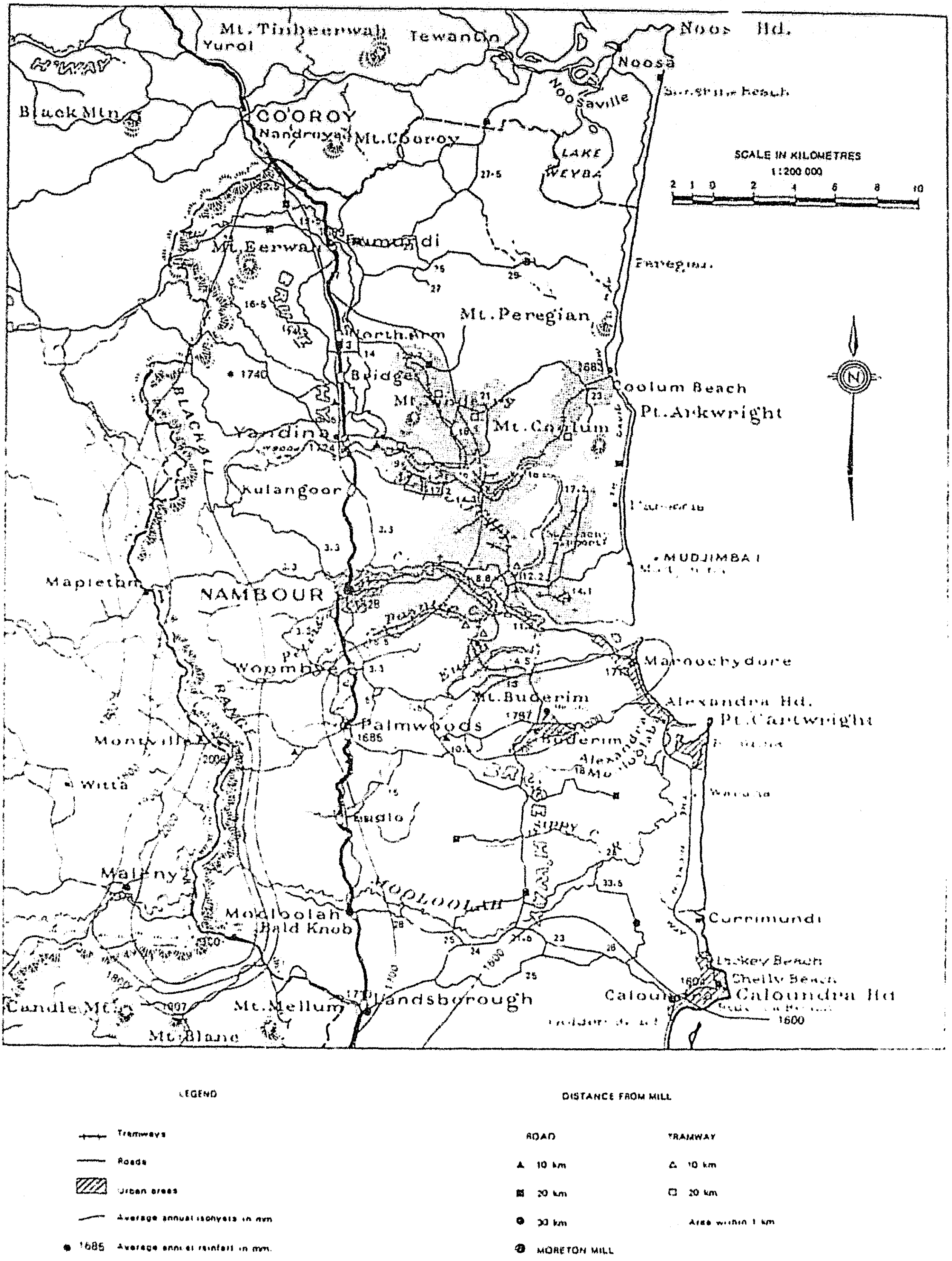

Figure 1: Location map of Moreton Mill area at Nambour, Queensland
Source: Capelin (1979, facing p 2)

The areas of the six predominant soil types used for growing cane in the Moreton Mill area were reported by Kingston and Linedale (1987). The relative importance of the main soil types growing cane is shown in Table 2 where the percentage that each comprises of the total assigned area is presented in decreasing order. The main characteristics of these soil types were described by Capelin (1979).

Table 2: Soil types used for canegrowing - Moreton Mill area

Soil type	Percentage of total area
Humic gley	41
Peaty gley	23
Yellow podzolic	16
Humus podzol	11
Red earth, earth red podzolic	5
Krasnozem	4

Source: Kingston and Linedale (1987)

Humic gley soils, and two other similar soil types, constitute the major group of soils on which sugarcane is grown in the Moreton Mill area. In 1983, 3 250 hectares, or approximately 68 per cent of the assigned area, was included in this classification.

Soils in the humic gley group have gradational texture profiles consisting usually of a loam or clay loam over a heavy mottled clay. Peaty gley soils that occur in more poorly drained locations are very similar. They make up nearly one quarter of the canegrowing area. Along the lower stream terraces, inter-mixed with the humic gley soils, a group of alluvial soils are found. Their sandy texture and better drainage distinguishes them from the humic gleys but they are similar in most respects. They are limited to about three percent of the assigned area. They are usually included with the humic gley classification because of their location.

Texture contrast between topsoil and the underlying layers distinguishes a group of soils in the mill area including yellow podzolics, red sands, red earths, and red volcanic soils or krasnozems. These soils are the second most important group in the area and 1 550 ha growing cane in 1983 constituted 25 per cent of the total assigned area. The red and yellow earth group of soils were formed on laterised sandstone and occur on moderate to steep slopes, and are prone to soil erosion and seepage problems. They are well drained and highly fertile but their moderate slopes and value for horticultural cropping mostly precludes their use for sugarcane.

The humus podzols are sandy textured soils that occur in the coastal lowlands. They are usually flat to slightly sloping and have poor to fair surface drainage. They are suited for reclamation for sugarcane production but drainage is essential and substantial fertiliser inputs are required. The humus podzol soils became important for sugarcane production in the Moreton Mill area when a significant proportion of the 1980-81 expansion in assignment was located in the Sippy Creek area.

The location of these four main soil types is illustrated in Figure 2.

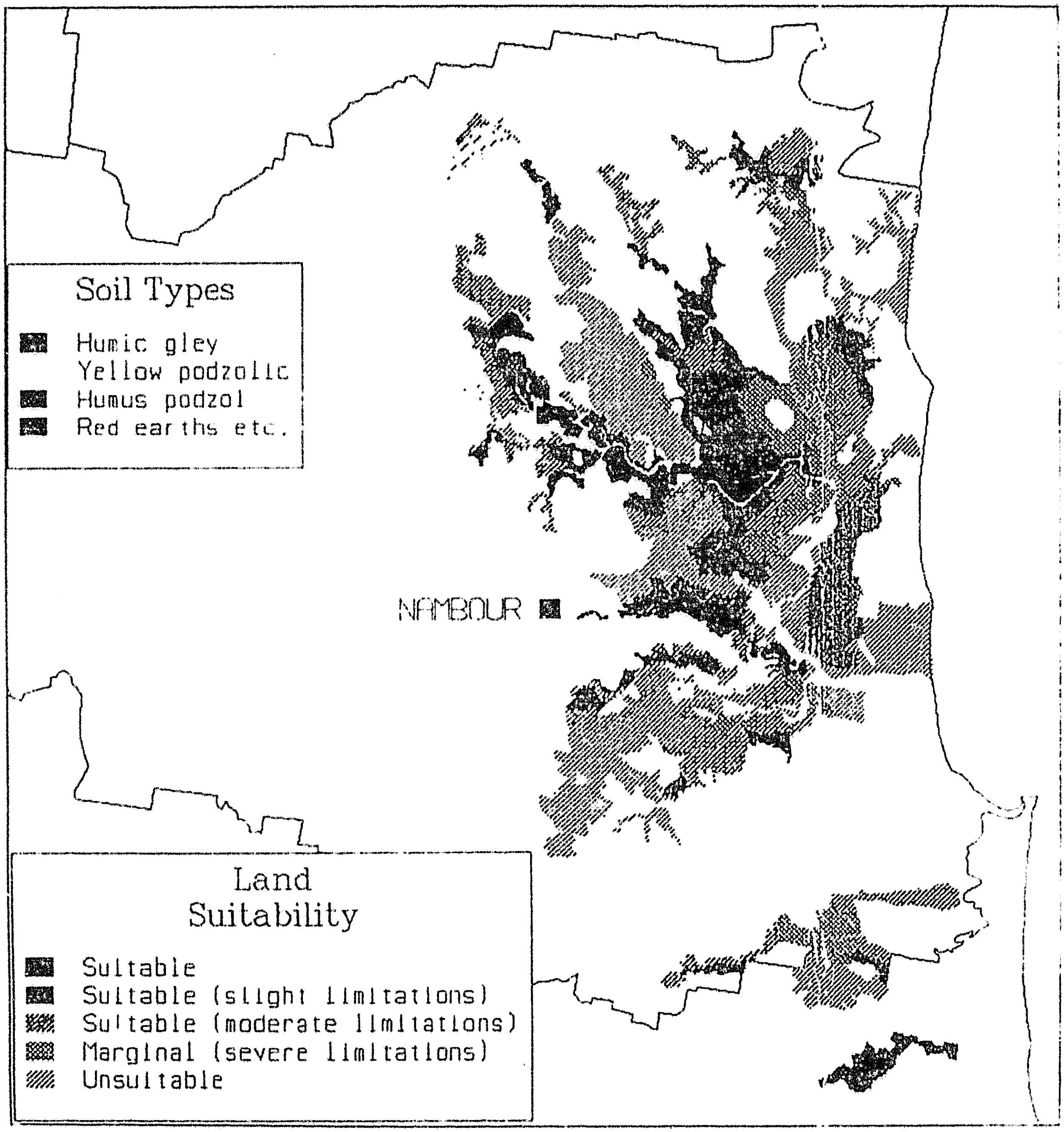

Figure 2: Location of major soil types in Moreton Mill area

Development of sugar industry in Moreton Mill area

The development of the sugarcane industry in the Moreton Mill area reflects the logical decisions of the early canegrowers to develop the better soils first and only when these soils were all in production did they grow cane on less suitable soils.

Linedale (1984 pers. comm.) in a Mill Area Situation Statement noted:

> The first major development of land for sugarcane production occurred on the fertile red volcanic slopes of Buderim and Mapleton. As the industry progressed however, the majority of sugarcane was grown on the productive alluvial soils along the Maroochy River and its tributaries, and later on the peat soils of the adjacent tea-tree swamps.
>
> The heavy texture and poor internal drainage characteristics of the alluvials posed significant problems to crop husbandry and productivity from the earliest days of their development. These factors still constitute a substantial limit to yield.
>
> Cultural practices in the area developed primarily on the alluvials. However, the development since 1956 of the yellow podzolic soils of the coastal hills and the humic gleys located in coastal depositional areas, posed different problems, especially in crop nutrition, cultivation, and drainage practices. Crop husbandry practices had to be modified to suit these soil types. Similar modifications have been found necessary with the development of the humus podzol soils in 1980-81" (Linedale, pers. comm., 1984).

Land resources information

In the mid-1970s, the Queensland Department of Primary Industries, recognising the intense competition for land resources between agricultural and urban uses on the narrow, high-rainfall coastal belt, carried out one of the earliest studies undertaken in Queensland to try to ensure that the limited area of prime agricultural land in the Moreton Mill area was retained for cropping, while allowing adequate scope for urban expansion (Capelin 1979). Capelin and other QDPI staff undertook land use studies to delineate suitable land within economic transport distance of each southern Queensland district mill. In the original report, Capelin found that Moreton Mill at Nambour, which in 1979 had an allocated mill peak of 49 300 tonnes of sugar or 1.5 per cent of the Queensland total, was facing problems through competition for suitable canegrowing land from developing urban and related uses.

In 1986, the Department of Primary Industries, in conjunction with local organisations including the Landsborough and Maroochy Shire Councils, the Moreton Central Mill, the Canegrowers District Executive, and BSES, updated the previous land suitability study. In the updated study, Capelin (1987) concluded that only 67 per cent of the land identified as available for sugarcane production in 1977 was likely to be available in the future because of increasing land use pressures. He considered that the area of land available to the sugar industry in the long-term was about 10 000 hectares and suggested that strategies to safeguard the future supply of land suitable for sugarcane be adopted.

Department of Primary Industries staff have therefore mapped the whole area between Landsborough and Lake Weyba and between the Blackall Range and the coast, dividing it into 663 separately mapped areas (Unique Map Areas or UMAs). Of these, 107 were eliminated immediately from further consideration because they were either crown land, urban land, or land considered unsuitable for sugarcane production.

Of the 513 UMAs remaining, they were able to assess whether the land was suitable for growing sugarcane and whether it was available. They assessed each UMA in terms of long-term potential productivity and the likely costs of land development were estimated for each. In addition to identifying the location of suitable areas, the cost of transporting cane from each UMA from the mill, either by both road or by mill tramline, was noted.

Most of the cane in the Moreton Mill area is grown within 20 km of the mill and no more than 1 km from a mill tramline. Areas not served by tramlines at present include the North Yandina Creek area where cane is trucked 5 km to a loading point on the tramline at Valdora. Areas on the Bruce Highway at Yandina, North Arm and Eumundi, truck cane to the mill marshalling yards at Nambour. Yandina and Eumundi are 10 and 20 km respectively from the mill by road. Assigned land at Doonan Creek is 30 km by road to the mill via Eumundi. The costs of transporting cane to the mill therefore fell into categories depending on the transport system that was applicable. At the time that these assessments were made the relevant charges were: Rail $2.00 per tonne, Road $3.00 and Road + Rail $4.00 ($2.00 + $2.00). Areas relating to these cost categories are shown in Figure 3. This information, as well as providing the physical basis for industry planning, has been invaluable for subsequent economic studies into the optimal location of cane production in the area.

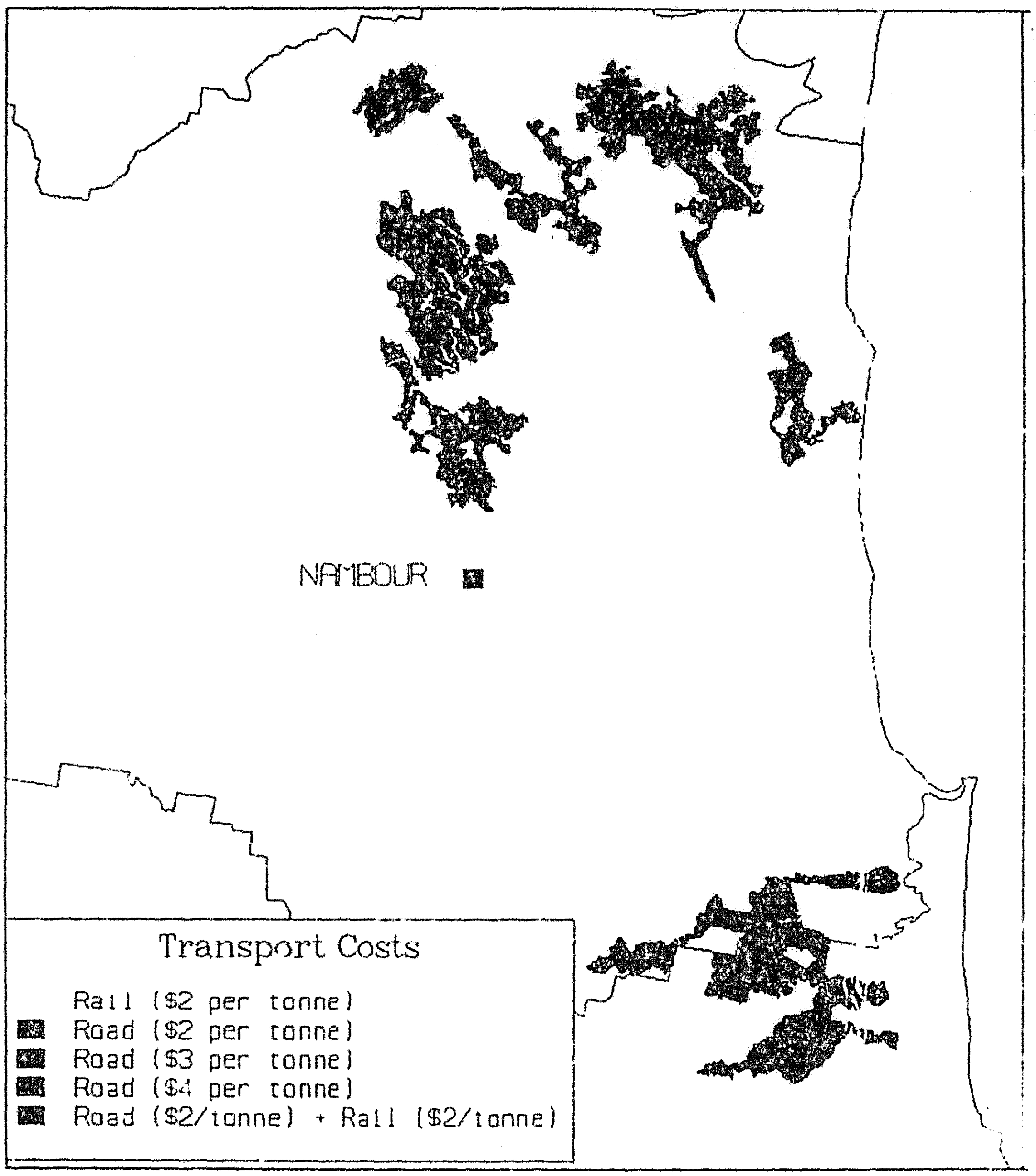

Figure 3: Transport cost zones in Moreton Mill area

Long-term productivity for each UMA was assessed by a panel of experienced sugar industry personnel which included the mill's cane inspector and the local BSES extension officer. Five productivity categories were established and this information was later used for the economic study.

In 1979, and again in 1986, Capelin noted that a major part of the area likely to be developed for sugarcane production in the Moreton Mill area would involve the humus podzol soils (Capelin 1979; Capelin, 1986, pers. comm.). The development of the humus podzol soils assumed long-term importance in the sugar industry in this area following the 1980-81 expansion. It is known that the humus podzol soils are lower producing and yields from this soil type are expected to be much more variable because they are more sensitive than other soil types to moisture surplus and deficit conditionss. Trials by Linedale and Kingston (1987) identified severe nutrient deficiencies including phosphorus and potassium in these soils. Possible responses from the addition of calcium and magnesium and from a reduction in soil acidity seem likely. This means that fertiliser costs on these soil types will be higher although these higher costs may be offset by easier cultivation and lower working costs for these extremely friable soils. These soils also seem to produce higher ccs levels. The major disadvantage is the distance that the areas of these soils are located from the mill.

For land not currently growing sugarcane, the costs of land development were determined for all areas that had that potential. These costs ranged from less than $500 to more than $5 000 per hectare.

In land suitability studies conducted by the Queensland Department of Primary Industries, the data that were collected and recorded against each unique mapping area comprised four separate coverages (Capelin 1987; Forster 1989):

- existing sugarcane growing areas;
- land tenure;
- land use; and
- land suitability for sugarcane.

For the Moreton Mill area, additional data, used in the subsequent economic analysis, were collected including:

- soil type (Soil type is an important variable to record because of its effect on productivity, fertiliser costs, and cultivation costs. Figure 2 shows the distribution of soil types within the study area.);

- location in relation to the sugar mill (important because of the effect of transport costs on farm returns. Figure 3 shows the location of transport cost zones.);

- land ownership and allotment size (for land availability); and

- cost of land development.

All of the information discussed in previous sections of this paper is contained in database files developed as part of the goegraphic information system (GIS) for the area and appropriate maps to illustrate many of these situations can be readily produced.

Cropping practices and productivity

A number of environmental and agronomic factors as well as grower attitudes and market forces influence productivity in canegrowing. Among these factors are some that act directly on the cane plant through supply of moisture, nutrients, and others that affect the surrounding micro-environmental conditions.

Limited information on average yields from each of the soil types currently used for canegrowing in the Moreton Mill area was available and is presented in the following table.

Table 3: Average yield for each soil type - Moreton Mill area

Soil type	Average yield Plant cane (t/ha)	Average yield Ratoon cane (t/ha)	Average yield All cane (t/ha)
Humic gley	81.3	90.6	88.4
Peaty gley	98.0*	106.0	105.0
Yellow podzolic	55.0*	80.4	76.2
Humus podzol	72.0*	66.8	67.6

Source: BSES Soil Fertility Monitoring program
* Single observations

Information on fertiliser inputs used by growers on the different soil types is available from a number of sources including the BSES Soil Fertility Monitoring program (Chapman *et al.* 1981), a survey conducted by Kingston and Linedale (1987), and from personal comments by extension officers who have serviced the district.

Information from sites on different soil types reveals that fertiliser rates vary according to soil type but that they do not necessarily reflect the yield expected - heavier fertiliser applications were generally made to the poorer soil types which have the lowest yield potential. Fertiliser application rates and yield differences between soil types are shown in Table 4.

Table 4: Yield differences at Soil Fertility Monitoring Sites Moreton Mill area

Site	Nitrogen applied (kg N/ha)	Average yield (t cane/ha)	CCS (units)
Humic gley	185	88.4	13.56
Peaty gley	151	105.0	12.50
Yellow podzolic	193	76.2	13.57
Humus podzol	296	67.2	13.84

Source: BSES Soil Fertility Monitoring program

In the light of this and other information, fertiliser recommendations ranging from 180 kg on the peaty gley/recent alluvium, krasnozem, red earth and red podzolic soil types through 200 kg for humic gley and yellow podzollic to 240 kg per hectare on the humus podzol soils, were developed by the local extension officer and have been used in the economic analysis reported later in this paper.

Mill viability

Long term studies undertaken by the management of the Moreton Mill have indicated that it should be producing at least 80 000 tonnes raw sugar per year (equivalent to crushing 560 000 to 600 000 tonnes cane per season in the 1990s to maintain its profitability (Coleman and Edwards 1991). This would require at least 3 000 hectares of additional land within convenient transport distance of the mill to be brought under cane. This is feasible given the land resources available, however, the rate at which land resources in the area are being lost is of concern.

Discussions with staff of the Moreton Mill have confirmed that they are concerned about the loss of productive caneland as well as the ineffective use made of existing cane assignment by a number of growers. There are a number of small farms, mostly now operated by older growers, in the area. Many other farmers have off-farm employment and other interests so they are not as concerned about growth and productivity as farmers who depend totally on the farm for their income. It is believed that few growers have been interested in farm expansion in recent years because of the high rates of interest paid on borrowed money, poor cane yields resulting from adverse seasonal conditions, and low sugar prices.

While there is considerable uncertainty about the long term future of the sugarcane industry in the Moreton Mill area, the mill management has expressed the view that the mill owners will continue to operate the mill as long as they are assured of a regular cane supply. The mill's crushing capacity, about 525 000 tonnes when crushing five days per week, is sufficient to handle the likely cane supply under existing conditions. The highest tonnage crushed to date was 523 175 tonnes in 1991. Previously, the best crushings were 480 000 tonnes in 1980 and 475 000 tonnes in 1985. If substantially increased cane supplies were to become available each year on a regular basis, the mill could change to continuous crushing and achieve an approximate 30 per cent increase in effective crushing capacity without the need for additional capital investment. However, there are additional operating costs and some social disadvantages (such as the need to continue harvesting at weekends) that have to be taken into account with a change to continuous crushing. On the other hand, the cane supply in this mill area has been shown to be especially variable on a year-to-year basis, reflecting the substantial effect of weather conditions on crop yield. Crops as low as 285 000 tonnes in 1983, 318 000 tonnes in 1986 and 430 000 tonnes in 1990 and 436 000 tonnes in 1992 show just how variable the mill cane supply can be.

During the 10-year period from 1980 to 1989, 133 hectares of land in the Moreton Mill area was rezoned to non-rural uses. Another 110 ha was resumed or purchased for roads, railways, schools, etc. and 335 ha was lost to other rural uses (hobby farms, other agriculture, special uses). During this time, 100 ha of assignment was also transferred to new land. The average distance of reassigned land to the mill was 25 km (Coleman and Edwards 1991). While the loss of land to other rural activities is not seen as being as serious as the loss of land to urban development because it is a reversible conversion and the land is not permanently alienated as a productive agricultural resource.

While small annual diversions of agricultural land to other, non-agricultural uses may have little impact on overall production in the short-term, eventually the cumulative effect of such incremental losses could precipitate the closure of the whole sugar industry in the area. Coleman and Edwards consider that loss of five to 10 per cent of the currently assigned land in a small single mill area would almost certainly result in the closure of the mill within a relatively short period.

While there might be a high-priced market for 5-10 percent of the land currently under cane in the Moreton Mill area, the remaining land would have a much lower value if the mill closed. Thus, while a few growers might benefit from the opportunity to convert their land to urban use, the majority could be left with land that is substantially reduced in value if the sugar mill was forced to close.

In order to encourage new growers to supply additional cane, the mill has been leasing cane assignment to growers. This represents a low cost method by which growers can meet the regulatory requirements involved in supplying cane to the mill.

The areas of likely future expansion in the Moreton Mill area are not served by tramlines and road transport of cane to the mill will be required. The mill is offering a road transport allowance as an incentive to growers who are required to deliver cane to the mill by road transport. This incentive is designed to encourage growers to increase output and improve the efficiency of the road transport system. Road transport costs (up to a maximum distance of 40 km from the mill) are subsidised by the cartage allowance paid to the grower. As the total quantity of cane crushed by the mill increases, the cartage allowance also increases so that at times when the aggregate amount of cane crushed by the mill reaches 120 per cent of mill peak, the transport allowance is set at 75 per cent of the actual haulage charges.

Economic Analysis

Regional programming models

Regional programming models are part of a class of economic models, including representative and regional as well as interregional models, that use mathematical optimisation of an objective function as the method of solution.

Large scale, price exogenous, linear programming models have therefore been used extensively by agricultural economists to simulate the impact of policy and other changes on the agricultural sector. While these models often included restrictive assumptions of fixed market prices or quantities, thereby ignoring the interrelationships between these two variables, they offer valuable insights into the agricultural adjustment process when the correct assumptions are made.

Regional programming models are based on the idea that the economic behaviour of a set of farms can be simulated by the actions of a single farm which is representative of some broader group or alternatively the whole agricultural region can somehow be modelled as if it were one large farm. Programming models are particularly suitable for analysis of new situations such as when large changes in relative prices, outside the historical experience of the industry, occur or institutional changes, such as the imposition of production quotas, are applied. In such cases, econometric techniques are unsuitable because they work by summarising past responses and their application to new conditions violates their underlying assumptions. Longmire *et al.* (1979) discussed some of the important features of regional programming models and listed a number of regional studies conducted in Australian agriculture prior to 1979.

Any attempt to model the economy of an agricultural region imposes non-trivial aggregation conditions upon the micro-units that constitute the universe of farms. All regional models involve some aggregation of farm units which is accompanied by aggregation error caused by treating different units as if they were a single, joint unit. This error is not confined to aggregation of farms: it also occurs when enterprises or resource supplies are aggregated. Although the literature on aggregation error in programming models is extensive, less than adequate attention has been paid to the use of combined resources (Longmire *et al.* 1979).

Most descriptions of agriculture explicitly incorporate spatial features enabling farms and regions to be identified by location. By their nature, regional and interregional models include transport activities to model interregional movement of farm products (Heady and Scrivastava 1975; Egbert and Kim 1975).

When regions are defined as representing all farms within a spatial boundary, production is assumed to occur at a specific site within the region to simplify estimation of transportation costs. This is a serious oversimplification of reality if the regions are large or if production of different products is concentrated in parts of the region.

Optimum land use determined by linear programming

Linear programming can be used to find the profit maximising (or cost minimising) way to satisfy some objective. The analysis will select the optimum combination of activities from among a range of alternatives so that profits are maximised or costs are minimised. The solution must also conform to whatever constraints are placed on the level at which activities can operate.

Any problem that can be represented by an objective to be maximised (or minimised) a series of alternative activities or processes by which the objective might be satisfied, and a set of constraints on the resources available to operate these activities, can be set up and analysed as a linear programming problem.

In the current example, the objective was seen as maximising the aggregate net revenue generated by canegrowers in the Moreton Mill area. Therefore an estimate of the net revenue that could be generated from each activity was required. In this analysis, the UMA was chosen as the basic unit of activity and so it was necessary to generate a net revenue estimate per unit area of each UMA in both existing and potential canegrowing areas.

The net revenue estimates included only those costs that were directly related to income generation for the activity under consideration. It was assumed that land preparation, cultivation and fertiliser costs were affected by soil type which was identified for each UMA. Harvesting and transport costs were affected by the level of productivity assumed for each activity unit and the distance from the mill. All other canegrowing costs such as planting, insect and weed control, were assumed to remain constant across activities, irrespective of soil type or the level of productivity. This assumption may not be correct but was made in the absence of information to the contrary.

Much of the information needed to calculate the net revenue estimates for each activity was available in the database of information collected for the land use study. Thus the database management program was used to generate the activity net revenues based on the following information:

- area of each UMA harvested;
- yield of cane for each UMA based on the productivity estimates included in the database;
- direct canegrowing costs (land preparation, planting, fertiliser, fungicides, insecticides, herbicides and crop cultivation costs were based on estimates provided by the local BSES extension officer (Linedale, 1989 pers. comm.); and

- harvesting and transport costs. A constant rate per tonne for harvesting was assumed and transport costs were provided by the sugar mill staff when the most recent land use data was collected in 1986.

For land not growing cane, development costs are an additional consideration. Development costs for each UMA with the potential to grow cane were estimated by the land use assessment team and recorded in the database. An annuity factor was applied to estimate the annual cost of bringing new land into cane production.

Land constraints

Using the GIS database management system software it was possible to select datasets on land use, land tenure and land suitability to determine the area of suitable sugarcane land which was available for cane production in the mill area.

The land use studies showed that there were significant areas of suitable and marginal land not yet growing sugarcane located on freehold, rural allotments. In the Moreton Mill area, the existing canegrowing area (7 030 hectares assigned in 1989) could expand by 123% if all of the 8 660 hectares of suitable and the 1 810 hectares of marginal land were all brought under cane production.

Some relatively small areas of existing canegrowing land in the Moreton Mill area have been assessed as unsuitable for long-term cane production because of various limitations, but principally because of erosion hazard due to excessive slope, wetness, stoniness, workability problems, or topography and access limitations. Nutrient deficiencies, soil depth, flooding, and frost are additional limitations.

Existing canegrowing land in the Moreton Mill area is assumed to continue in production with the exception of areas that have been assessed as unsuitable for long-term canegrowing or which are genuinely required for residential use or other purposes. Land ownership is an important criterion to consider when deciding on future land use since individuals without an interest in long-term cane production may discontinue canegrowing in favour of other uses.

The area of assigned land in 1987 which was suitable and available for canegrowing is shown in Table 5.

Table 5: Land use constraints on existing assigned land in the Moreton Mill area (1987)

Soil type	Area of exixting assign-ment (ha)	Suitable and marginal land (Classes 1-4) (ha)	Land owned by primary producers (a) (ha)	Area available for cane-growing (b) (ha)	Area available for cane-growing (c) (ha)
Alluvial plains Humic gley, peaty gley, alluvial	4 519	4 271	4 198	4 141	4 046
Coastal plains Humus podzol	889	886	854	846	834
Uplands Yellow podzolic	1 120	1 011	937	875	826
Red earth, yellow earth, red podzolic	429	354	342	320	301
Total	**6 957**	**6 9522**	**6 331**	**6 181**	**6 007**

Notes: (a) Excludes land owned by development companies, urban land and Crown land.
(b) Includes land with uncertain availability.
(c) Land available for agriculture definitely.

The area of land for growing cane is progressively reduced as more realistic expressions of the effective limits to land availability are applied. Thus there could be a possible reduction in the 1987 assigned area by 6 percent if canegrowing was discontinued on unsuitable land, a further 3 percent reduction would occur if canegrowing was restricted to land owned by primary producers. and another 5 percent reduction in the canegrowing area is likely if land that was not available for agriculture indefinitely was excluded.

The impact of these losses, particularly on the continued operation and viability of the processing mill, in the absence of replacement land being brought into production would be significant.

Land potentially available for canegrowing

Economic considerations should predominate in determining whether a particular area of land suitable for canegrowing will be used for that purpose. Land suitability, land availability, and land ownership constraints will condition the extent to which this will occur. It was assumed that only land assessed as suitable for long-term canegrowing would be developed in future. Land considered unavailable for agriculture in the future, and land not owned by canegrowers or other agriculturally interested groups, was excluded from further consideration.

The constraints on land potentially available for canegrowing in the Moreton Mill area are listed in Table 6. Almost 60 per cent of the area suitable for long-term canegrowing, but not yet growing cane, is owned by groups without a current interest in cane growing.

Table 6: Land potentially available for growing cane Moreton Mill area (1987)

Soil type	Suitable and marginal land (Classes 1-4) (ha)	Land owned by primary producers (a) (ha)	Area available for canegrowing (b) (ha)	Area available for canegrowing (c) (ha)
Alluvial plains Humic gley, peaty gley, alluvial	6 110	4 108	5 236	2 747
Coastal plains Humus podzol	1 221	687	1 108	642
Uplands Yellow podzolic	3 918	3 102	3 307	2 120
Red earth, yellow earth, red podzolic	1 071	829	909	393
Total	**12 321**	**8 726**	**10 560**	**5 902**

Notes: (a) Excludes land owned by development companies, urban land and Crown land.
(b) Includes land with uncertain availability.
(c) Land available for agriculture indefinitely.

Results

Results from preliminary runs of the model were designed to reflect the existing pattern of land use in the mill area and so the resource supply coefficients were set to existing levels. For example, the assigned area and the allocation of assignment between the various soil types reflected the current situation as did the constraints included in the model for harvesting, transport, and crushing capacity of the mill. The activities available to supply cane were restricted to UMA's with existing assignment including a relatively small number assessed as unsuitable for long-term sugarcane growing. The optimum solution under these assumptions was close to the existing pattern of production indicating that the model was interpreting the economic conditions in the mill area sufficiently well that subsequent analyses could be undertaken with confidence.

In September 1990, the Queensland Minister for Primary Industries announced an approximate 8 per cent increase in cane assignments for the sugar industry, raising the possibility that small, frequent increases in assigned area may become the general policy in the future as the industry moved towards a more deregulated structure. This trend has been confirmed by more recent announcements, for example in November 1992, when the minister announced another five percent increase is assigned caneland. This expansion continued the process which has seen the assigned area expand at an average rate of five percent per year over the past four years. Thus two concurrent trends are occurring in mill areas such as Moreton, on one hand, existing caneland is being lost through urbanisation and conversion to other uses while, at the same time, the mill area is sharing in overall industry expansion. Under such circumstances, it is desirable to understand which of the land resources available to the industry may be developed for canegrowing and which areas might go out of production. Linear programming analysis can be used effectively to predict likely outcomes under these circumstances.

Three basic scenarios have been examined:

1. where existing canegrowing land resources are reduced in line with land suitability, land availability and land ownership constraints;

2. where an area equivalent to the existing canegrowing area is maintained through substitution of new areas for those expected to be lost to urbanisation and conversion to other uses; and

3. where both the existing canegrowing area is maintained and the local industry shares in industry growth to a similar extent as other parts of the industry.

The effects of applying more stringent land use constraints in the Moreton Mill area were examined by progressively reducing the land suitability and land ownership constraints in the linear programming model and results are presented in Table 7. The results show the effects on assigned area, total cane production, and regional net revenue, of restricting land use, firstly by land suitability and secondly by land availability. In this set of results, no allowance was made for substitution of new land to compensate for the loss of land taken out of canegrowing as the land constraints became progressively more restrictive. The results can also be displayed by appropriate maps.

Table 7: Effect of increasing land use restrictions on area, production, and net revenue for the Moreton Mill area

	Unrestricted land use	Land suitability restrictions applied	Land ownership restrictions applied
Assigned area (ha)	6 957	6 501	6 331
Area of soil type Humic gley (ha) Humus podzol (ha) Yellow podzolic (ha) Red earth, etc (ha)	 4 519 889 1 120 429	 4 263 884 1 010 353	 4 198 854 937 342
Total cane production (t)	437 650	424 220	412 480
Total net revenue ($m)	7.86	7.62	7.38

It is unlikely that the process outlined in this table would proceed without land with the potential to grow cane being substituted for that taken out of production. These effects are described in Table 8 and again can be illustrated by accompanying maps.

Table 8: Effect of changes in land resources on production and revenue

	Existing land resources	Substitute potential land for unsuitable areas		Include 1990 increase in assignments		Medium-term future position	
Assigned area (ha)	6 957	6 957		7 515		8 415	
Area allocated by model (ha)	6 957	6 937		7 491		8 415	
Land resources used (by soil type)	Assigned area (ha)	Assig. (ha)	Potent. (ha)	Assig. (ha)	Potent. (ha)	Assig. (ha)	Potent. (ha)
Humic gley	4 519	3 763	748	4 036	909	4 197	1 129
Yellow podzolic	1 120	894	224	937	224	937	280
Humus podzol	889	734	152	788	178	850	222
Red earth, etc	429	339	86	336	86	341	107
Cane production (t)	437 720	471 418		504 219		538 604	
Total net revenue ($m)	7.85	8.38		8.88		9.40	

The data in this table indicates that if there was free movement of resources within the sugar industry as the model assumes, canegrowing might cease on some of the exising assigned land. Some land not currently growing cane would come into production to meet the economically optimal pattern of production. It is instructional to examine the location of areas that the model suggests should be brought into production.

In determining the optimum solution, the linear programming algorithm calculates "shadow prices" or marginal value products for limiting resources. These indicate the amount by which total net revenue for the region would increase if one more unit of a limiting resource was available. For each UMA entering the optimal solution, at the level of its maximum constraint, the marginal value product (MVP) shows how much the revenue of the region would be diminished by the loss of additional land for canegrowing. The MVPs provide a way of gauging the relative value of scarce resources. When sorted into order and mapped, the MVPs show broadly which parts of the canegrowing area should preferentially be retained for canegrowing on economic grounds.

Figure 4 shows the location of preferred canegrowing areas mapped according to the marginal value products generated by the linear programming analysis.

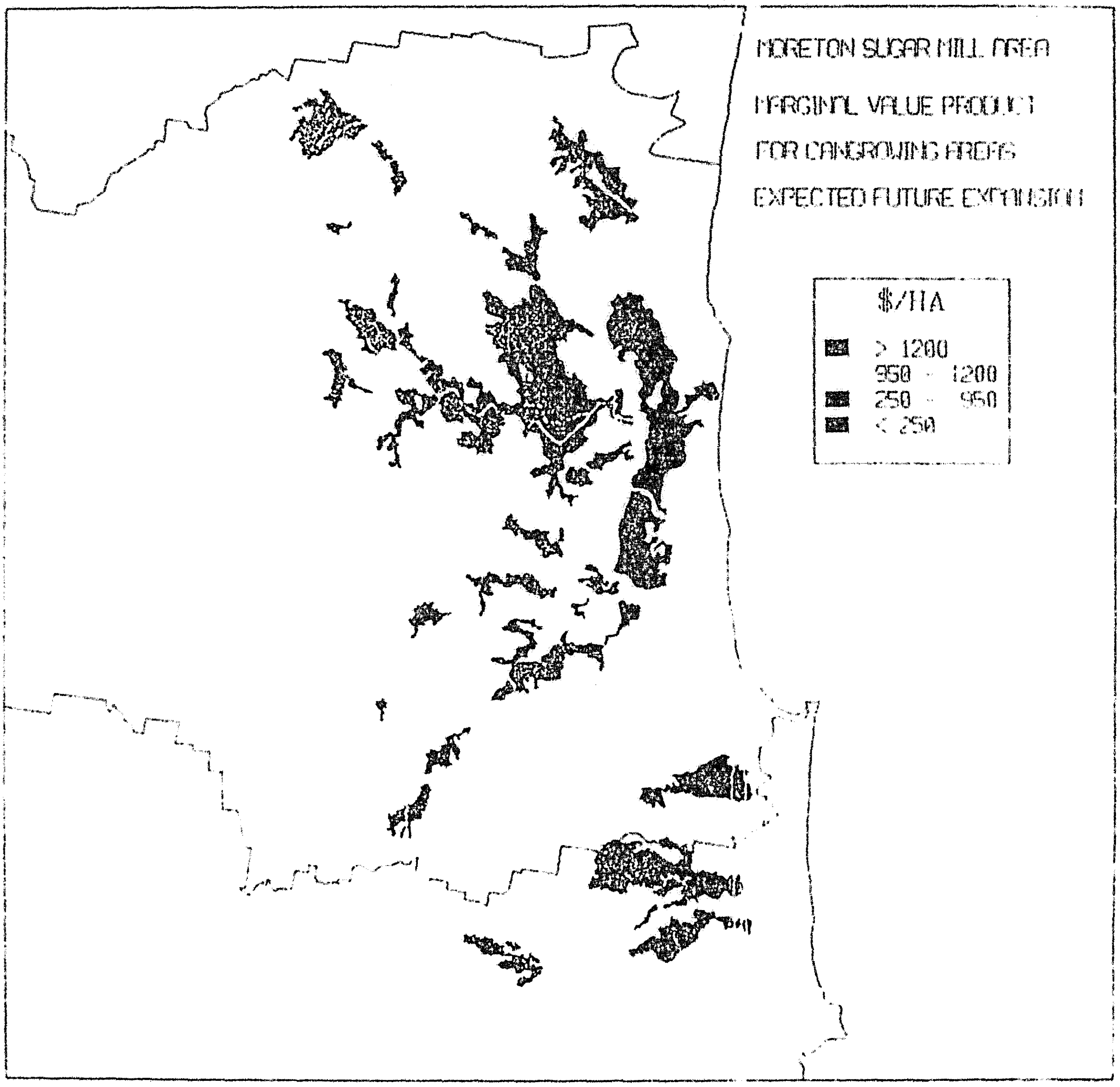

Figure 4: Preferred canegrowing areas in Moreton Mill area mapped according to marginal value product

Use of a GIS mapping package was the only feasible way to interpret the information generated by this analysis. The results roughly correspond to the expected pattern described by von Thünen and his successors. Basically, areas of higher marginal value product were consistent with areas of productive land close to the mill where transport costs are least and areas with lower MVPs were located on less productive soil at greater distances from the mill. The regular pattern of concentric rings suggested by location theory is upset in this case by the mix of soils that have been developed for canegrowing. The upland soils along the sides of the river valleys have lower production than the highly productive land on the valley floors and consequently their MVPs are reduced. In effect, we are not dealing with the uniform plain with an even distribution of resources as described in theory, but with a more realistic situation in which different land capabilities have been taken into account.

Once such a model has been set up, various alternative strategies can be evaluated. For example in the present study, the proportion of each soil type that was permitted to come into production as the area under cane expanded was made to correspond with the present distribution. It would be possible to show preferred canegrowing locations if the proportion of individual soil types changed.

Although not attempted at this stage, it would be desirable to examine the effects of changes in the price of sugar, or changes in other important cost parameters, on the optimum pattern of land use in the mill area.

Conclusion

One of the major problems confronting effective management of land resources is the lack of awareness within the community of the importance of the issue. Because Australia is usually seen as a country with abundant land resources and a small population, careful land management has been an issue of little concern. Australia's resources of highly productive rural land are more limited than those of most other countries and a more conservative policy in regard to these resources should be adopted.

It is hoped that the present study will contribute to a better understanding of the problems associated with the loss of agricultural land and of the economic consequences of following non-optimal land use practices.

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References

Beckmann, M.J., 1984. "Reflections on Palander's "Beiträge zur standortstheorie" pp 31-40 in Å.E. Anderson, W. Isard, and T. Puu (eds) *Regional and industrial development theories: Models and empirical evidence*, Elsevier Science Publishers B.V., North Holland.

Capelin, M.A., 1979. *Moreton Mill area: a sugar land suitability study.* Queensland Department of Primary Industries, Division of Land Utilisation Technical Bulletin, No. 37, Queensland Department of Primary Industries, Brisbane, 99p.

Capelin, M.A., 1987. "Assessment of the availability of suitable land for cane growing in the Moreton Mill area - south east Queensland", in *Moreton Mill long-term sugar viability planning study report.* Maroochy Shire Council, Nambour.

Capelin, M.A., and Wegener, M.K., 1990. "Future land use options for sugar-cane growing in southern Queensland". *Proceedings of International Symposium on GIS for property and environmental management: Current applications and future directions*, Brisbane, 16-20 September 1990. Queensland Government, Department of Lands, Brisbane, pp 2.2.2-2.2.15.

Chapman, L.S., Haysom, M.B.C., and Chardon, C.W., 1981. "Checking the fertility of Queensland sugar lands". *Proceedings Australian Society Sugar Cane Technologists Conference*, pp 325-332.

Coleman, G., and Edwards, L.D., 1991. "Management of arable land resources". *Proceedings Australian Society Sugar Cane Technologists Conference*, Bundaberg, 14-17 May 1991, pp 17-25.

Egbert, A.C. and Kim, A.S., 1975. "Analysis of aggregation errors in linear programming models", *American Journal of Agricultural Economics*, Vol. 57(2), pp 292-310.

Forster, B.A., 1989. "Availability of suitable land for sugar-cane growing - Rocky Point sugar mill area. Report for the Albert Shire Council, Nerang". Queensland Department of Primary Industries, Land Resources Branch, Brisbane.

Harris, B., 1984. "Spatial analysis: Some working principles" in Å.E. Anderson, W. Isard, and T. Puu (eds), *Regional and industrial development theories, models and empirical evidence*, Elsevier Science Publishers BV, North Holland.

Heady E.O. and Scrivastava, U.K. 1975, (eds), *Spatial sector programming models in agriculture*, Iowa University Press, Ames, Iowa.

Isard, W., 1956. *Location and space-economy: A general theory relating to industrial location, market areas, trade, and urban structure*, The M.I.T. Press, Cambridge.

Isard, W., 1960. *Methods of regional analysis: An introduction to regional science*, The M.I.T. Press, Cambridge.

Kingston, G., and Linedale, A.I., 1987. "Soil fertility and fertiliser application to ratoon cane in the Moreton Mill area". *Proceedings Australian Society Sugar Cane Technologists Conference*, Mackay, pp 59-64.

Longmire, J.L, Brideoake, B.R., Blanks, R.H. and Hall, N.H. 1979. *A regional programming model of the grazing industry*. BAE Occasional Paper No. 48, Australian Government Printing Service, Canberra.

McKenzie, S.A., 1990. "Geographic information systems for the sugar industry". *Proceedings Australian Society of Sugar Cane Technologists Conference*, Townsville, 1-4 May 1990, pp 9-12.

Nijkamp, P., 1984. "A multidimensional analysis of regional infrastructure and economic development", pp 267-293 in Å.E. Anderson, W. Isard, and T. Puu (eds) *Regional and industrial development theories: Models and empirical evidence*, Elsevier Science Publishers B.V., North Holland.

Queensland Department of Primary Industries, Land Resources Branch, (1990). "Assessment of the availability of suitable land for sugar-cane growing in the Maryborough Mill area. Report for the Maryborough District Local Authority Land Use Committee". Queensland Department of Primary Industries, Land Resources Branch, Brisbane.

Queensland Government, Department of Housing and Local Government and Department of Primary Industries, 1991. *Development and conservation of agricultural land*, Planning Bulletin No. 1/91, May 1991. Queensland Government, Department of Housing and Local Government and Department of Primary Industries, 5p.

Wills, I, 1992. "Do our prime lands need saving?" *Agricultural Science*, Vol. 5(4) New Series, pp.25-27.