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Resources Study and Problem Analysis for Primary Industries in the Condamine-Maranoa Basin of Southern Queensland

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SUMMARY

The Condamine-Maranoa basin of southern Queensland is an area of diverse soil and vegetation types. It is divided into 10 agro-ecological groups which combine soil and vegetation types on which similar production occurs. Plant and animal production systems are described for the major groups and these are examined to expose limitations to maintained or increased production. The limitations to production are used as a basis for recommendations of research needs.

Forty-three fields of useful investigation emerge. Priorities for research are for the *Eucalyptus* spp. woodlands which occur on red earth and solodic soils in the western part of the area.

The report also contains an inventory of physical resources and a review of published and locally practised technology.

RÉSUMÉ

This study aimed at determining the relevance and adequacy of existing rural technology and to recommend priorities for research.

The area. The 7·3 million hectare evaluation area in southern Queensland contains diverse land types and a climate range which permits cropping and a high level of animal production in the east but only extensive pastoral activities in the west. The area embraces the shires of Waggamba, Tara, Balonne and Warroo and parts of Inglewood and Millmerran. Its contribution to Queensland's rural product is high with one-quarter of the value of wool and one-fifth of the wheat production originating in the area. Approximately 3 000 000 sheep and 600 000 beef cattle were depastured in 1972-73.

Annual rainfall increases from 400 mm in the west to 600 mm in the east. Approximately one-third of this falls in the winter. By comparison with other geographically similar areas in Queensland, rainfall is reliable, having a variability of only 25 to 30%. Extremes of temperature are recorded. Frosts are more significant than heat waves as they place greater restrictions on crop and pasture production.

The soils of the area fall into three broad categories. Cracking clays, predominantly gilgaied brigalow lands but also with woodland and grasslands communities, are the most productive soils and occupy the central part of the region. Red earths supporting *Eucalyptus* woodland and poor quality native grasses occupy the more arid western areas. Distributed throughout are the solodic soils which range from solodized solonetz to hard-setting loamy solodics and weakly solonised brown clay loams.

Plant and animal production. Large increases in cultivated land have occurred during the last 20 years. Wheat is the main crop and is planted mainly on clay soils. Forage oats, the second-most important crop, increases in importance on the lighter-textured soils and in the lower rainfall areas. A peak of 400 000 ha was cropped in 1969-70, half of which was to wheat. Diversification into summer crops, particularly grain sorghum and sunflower, has occurred. Summer forage crops are grown for cattle grazing in autumn. Interest in fodder conservation was stimulated by the dry years of the late 1960s and a peak of silage making occurred in 1970-71.

Despite the availability of suitable pasture species, less than 2% of the area is occupied by sown pastures. The summer-growing native pastures on gilgaied clay soils provide good quality grazing but are less bulky than the introduced *Cenchrus ciliaris* (buffel grass) and *Panicum maximum* var. *trichoglume* (green panic). In the *Eucalyptus* woodlands on red earth and solodic soils,

native grasses are sparse and generally of poor quality. Although timber treatment promotes grass dry matter production, *C. ciliaris* can greatly improve the continuity of forage supply. In the higher rainfall areas *Medicago sativa* (Hunter River lucerne) can provide valuable grazing but its productive life is short. The naturalized annual *Medicago* species (medics) are widespread and under favourable conditions provide quality grazing.

Both sheep and cattle are found throughout the area, with densities decreasing towards the west. Although important during the development of the area, dairy cattle have now virtually disappeared. Pig breeding is confined mainly to the eastern areas.

Sheep numbers declined by approximately 50% during the 10 years prior to 1973, largely due to a progressive decline in wool prices. Since then they have been stable, contributing factors being a short period of high prices and the wool price stabilization scheme. Cattle numbers doubled during the period 1966 to 1973. This trend will be modified by price decline in the cattle industry during 1974. Merino sheep are run almost exclusively while Hereford cattle constitute approximately two-thirds of all beef animals. The proportion of pure and crossbred *Bos indicus* cattle is very low.

While cattle brandings average 80% with minor variation throughout the region, lamb-marking percentages range from 50 to 95%.

The reason for this variation has not been defined though nutrition is suspected as the major contributing factor. Wool is the major sheep product while fat lamb production fluctuates, but remains generally low. The sale of surplus young sheep is an important component of income in areas with high reproduction rates. Beef cattle production ranges from vealers in the more favoured eastern areas to fat steers or bullocks in the central areas, with store cattle in the more arid western regions. The fattening of cattle on forage oats is an important activity.

Economics. Key factors in the profitability of production in the major industries are the recession in wool price in the late 1960s and early 1970s, the abnormally high beef price in 1973 and the subsequent slump in 1974, and the absence of major market fluctuations in the wheat industry where a price stabilization scheme operates. Within this framework, the average debt per property in the Condamine-Maranoa basin is lower than that of comparable properties in other parts of Queensland. In the face of extensive timber treatment and agricultural development, this situation reflects the greater income earning capacity of the study area. Production is well diversified, with few properties concentrating on a single enterprise. Wheat, wool and beef are often produced on the one unit. Of these enterprises, wheat growing gives the highest returns while wool and beef give lower but similar returns.

Data collection and presentation. Resource data and technology both published and locally practised are reviewed. Discussion interviews were conducted between primary producers and the three members of the evaluation team. These sought to ascertain the type and extent of production, the management procedures employed and the production limitations recognized.

The area is divided into 10 soil-vegetation groups which are easily recognized units on which similar production systems occur. These groups are 1. gilgaied clay and clay loam—brigalow and brigalow-belah forest; 2. flooded clay—coolibah open woodland; 3. undulating clay—Mitchell grass grassland; 4. solodic—cypress pine-bull oak forest; 5. solodic—poplar box-(false) sandalwood woodland; 6. red earth—poplar box-mulga woodland; 7. red earth—mulga-*Eucalyptus* shrubland; 8. shallow loamy soil—bendee shrubland; 9. shallow loamy soil—ironbark woodland; and 10. alluvial soil—*Eucalyptus* woodland.

A description of production systems is presented for each of the major soil-vegetation groups. The range of products suited to the particular environment of each group is examined, and the commonly-encountered enterprise combinations are described. The limitations to production are used as a basis for recommendation of research needs.

Recommendations. Forty-three fields of useful investigation are presented. Within these research priorities are indicated.

Priority is given to the two communities broadly described as the 'red country'. These are Groups 5 and 6, *Eucalyptus* woodland communities which occur on solodic and red earth soils respectively. Land clearing is already in progress and research should aim to quantify soil and plant changes associated with this practice. The returns from this research will be from increased animal production on the more fertile areas and from protection of those woodland communities where disturbance can lead to deterioration of the ecosystem. *Cenchrus ciliaris* can make a significant contribution to animal production in some parts of these groups and investigations which highlight its role as a complement to native pasture are favoured. Introduction and/or breeding programmes with legumes are warranted as these could contribute to the sustained production as well as the grazing value of pastures in the 'red country'. Agronomic investigations aimed at determining the cropping potential of the higher rainfall-higher fertility sections are also indicated.

In the southern brigalow forests on gilgaied clays (Group 1), a large amount of component research has been carried out and this is likely to generate further work. The use of systems analysis techniques to integrate the dry matter available from various sources into the best compromise between stable and maximum production is suggested. Because of the diversification possible in these groups economic analysis involving optimizing techniques to determine optimum enterprise combinations would be valuable. These two projects would also apply to the groups covering the flooded clay—coolibah open woodlands (Group 2) and the undulating clay—Mitchell grass grasslands (Group 3). Invasion of the *Astrebla* spp. pastures of these two groups by weed species has lead to concern for the stability and future productivity of these valuable native pastures. Studies of the condition and trend in these pastures are recommended initially.

In the red earth—mulga-*Eucalyptus* shrublands, it is timely to integrate the information arising from current research and that from existing technology into production systems, and to test such systems in trials involving both plant and animal measurements. Indications are that programmes which consider the productivity, regrowth and management of cleared shrublands are warranted. In this work, utilization studies which identify the plant species making the major contribution to animal nutrition will give direction to other facets of the research programme.

Some studies apply to the area in general. Throughout the region, the low proportion of introduced pasture highlights the important contribution of native pasture to animal production. On clay and clay loam soils particularly, the growth rate, quality and utilization of important native species should be studied. Production measurements for sheep and cattle grazing deferred pasture and forage crops should be determined. General production data for sheep on the more important soil-vegetation groups are needed. An understanding of the reasons for different levels of reproduction and wool growth on closely associated soil-vegetation groups could lead to improved husbandry practices.

Two important fields of research involving cattle are dystocia and eye cancer. The losses in breeding herd efficiency and revenue and the direct costs associated with both should be determined as a priority.

To facilitate efficient development of research programmes, a research team involving specialists in the plant and animal sciences is recommended. The location of personnel and facilities in close proximity to the 'red country' and to the existing extension staff offers distinct advantages. Such a situation would be achieved by the development of a technical laboratory at Roma. Future problem definition and the communication of research results as they become available would be two advantages of this type of organization.

PART 1

INTRODUCTION

General

This resources evaluation study was carried out with the objective of determining the relevance and adequacy of existing rural technology and of recommending fields of research requiring investigation in order of priority. It was carried out by a group consisting of an agriculturalist, a husbandry officer and an economist. Such an interdisciplinary group afforded the opportunity of viewing problem definition from a wide perspective. It aimed at avoiding the bias described by Moule (1969) where most research workers visualize research through their own activity.

The study region is one of diverse soil types and productivity with a total area of 7.3 million hectares. It is contained in the local government areas of Inglewood, Millmerran, Waggamba, Goondiwindi, Tara, Balonne and Warroo (map 1). The eastern margin coincides with the geological boundary between the Blythesdale sediments of the Mesozoic era and the undifferentiated bedrock of the Palaeozoic era. This excludes approximately two-thirds of the shires of Inglewood and Millmerran. The local government area of Goondiwindi refers to the town area of that name and is only included in tables-figures-text where appropriate. Where the authority for data is the Australian Bureau of Statistics it applies to the total area of the shires and where appropriate to the Goondiwindi town area. The description of physical features and the interviewing of primary producers however are limited to the reduced area. Throughout the report, this area will be referred to as the Condamine-Maranoa basin or the study area.

Referred to generally as the higher rainfall sheep zone of Queensland, the favourable environment in the east allows a high productivity per unit area involving cash cropping and intensive animal production. Lower rainfall leads to purely pastoral activities in the west.

In industry surveys the shires of Inglewood, Millmerran and Tara are classified as 'Wheat-Sheep' zone while Waggamba, Balonne and Warroo are 'Pastoral' zone (Bureau of Agricultural Economics 1973*b*). A large part of Waggamba shire is obviously 'Wheat-Sheep'. However, the divisions are established by reference to statistics of cropping activity, using the smallest statistical area available (Bureau of Agricultural Economics 1962).

This report is structured to contain four parts: 1. an introduction; 2. a description of production systems, production limitations and consequent recommendations; 3. a description of resources; and 4. a review of primary industries. Where possible, resource information has been prepared in map form.

Method

All published literature with some relevance to the Condamine-Maranoa basin was assembled and has been reviewed. The division of the area into soil-vegetation groups was carried out to establish easily recognised field units and to facilitate data collection and presentation. The basic units for these groups are the soil associations defined in the Atlas of Australian Soils (Northcote 1966; Isbell *et al.* 1967). This series contains the only complete coverage of soils for the Condamine-Maranoa basin.

A formal survey of primary producers was not attempted. Discussion-interviews were conducted between primary producers and the three members of the evaluation team. These were followed by a property inspection to confirm the soil-vegetation groups present and to gauge the stage of development and effectiveness of management. Interviews were carried out in a manner which avoided the soliciting of answers and opinions on a wide range of subjects. The primary producer was, however, encouraged to expound on those aspects of his production or industry which he considered important. He was asked to describe the type and extent of his production, the management procedures employed and the limitations to maintained or increased production which he recognized. There appeared to be no alternative to this subjective approach. The use of formal survey techniques would have presupposed a knowledge of the nature of the problem and in its operation would have introduced bias. Interviews were also conducted with non-landholders with the aim of describing existing technology and recognized limitations to production.

Interviews were recorded by each member of the evaluation team. These records were examined for information on property characteristics, land development and maintenance practices, product types, level of production, enterprise combinations, production advantages and deficiencies and management practices. A summary of features common to producer interviews is shown (Appendix 1).

The number of holdings eligible for inclusion in a sample was 1724. Excluded were those properties in the eastern part of Inglewood and Millmerran shires (406 holdings) and properties of less than 200 hectares in the remaining area (43 holdings). In the course of field work, 93 properties belonging to 83 landholders were visited. This represents 5·39% of eligible holdings and 6·86% of the area. In addition, 20 properties in adjoining areas were visited.

The number of research, extension and service personnel associated with the study area who were interviewed totalled 150. These included people from within and from adjacent areas, from Brisbane and from interstate.

It will be appreciated that the data obtained are not the result of rigorous sampling and analysis techniques, and figures related to interview data should be regarded as indications only. Information obtained in interviews has been used to prepare diagrams of the plant and animal production practised on the major soil-vegetation types. Within the range of production alternatives, the typical production units have been defined.

Soil-vegetation groups

To provide convenient working units, the Condamine-Maranoa basin is divided into 10 agro-ecological groups. Using the Atlas of Australian Soils (Northcote 1966; Isbell *et al.* 1967) as a basis for division, these groups combine soil and vegetation types on which similar production occurs.

GROUP 1. GILGAIED CLAY AND CLAY LOAM—BRIGALOW AND BRIGALOW-BELAH FOREST. This group is located in a broken band across the shires of Tara and Waggamba with scattered outliers in the red earth soils to the west and the solodic soils to the east. Soil associations are described (Northcote 1966; Isbell *et al.* 1967) as CC20 (grey, cracking clays with brigalow and brigalow-belah vegetation); Ro3 and Ro4 (hard-setting loamy soils with brown clayey subsoil growing brigalow-belah and belah vegetation); and MM1 (brown, cracking clays with brigalow-belah vegetation). Also included are Mq1 and Mq2 (alkaline grey earth with a gidyea community) which are minor soil associations classified by Galloway *et al.* (1974) with the CC20 soil association. The group occupies a total area of nearly 2 000 000 ha.

GROUP 2. FLOODED CLAY—COOLIBAH OPEN WOODLAND. The major areas occur along the Macintyre-Barwon, Moonie and Condamine-Balonne-Culgoa River systems. Soil associations are described (Northcote 1966; Isbell *et al.* 1967) as CC17 (cracking clay plains, portions of which may be flooded seasonally); and CC19 (cracking clay plains of similar description). A coolibah-Mitchell grass community predominates. A minor soil association, Rt1, consists of gently undulating alluvial plains fringing major drainage lines which are subject to flooding. Although duplex in nature, the agricultural characteristics of the surface soils and the vegetation type are similar to those of the clay-coolibah group. Collectively the group occupies nearly 1 000 000 ha.

GROUP 3. UNDULATING CLAY—MITCHELL GRASS GRASSLAND. Although only small areas occur in the Condamine-Maranoa basin, a large area is located close to the north of the region between Roma and Mitchell. Two soil associations (Northcote 1966; Isbell *et al.* 1967) are included. They are MM4 (brown clays with slight gilgai micro-relief); and MM2 (cracking red brown clays). The vegetation is grassland with occasional scattered trees. The area occupied by the group is approximately 150 000 ha.

GROUP 4. SOLODIC—CYPRESS PINE-BULL OAK FOREST. Commonly referred to as the Kogan type solodics, the major area occupies the eastern part of the study area. The soil associations included are described (Northcote 1966; Isbell *et al.* 1967) as Va24 and Va28 (shallow clay loam solodics) and Wa13 and Wa15 (sandy soils). Communities of bull oak are dominant on the former and cypress pine on the latter. Minor soils are Si2 and S12 (hard, alkaline, yellow soils). All of the soils are hard-setting, the major group with mottled yellow clayey subsoils and the minor soils with yellow clayey subsoils. The total area of this group is 670 000 ha.

GROUP 5. SOLODIC—POPLAR BOX-SANDALWOOD WOODLAND. The major occurrence is to the west of the brigalow lands and is characterized by a tree layer of poplar box with a shrub layer of variable but often dense (false) sandalwood. Soils belonging to four soil associations are described (Northcote 1966; Isbell *et al.* 1967) as Oc21 and Oc22 (hard-setting, loamy soils with red, clayey subsoils), and HG1 and HG2 (hard-setting, loamy soils with dark clayey subsoils). The total area is approximately 1 000 000 ha.

GROUP 6. RED EARTH—POPLAR BOX-MULGA WOODLAND. This extensive woodland group occupies most of the western part of the Condamine-Maranoa basin. The major soil associations are described (Northcote 1966; Isbell *et al.* 1967) as My5 (sandy red earths, low dune ridges); My3 (red earths, gently undulating plains); and My2 (red and yellow earths). Associated with poplar box and mulga are silver-leaved ironbark, apple and cypress pine. Minor soil associations are deep sands (AB2, B10 and B12) and the duplex friable loamy Rz1 soils. This is the largest group and covers an area of just over 2 000 000 ha.

GROUP 7. RED EARTH—MULGA-EUCALYPTUS SHRUBLAND. Although minor in extent in the study region, this group is representative of extensive areas of mulga shrublands between the western edge of the Condamine-Maranoa basin and the Warrego River. Only two soil associations are present and these are described (Northcote 1966; Isbell *et al.* 1967) as My1 and My4 (red earths with neutral reaction trends). The approximate area is 130 000 ha.

GROUP 8. SHALLOW LOAMY SOIL—BENDEE SHRUBLAND. A group of minor importance occurring as dissected tableland remnants is located north-east of St. George. The soils are Fz1 association, described (Northcote 1966; Isbell *et al.* 1967) as loamy soils of minimal development. Dense bendee shrublands contain emerging eucalypts. The area involved is 90 000 ha.

GROUP 9. SHALLOW LOAMY SOIL—IRONBARK WOODLAND. These soils occur as low hills and dissected low ranges throughout the central and eastern parts of the Condamine-Maranoa basin. The woodland vegetation contains both narrow-leaved and silver-leaved ironbark. The soil associations are described (Northcote 1966; Isbell *et al.* 1967) as Fz2, Fz3, and Fz7 (loamy soils of minimal development). Some 200 000 ha are contained in scattered occurrences.

GROUP 10. ALLUVIAL SOIL—EUCALYPTUS WOODLAND. This very small group contains the river terraces and levees of the Macintyre River, Macintyre Brook and Dumaresq River east of Goondiwindi, and part of the Weir River. The alluvial soils are described (Northcote 1966) as loams belonging to the LM1 soil association. A range of eucalyptus species occurs. The total area involved is only 50 000 ha.

PART 2

PRODUCTION ANALYSIS AND RECOMMENDATIONS

Production systems and limitations

This section discusses the production alternatives which are technically feasible within the soil-vegetation groups, the production systems commonly encountered, and the limitations to production presently recognized. This information originates from field interviews carried out during 1972 and 1973.

Group 1. Gilgaied clay and clay loam—brigalow and brigalow-belah forest. The CC20 soils are deep, of fine texture and good water-holding capacity, with a moderate phosphate and high nitrogen content. Despite their gilgaied microrelief, extensive areas have been developed for agriculture. The Ro3 and Ro4 associations are of similar fertility, more loamy in texture, readily cultivated for winter cereals but somewhat erodible during bare cultivation. Weak solonization has taken place and only slight gilgai development occurs. The MM1 soils are similar to the CC20 type but with only moderate gilgai and a more undulating surface. *Acacia harpophylla* (brigalow) occurs throughout with varying proportions of *Casuarina cristata* (belah), *Eucalyptus* spp. and shrubs as associated species. Almost pure stands of *C. cristata* are found on some of the weakly solonized soils. Sparse native pastures increase in density to support a dry sheep to 0·6 ha when the forest layer is modified.

PRODUCTION ALTERNATIVES. The production alternatives following clearing are numerous (figure 1) as climatic conditions, topography and soils are favourable for a wide range of both agricultural and pastoral activities. Many cropping practices are still innovative in the western parts compared with their equivalents in the east. Sheep breeding for wool and mutton, and cattle breeding and fattening are the major pastoral enterprises. Wheat, sorghum, barley, oats, and sunflower grains and oats, sorghum and millet forages are grown under dryland conditions. Crops which are restricted to the more favoured areas are cowpea, canary seed, linseed and safflower.

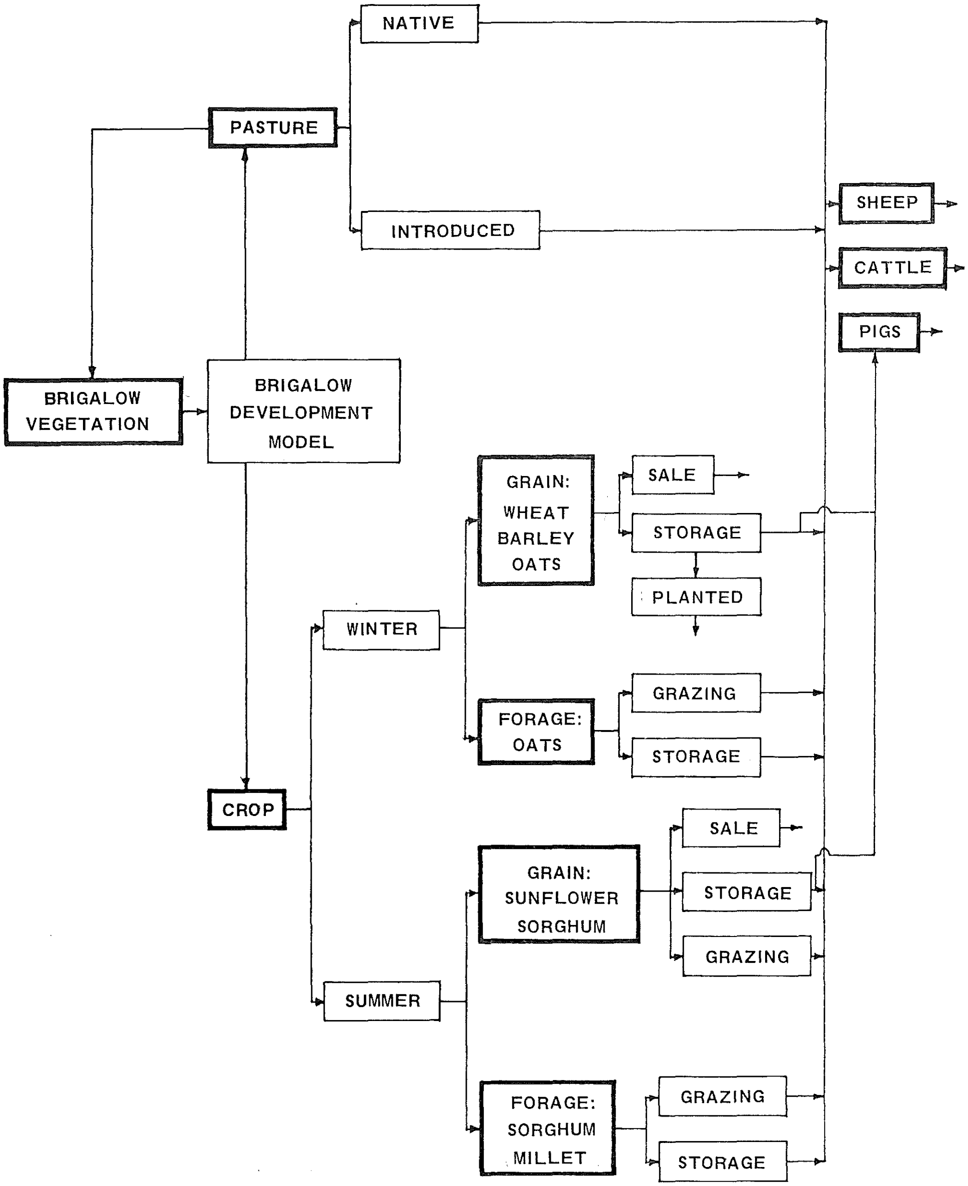


Figure 1.—Plant production alternatives for the brigalow-belah forest.

Sheep enterprises include breeding for the sale of sheep and wool and to a minor extent prime lamb production. These compete with cattle breeding and fattening for marketing at a range of ages and degrees of finish (figure 2). Yearling or vealer type cattle are produced from dairy and dairy-cross breeders in the east while the production of fat steers or bullocks throughout the remaining brigalow areas is determined largely by market requirements and personal preferences.

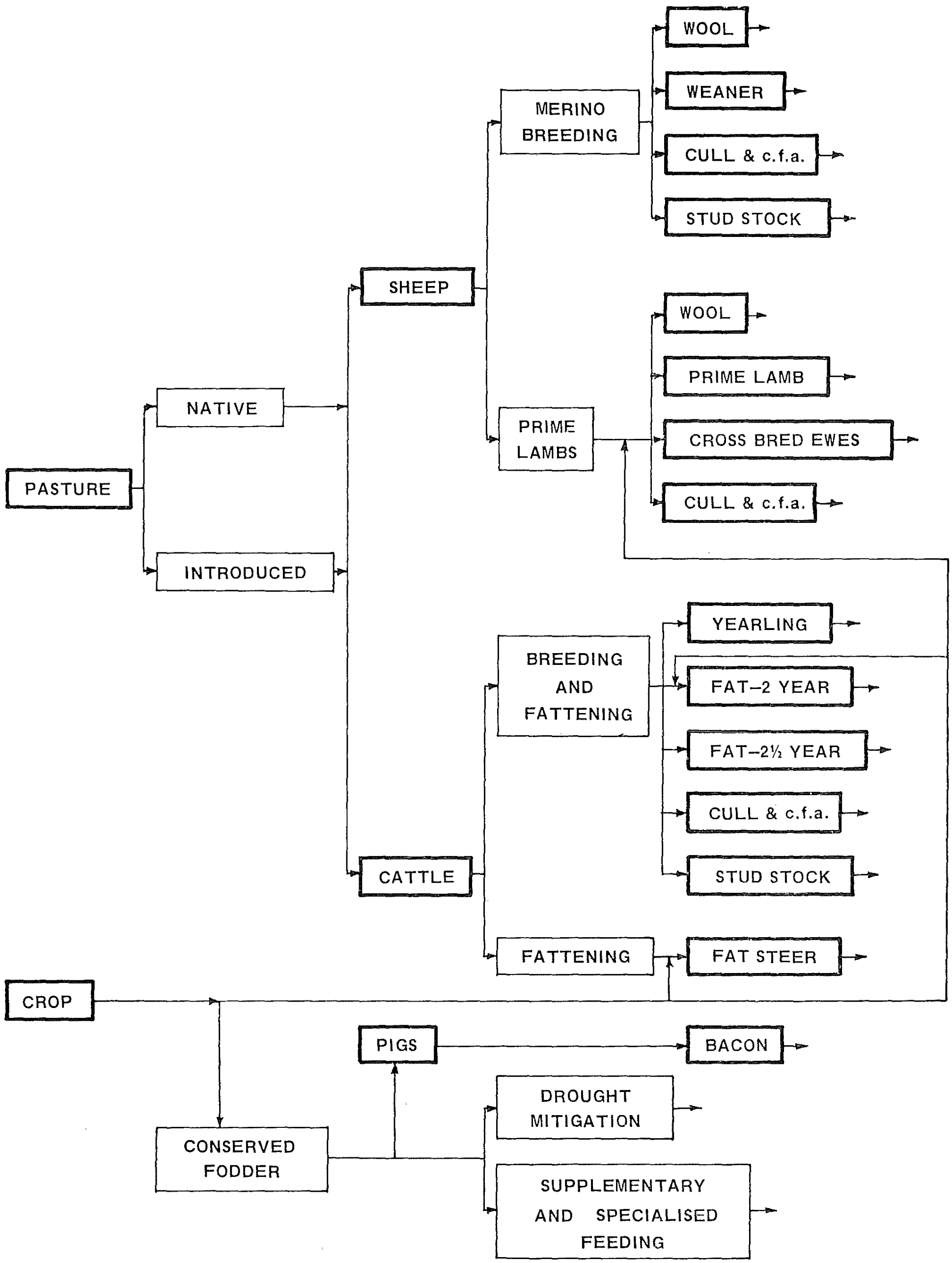


Figure 2.—Animal production alternatives for the brigalow-belah forest.

COMMON PRODUCTION SYSTEMS. In Tara and Waggamba shires, where Group 1 predominates, two common types of production units are encountered.

An example of a typical property of the first type had a total area of 2 800 ha containing 300 ha of cultivation on which were grown 220 ha of wheat, 60 ha of grain sorghum and 20 ha of forage sorghum, the forage sorghum normally used as standover fodder for cattle. Cattle totalled 354 head, including 150 breeders. Fat bullocks were marketed at 30 months of age off native pasture. An alternative to this type of production was marketing 24 month-old fat steers off forage oats. Some 70 ha of forage oats were planted. Sheep numbers had been reduced and only a nucleus sheep flock of 800 ewes and 600 wethers were retained. An example of a typical property of the second type had 4 000 ha available and specialized in cultivation and cattle raising. Wheat was planted on 700 ha out of a total cultivated area of 1 000 ha. The remaining cultivation was planted to forage oats (120 ha), grain sorghum (120 ha) and sunflower (60 ha). No sheep were run and cattle were produced as fat steers off forage oats at 24 months of age. Of the total herd of 543 cattle, approximately half were breeding cows.

Local soil differences can cause variation in production patterns. Where the soil surface is heavily gilgaied, grain growing is initially avoided and forage crops are used. Where high salt levels occur, land may be returned to pasture. The hard-setting, loamy soils (Ro4 and Ro3) are suited to broad-acre farming but erosion risks are greater. Pasture strips and contour cultivation are common protection methods.

LIMITATIONS TO PRODUCTION AND AVENUES OF INVESTIGATION. Of the 10 soil-vegetation groups described, technology is best developed for the cracking clay type, and research and extension facilities are well established.

CROPPING. The major limit to productivity is moisture and both the accumulation and management of soil moisture are important. With wheat growing, early ploughing will conserve any moisture remaining from the previous crop, will facilitate the accumulation of moisture from early storms and will incorporate stubble to take maximum advantage of the time available for straw breakdown.

Two important aspects of soil moisture storage on cultivated lands are relevant here. These are, firstly, the gain and loss of moisture in the cultivation zone and, secondly, the accumulation of moisture in the storage zone. From discussions with wheat farmers, it is apparent that the characteristics (structure and depth) of the cultivation zone depend on such factors as type of cultivation machinery used and the time of cultivation in relation to falls of rain. The amount of rainfall required to wet this zone will vary with the same factors. In turn, this will influence planting opportunities, particularly for winter cereals.

A model designed to imitate soil water accumulation, storage and use for a wide range of soil and environmental conditions has been developed (Berndt 1972-73). However, if such a model is used to estimate agricultural potential (Berndt 1973-74) and the cultivation zone moisture relations are based on inefficient cultivation practices, then these estimates will be sub-optimal. Experiments investigating alternative management strategies for the cultivation zone are not reported. These strategies are important, particularly with cereal cropping expanding into the lower rainfall regions.

The pattern of moisture use in wheat crops will be influenced by time of planting, climatic conditions and nutrient levels. Early planting will expose the flowering plant to a higher risk of frost injury and this must be balanced against the probability of yield increases from an extended growing season. The imitation of wheat crop growth using long term climatic data is indicated and simulation techniques are being applied to this problem. To improve existing crop system models, however, requires the serial monitoring of a range of soil, crop and atmospheric parameters over a range of contrasting treatments (Nix 1969-70). The site range should include representatives from Groups 1, 2 and 3 in the Condamine-Maranoa basin.

Summer cash crops are grown because of the opportunity to spread machinery and labour use and for diversification. The practice of early spring planting of grain sorghum causes many crop failures as the probability of receiving moisture decreases until midsummer. Late planting (midsummer) exposes the plant to a period of increasing soil moisture (figure 12), but the probability of increased midge activity will offset some of the gains.

The demand for summer forage and standover crop for autumn and early winter grazing has increased with greater cattle numbers. The important crops are sweet sorghum, hybrid forage sorghum and millet. The testing of additional crops, particularly of the pulse type, and investigations into systems of utilization for the whole range of summer forage crops is indicated.

With the expansion of cropping areas, it is to be expected that there will be interest in a wide range of crops. Investigations aimed at describing the growth requirements for some of these are warranted. The diversification afforded by sunflowers and barley could be valuable.

Work is in progress to measure trends in soil fertility in northern brigalow lands (Coaldrake *et al.* 1968-69; T. W. Graham personal communication). An indication of declining soil nitrogen is the disappearance of *Chloris gayana* (Rhodes grass) on many areas of the southern brigalow (Isbell 1962). While absolute measurements of nitrogen decline are few, reports of responses in crop yield and grain protein following legume-crop rotations on the Darling Downs are available (Littler 1964; Harty *et al.* 1966). Such evidence provides justification for programmes which measure soil nutrients over long periods. In anticipation of a need for nitrogen additions, investigation of the nitrogen contribution of the available legumes to crop and pasture lands is also warranted.

The history and principles of distribution of soils in the southern brigalow lands with emphasis on variation in soil fertility elements are being investigated (van Dijk 1969). The detection of repeated patterns in gilgai formation will allow more accurate description of sites for both research and land capability assessments. This work may define areas where nutrient deficiencies (phosphorus) and excesses (sodium) could influence land use. The nutrient screening work of Wall *et al.* (1971-72) will provide information on response to mineral applications on wheat-growing soils both with unlimited moisture and in a field situation with variable moisture.

The gilgaied surface of the southern *A. harpophylla* areas leads to differences in moisture content which result in planting difficulties and uneven growth. Although a slow levelling occurs with cultivation, land levelling is also practised. Responses have been observed to nutrients on areas where soil is removed during levelling and more acid, more saline soil with lower organic matter and available phosphorus are exposed (Russell 1972-73*a*).

NATIVE AND INTRODUCED PASTURES. While there is ample botanical description of the species present in modified *A. harpophylla* communities, little data are available on production and utilization of the native pasture. Grazing trials report high levels of animal production during some periods but the species contributing to this performance are not defined. Their contribution to the total dry matter of the pasture, their quality, and the influence of sheep and cattle grazing on their dynamics is likewise undescribed. In any systems analysis study of the southern brigalow lands, this type of information will be required. Land use figures reveal that native or modified native pastures cover 82% of the area of Waggamba and Tara shires.

A case for the large-scale development of introduced pastures in the brigalow region has yet to be accepted by primary producers. Skerman (1953), when reviewing progress in the *A. harpophylla* country, stated: 'the next step in the development of the brigalow areas in the sheep country must surely be the cultivation of improved pastures or crops.' Although crops have increased in importance, the area of introduced pasture is still negligible despite encouragement from both extension and research workers.

Several factors will influence the use of introduced pasture species in the future. When large areas of *A. harpophylla* forest were available, the returns from forest development were more attractive than those from the intensive development of small areas of introduced pasture. However, little forest now remains other than on shade and shelter areas and on land which is difficult to develop. Introduced pastures are now an attractive means of increasing dry matter production per unit area. As a follow-up to the rapid increase in cultivation area, land found to be unsuitable for cropping will be returned to pasture and much of this could be planted to introduced species. Trends in cattle numbers will also influence pasture plantings, increases in pasture areas in 1972 being related to cattle increases.

Establishment difficulty is a major problem with pasture grasses. Given adequate rainfall the clay loams (Ro4 soils) provide suitable conditions for pasture establishment. However, establishment on the cracking clay soils is unpredictable: both successes and failures result from planting at most times of the year. Such factors as climatic conditions, amount of seed applied, time of planting, seedbed preparation and method of seed distribution can influence the success of a planting. Introduced pasture must compete for area with cash crops, forage crops and native pastures, so that an extended establishment phase is a serious handicap. Increased rate of seed germination, reduced rate of soil drying, accurate control of sowing depth, selection of suitable species and reduction in crumb and crust size of the natural mulch could influence establishment on cracking clay soils (Leslie 1965*b*). On gilgaied surfaces, ponding of the lower parts of the microrelief influences species establishment and persistence. Communities of different composition may develop in different parts of the gilgai. At Meandarra, *Digitaria decumbens* (pangola grass) and *Panicum coloratum* yielded well on the lower parts of the gilgai in comparison with *Cenchrus ciliaris* (buffel grass) and *Chloris gayana* which preferred the tops (Russell 1972-73*b*).

Medicago sativa (Hunter River lucerne) and the naturalized annual *Medicago* spp. can provide fodder for sheep, but lucerne is short lived and the annual medics have been unpredictable in their productivity. Current work on *M. sativa* (Leach 1972-73) and on the annual *Medicago* spp. (Clarkson 1974) could increase the usefulness of these plants. Investigation of establishment and re-establishment, productivity and management of annual *Medicago* spp. in the field, is indicated. Measurement of their nitrogen contribution to native and introduced pastures and crop lands will indicate the role of these species in soil fertility maintenance under these types of land use.

A number of introduced grass species is well adapted to the area. While many of these are more suitable for cattle grazing, cultivars are available which are well used by sheep.

Rates of animal production have been determined for the major pasture species at 'Tarewinnabar' (Coaldrake *et al.* 1969) and Meandarra (Tothill 1972-73) within the study region and at Narayen (Silvey and Russell 1972-73), Norwin (Lloyd 1971-72) and Eastwood (Orr, Payne and Roberts 1972; 1973) outside the area. However, many alternative systems of management have not been considered. Two phases in the increased use of introduced pastures will occur.

Firstly, when relatively small areas are available, introduced pastures will be managed as deferred grazing for specific classes of stock such as bulls, weaners and calving cows. This will result in heavy grazing for short periods when native pastures are poor. In the second phase, a significant proportion of the pastures of a holding will be of the introduced type. These pastures will be used over longer periods and integrated into feeding systems with native pastures and the products and residues of cropping.

The first stage requires the ability to predict animal performance from reserved pasture at different times of the year and the effect of intermittent heavy use on pasture production. The second stage requires consideration of more complex grazing systems. These should be designed to involve maximum grazing pressure at those times when feed is not available from other sources on the property.

SHEEP AND CATTLE PRODUCTION. The large differences in performance of 0·41 to 1·54 kg liveweight gain per day reported for cattle fattening on oats (Howard 1961, 1968; Marlow, Arbuckle and Alexander 1962; Stubbs, Arbuckle and Alexander 1964; Coaldrake and Smith 1967; Strachan 1968; Strachan and Boorman 1970) are not well explained. The differences are sufficient to have a major effect on the economic outcome of the practice and should be investigated. Factors that could influence the rate of weight gain are: intake, pre-treatment of cattle, management (including stocking rate, control of lice, supply of supplements and the effects of including alternative grazing with forage oats) and climatic conditions during grazing.

Measurement of the level of sheep production when depastured on forage crop and crop residue, is indicated. Few local measurements are available on the effect of improved nutrition on wool growth, growth rate and reproductive performance. Grazing systems most likely to optimize crop and animal production can only be surmised.

Infertility diseases in cattle occur throughout the study area and the build-up in numbers involving purchase and movement of cattle has aggravated this situation. Of greater importance is the increase in calving disorders (dystocia) in young breeders. Although found in all breeds, this condition appears to be most prevalent in Herefords and these predominate in the Condamine-Maranoa basin. Eye cancer, a problem which causes wastage in breeding herds, is also largely confined to the Hereford breed. Selection for desirable eye characteristics has been recommended to counteract this condition, but losses persist. Although cross-breeding is a means of reducing both eye cancer and dystocia many producers maintain that they avoid this practice because of a buyer preference for Hereford cattle. A measure of the losses associated with eye cancer and of the costs to the beef enterprise of both dystocia and eye cancer should be obtained.

GENERAL. Because of the range of production alternatives on Groups 1, 2 and 3, economic analysis to determine the optimum combination of enterprises for maximum profit is indicated. An optimizing technique such as linear programming is suitable. With the relationship between market values and the cost of production changing constantly, the application of such a technique should be repeated whenever necessary.

A more complex problem is the integration of the dry matter available from various sources into the best compromise between stability of production and maximum plant and animal product. A land use trial which aims at providing information on some characteristics of production when crop, pasture and cattle grazing systems are combined is already in progress on the sedentary brigalow lands (Silvey and Russell 1972-73).

On the gilgaied lands of the southern brigalow, dry matter is potentially available from eight sources: storage of crop and crop residues (both on and off-farm); agistment; native vegetation; introduced grasses and legumes; winter forage crops; summer forage crops; winter grain crops; and summer grain crops. Depending on the primary producer's assessment of risk, different emphasis is placed on different types of dry matter. The farm unit can then be either production-oriented or drought-oriented. A more objective approach is to determine the effect of year by year rainfall on a model designed to mimic plant and animal production and involving these dry matter sources. Experimentation with such a model will show the influence of dry matter source on variation in total production. While a volume of data from component research is available, such a systems analysis approach will highlight areas of data relevance and deficiency. It thus provides a framework for research planning.

Group 2. Flooded clay—coolibah open woodland. The soils included in this group are either subject to varying degrees of flooding or were formed under the influence of flooding. Pastorally, they are an important group as the natural vegetation supports a high level of animal production. Two distinct areas occur. The first is along the Macintyre-Barwon River from Goondiwindi to Mungindi and northwards to the lower reaches of the Weir River. This is linked by similarity of production with the flood plains of the Condamine River between Condamine and Surat. The second area is associated with the Balonne-Culgoa and lower Moonie Rivers and extends from Surat to the Queensland-New South Wales border, developing a fan-shaped area southward from St. George. The soils are cracking clays (CC17 predominantly) and the vegetation is a fringing community to the watercourses.

PRODUCTION ALTERNATIVES. The production alternatives for the Macintyre-Barwon-Weir-Condamine Rivers system are similar to those of the brigalow lands (figures 1 and 2). However, less emphasis is placed on cultivation because of the flood risk involved. On elevated clay soils and on areas infrequently inundated, winter grain and forage crops are grown. Both sheep and cattle breeding enterprises exist, though wool has been the major source of income until recent years. Management must allow for stock movement in times of flooding. Forecasting of river rises is important.

On seasonally flooded country, the response to winter moisture is poor. *Cyperus bifax* (downs nut-grass) is an important and valuable summer pasture species which grows in response to flooding. Although its value is low after winter frost, it responds quickly to moisture when temperature conditions are suitable. On the higher plains carrying *Astrebla* spp. (Mitchell grasses), the annual *Medicago* spp. (burr medic and small woolly burr medic), *Erodium cygnorum* (crowfoot) and *Plantago* varia (lamb's tongue) provide valuable fodder when seasonal conditions in winter are favourable.

In the second area of flooded country below St. George, moisture is a major limitation to cropping and only small amounts of forage crop are grown. The production alternatives are a restricted version of those shown for the brigalow lands. The area is, however, specialized in sheep breeding and is regarded as some of the best natural sheep breeding country in Queensland. Lambings average 95% and properties obtain a significant proportion of their income from selling weaner sheep. Small herds of cattle are run for breeding and fattening.

COMMON PRODUCTION SYSTEMS. With the similarity of the Macintyre-Barwon-Weir-Condamine Rivers area to the brigalow lands, no separate production systems are defined. On the Balonne-Culgoa-Moonie Rivers area, the typical property was one of 4 000 ha carrying 1 500 breeding ewes, a negligible number of wethers and a herd of 236 head of cattle containing 100 breeders. Some 80 ha of cultivation were planted to forage crops. Fat steers and bullocks were normally marketed but, in favourable seasons, yearling cattle could be produced.

LIMITATIONS TO PRODUCTION AND AVENUES OF INVESTIGATION. The natural productivity of these areas is high, and sheep are stocked at one dry sheep to 0·8 ha, and heavier in the east. There is only a limited opportunity for increased dry matter productivity. Some thinning of the open woodland could increase grass but, at the same time, it may cause instability of river, creek and channel banks during floods. *Eucalyptus microtheca* (coolibah) and *E.camaldulensis* (river red gum) can germinate in dense stands following flooding and these are thinned.

Introduced pasture species have little to offer where native pastures are sound. Where areas are subject to variable periods of inundation, *Panicum coloratum* is a suitable introduced species. On the higher areas largely free of flooding, *Astrebla* spp. and *Dichanthium sericeum* (Queensland blue grass) can deteriorate when low lying country is flooded for prolonged periods and stock concentrated on these species. The management practices which will favour the survival and productivity of these pastures should be ascertained. Investigation relevant to the principal species and the plant communities of this group are discussed with Group 3.

A problem specific to sheep is high parasite populations, both internal (barber's pole worm, tape worm, hair worm and nodule worm) and external (blow-fly). This is not peculiar to the flooded country, but conditions in this area are particularly favourable for the multiplication of these pests. The high reproductive rate of sheep in the Balonne-Culgoa-Moonie Rivers area might well be investigated, as adjoining areas of similar climate characteristics give much poorer results.

The topography of the flooded country provides suitable conditions for the development of high populations of feral pigs. The damage caused by these animals can reach major proportions in grain crops, while, in periods of poor nutrition, weak sheep may also be harmed. Control measures, such as shooting, poisoning and trapping, are employed to reduce numbers. It appears that, in the presence of grain crops, control is most difficult as the animal is slow to accept the traditional poisons. New poisoning techniques involving sodium fluoroacetate (1080) appear more effective.

As an aid to property management, information on the frequency and extent of floods is required. The Irrigation and Water Supply Commission and the Australian Bureau of Meteorology have gauging stations which provide records of flood frequency and water discharge on the major rivers in the Condamine-Maranoa basin. However, only in certain locations have river height data been related to areas of inundation. For example, the 1971 flood on the Macintyre River was mapped for an area from Goondiwindi township eastward to a point at longitude 50°30′. Aerial photographs are also available for flood events in 1956 and 1966 for this area. Property owners are able to relate river height reports and forecasts to the amount of flooding which might occur locally but this experience may be lost and river height information should be related to contour data. Remote sensing apparatus contained in the Earth Resources Technology Satellite I (ERTS I) was employed in mapping the 1973 Mississippi River floods (Currey 1973). The resulting photomaps are used to prepare flood maps with an accuracy suitable for regional planning purposes and for assessment of the environmental impact of flooding. A similar approach could be employed in southern Queensland.

Group 3. Undulating clay—Mitchell grass grassland. Examples of this group occur in two distinct areas. The first (MM4) is located to the south and east of Surat, while the second (MM2) is south of Glenmorgan. The vegetation is tussock grassland (*Astrebla spp.*) with scattered trees (*Eucalyptus spp.*). The expressions of undulating grassland or rolling downs arise from the type of topography present.

PRODUCTION ALTERNATIVES. These are similar to those described for the brigalow lands of Group 1 (figures 1 and 2). Traditionally, the undulating grasslands are highly valued as pastoral lands. Sheep breeding for wool production had been the major source of income before the introduction of agriculture. Wheat and forage oats are the major crops while smaller areas of summer forage crops, sunflower and grain sorghum are also grown. The self-mulching clay soils are easily cultivated but are prone to erosion because of their undulating topography. Cattle breeding and fattening have gained in importance with both the availability of forage crop and market pressures. Cattle are fattened on both native pasture and forage oats.

COMMON PRODUCTION SYSTEMS. No specific production systems have been defined for the area. Those of Group 1 serve to describe the common land use. If a difference were to be defined, it would be related to the size of property, as aggregation of holdings has occurred.

LIMITATIONS TO PRODUCTION AND AVENUES OF INVESTIGATION. The type of native pasture and the topography lead to different problems from those of the brigalow lands. A satisfactory native pasture already exists and the major limitation to long-term productivity is the lack of information on the management practices necessary for stability of composition. The native pasture contains a range of useful species of which *Astrebla* spp. and *Dichanthium* sp. are the important perennials. Heavy stocking is possible as these species provide carry-over dry matter to maintain animals during periods of low pasture production associated with moisture stress. However, in so doing, their survival is reduced (E. J. Weston, unpublished data 1975) and persistent heavy utilization has allowed the invasion of weed species such as *Aristida leptopoda* (white spear grass) and *Salvia reflexa* (mintweed). In some minor land units, the perennial grasses can be completely replaced by the annual *Atriplex muelleri* (annual saltbush). The quality of the annual is superior, but the continuity of feed is reduced and land is exposed to erosion.

Investigation of productivity and utilization aimed at development of management systems favouring a desirable botanical composition will eventually be required. Initially, however, the condition and trend in the native pastures of Groups 2 and 3 should be determined. Such studies should also involve the *Astrebla* spp. grasslands of the Roma-Mitchell area.

The section in Group 1 referring to optimum combinations of enterprises and to the influence of management decisions on integration of the available sources of dry matter applies also to this group.

Group 4. Solodic—cypress pine-bull oak forest. *Callitris columellaris* (cypress pine) and *Casuarina luehmannii* (bull oak) can form forest structures with few other tree species present. However, in areas of mixed vegetation *E. melanophloia* (silver-leaved ironbark), *E. drepanophylla* (narrow-leaved ironbark) and *E. populnea* (poplar box) are common. A massive subsoil structure combines with high magnesium and sodium and low calcium levels to make these solodized-solonetz unsuitable for many introduced species. Low soil phosphorus and nitrogen are reflected in poor plant and animal production. The hard-setting nature of the surface soil leads to poor infiltration, high run-off and where vegetation has been disturbed erosion is accelerated. Despite the fact that *Callitris Columellaris, E. maculata* (spotted gum) and *E. drepanophylla* have been cut for commercial timber, man's impact has been small (Dawson 1972*b*). Sparse ground cover comprises predominantly *Aristida* and *Eragrostis* species.

PRODUCTION ALTERNATIVES. Although a major proportion of this group is controlled as State Forest (map 7), a significant area remains for commercial development. Production alternatives are limited when forests are in the virgin state ('green country'), and even after some development. As 'green country', it is of value only as reserve grazing, with short-term use of browse species and the quick-maturing ephemerals which appear after effective rain. Some ring-barking has been carried out, generally in land units of better moisture and nutrient characteristics such as frontages to creeks and drainage lines. Located in the east of the region, the area is favoured by a high proportion of winter rainfall (40%) and good wheat yields are obtained on the associated clay soils. More recently some country has been cleared. As regrowth of *Eucalyptus, Acacia* and *Casuarina* species occurs if development is not continued, a limited amount of cultivation of the solodic soils is practised.

Dry sheep are run for wool production and breeding cows for the production of weaners (figure 3). Enforced early turn-off of weaners is a reflection of the poor nutrient status of the soils and the resultant poor growing conditions for young animals.

COMMON PRODUCTION SYSTEMS. Properties with Group 4 soils have depended for economic survival on having access to land of higher fertility and dry matter productivity. Associated soils have normally been of the CC20 type. These are developed for cropping which provides cash income, crop residues and forage crops for grazing. In the future, units composed entirely of solodic soils may exist but only after considerable development for increasing productivity through improved soil fertility and the introduction of improved species.

The typical production system was one of 6 000 ha running 1 800 wethers. Aged wethers were fattened on crop residue or sold as stores. Cattle were bred for the sale of weaners. Of a herd of 217 cattle approximately 140 were breeders.

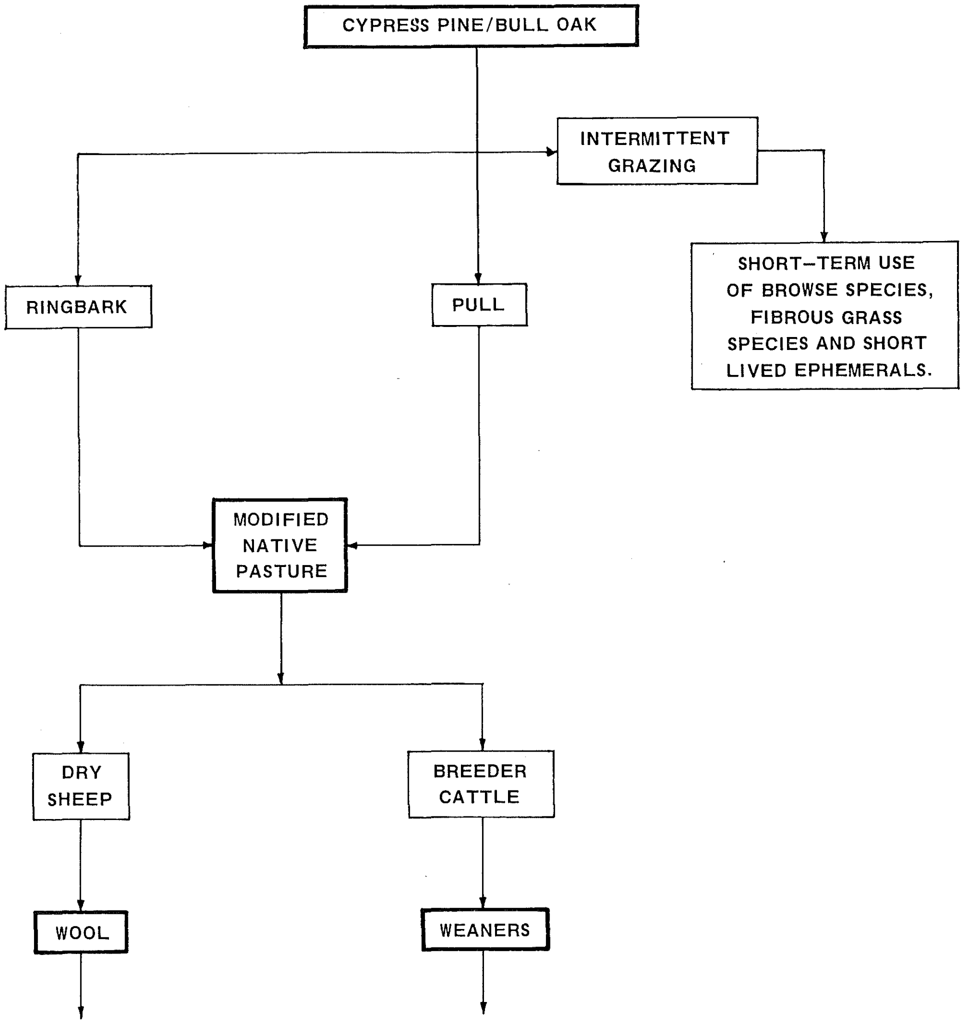


Figure 3.—Production alternatives for the cypress pine-bull oak forest.

Cultivated land was planted to 80 ha of wheat, 40 ha of grain sorghum and 30 ha of forage sorghum.

LIMITATIONS TO PRODUCTION AND AVENUES OF INVESTIGATION. The major limitations to increased production are soil chemical and physical factors and poor native pasture species. Because of these the advantages of location and rainfall of this tract of country cannot be exploited. The various soils are deficient in many of the major and minor nutrients including nitrogen, phosphorus, calcium, potassium, copper, zinc, manganese, molybdenum and boron (Leslie 1963; Leslie, Mackenzie and Glasby 1967; Russell 1967; Russell 1969-70). These deficiencies, combined with high levels of sodium and magnesium, low water holding capacity, high erodibility and a forest vegetation, make this area difficult and costly to develop.

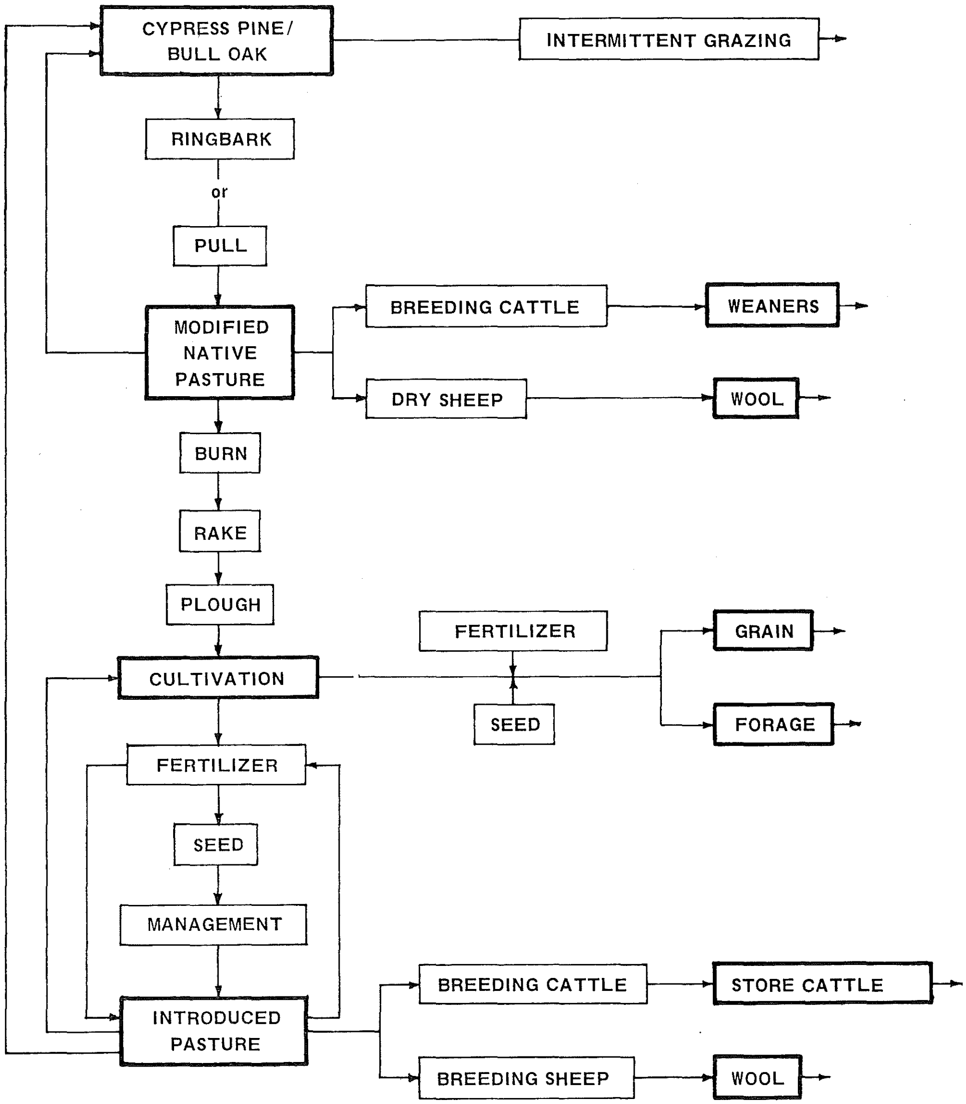


Figure 4.—Potential production alternatives for developed cypress pine-bull oak forest.

Because of erodibility, and to avoid the major recurring cost of annual nitrogen applications, a grass-legume pasture is indicated. *Macroptilium atropurpureum* cv. Siratro and the annual *Medicago* spp. have the potential to be productive in a modified edaphic environment. Continuation of the present lines of research and data from animal production trials (Russell 1973-74) should provide the technology needed to develop the southern solodic soils. The commercial acceptance of this technology will depend on prevailing economic conditions.

The type of development which is indicated by the present technology has been presented (figure 4). It is hypothesized that for a manageable system to be obtained, development must proceed at least to the stage of cultivation. Regrowth control is achieved as required by ploughing which may or may not be associated with the planting of a crop. Alternative control measures should also be investigated.

Under full property development to introduced pasture, involving timber control, seed, fertilizer and improved management of stock and pastures, a range of cattle types could be produced. However, development of a large 'green' block is most likely to be carried out in stages. As the forest vegetation already provides cattle breeding conditions, the returns for additional quality forage are likely to be maximized when weaner cattle are grown to store steer weight. At a stage of full property development, the type of cattle produced would be determined by market requirements. At that stage, a breeding sheep flock would also be possible with both wool and replacement sheep produced.

Group 5. Solodic—poplar box-sandalwood woodland This group is most commonly represented by very gently undulating plains or terraces fringing drainage lines. Hard setting loamy soils of the Oc21 type predominate. Their fertility is higher than that of the related solodized solonetz (Group 4) and they have 20 to 25 cm of top-soil, sufficient to attract some development to cultivation.

A high proportion of the *E. populnea–Eremophila mitchellii* (sandalwood) vegetation has been rung and now contains regrowth. *Bothriochloa decipiens* (pitted blue grass) is the major grass species while *Aristida* spp. can increase with overgrazing.

PRODUCTION ALTERNATIVES. The agricultural potential of this group is restricted by a shallow A horizon, a moderate water holding capacity, and a duplex profile. The loamy texture is an advantage in winter when small falls of rain occur, but the potential for summer grain cropping is lower. Forage oats production is the most suitable type of cropping. Control of woody weeds has been a motivating force behind many agricultural ventures.

Both sheep and cattle breeding are practised (figure 5), sheep breeding for wool and replacement sheep, and cattle breeding for store steer production. Although alternative sources of fodder are available, native pastures still support most of the grazing pressure. Forage oats are preferentially used to improve the performance of breeding and growing cattle. Only when surplus crop is available are store cattle fattened to be sold in early spring.

Introduced pastures are more commonly found in this group. These are exclusively *Cenchrus ciliaris,* a bulky grass which bridges the feed deficiency caused by periods of soil moisture shortage and provides improved winter and spring grazing. Although many of the taller cultivars of *Cenchrus* are more suited to cattle, the shorter-growing Gayndah and American types predominate in the area. Properties with significant areas of introduced pasture increase the size and quality of sale cattle by general improvement in all ages of animals.

COMMON PRODUCTION SYSTEMS. The typical production system was a property of approximately 8 000 ha which grew a small area of forage crops and ran both sheep and cattle. The cultivation was planted to 80 ha of oats and 40 ha of standover forage sorghum, the sorghum for autumn grazing by cattle. Adult sheep numbers were 1 000 ewes and 1 368 wethers. Traditionally a wool-growing area, lambing percentages in the mid sixties provided replacement sheep and allowed a moderate culling rate. Cattle increased in importance with low wool prices and store steers 18 months of age were usually marketed. The cattle herd was composed of 150 breeders in a total of 288 cattle.

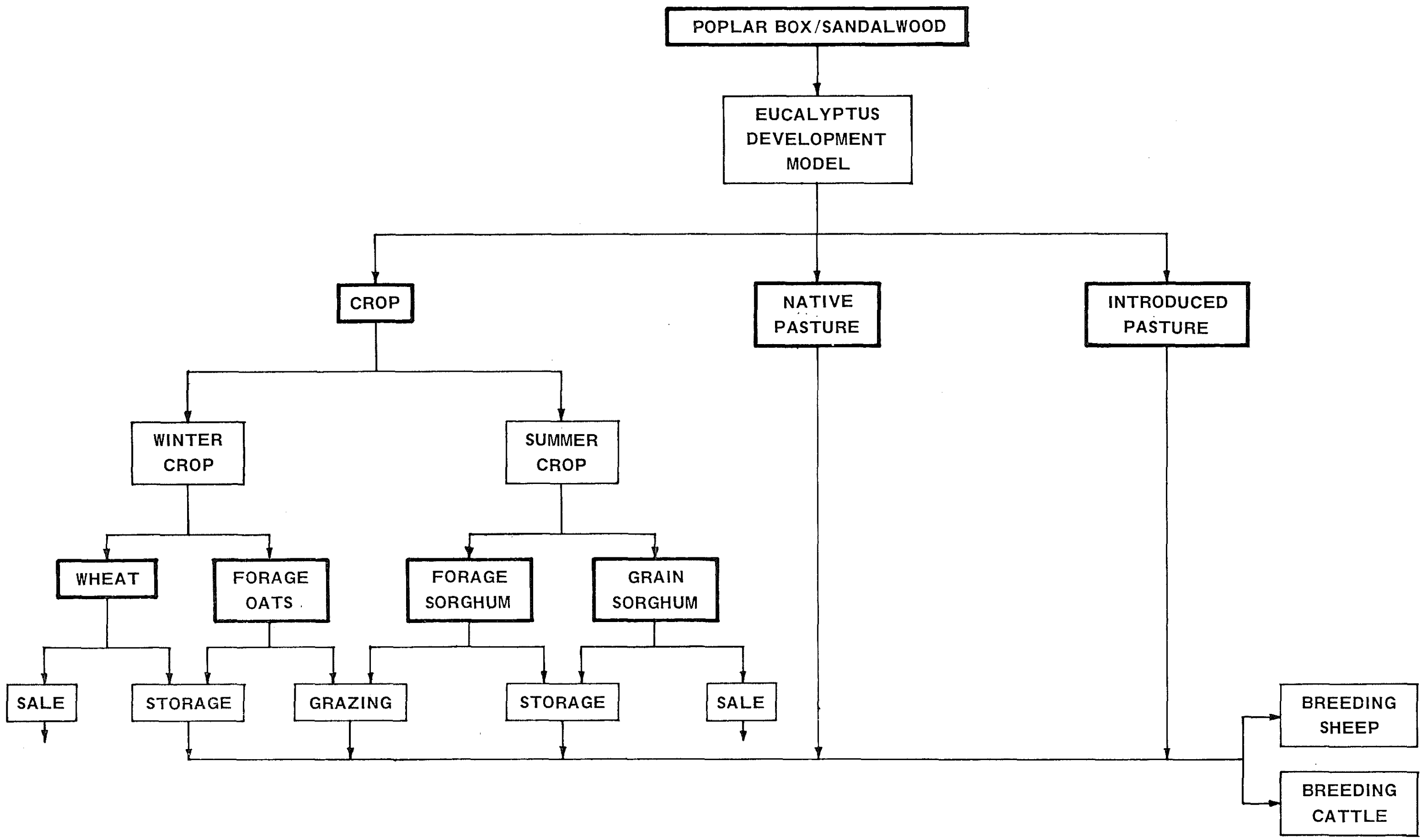


Figure 5.—Production alternatives for poplar box-sandalwood woodland.

LIMITATIONS TO PRODUCTION AND AVENUES OF INVESTIGATION. Dry matter availability and continuity are the chief limitations to sheep and cattle production. Tree cutting and ringbarking have been practised since the early days of settlement on these woodlands. Where modification of the tree layer has not been followed by sucker treatment where necessary, regrowth of *Eucalyptus populnea* and accelerated growth of the shrub layer have occurred. Where further development is feasible, a predictable control of these plants is obtained by cultivation. However, greater areas of this group are available for development than are likely to be cropped. The effect of strategic grazing and fire on woody weeds should be investigated. Such management practices have been applied with beneficial results to woodland communities on red earth soils (Moore and Walker 1972).

Even following timber treatment, the low bulk of native pasture still limits production. The available technology indicates that this can be overcome by the introduction of *C. ciliaris*. The acceptance of this grass has been slow, however, and no clear production systems involving the species have emerged. Some reasons for this are the misinterpretation of the real value of the plant, uncertainty of establishment and a lack of information on some aspects of establishment and management of *Cenchrus* pastures. Extension literature often obscures the valuable role *Cenchrus* sp. can play by alluding to its fattening potential. Its real strength lies in its ability to retain nutritional value after frosting and to provide a high carry-over of fodder to even out the frequent short-term deficiencies in bulk. In the present economic climate, the increase in introduced pastures will be slow. When money is available for development, more precise information will act as a stimulus to pasture plantings.

A limited amount of deterioration in some older stands of introduced pasture on sandy and loamy soils has been observed. Dry matter responses of *Chloris gayana* cv. Samford, *Panicum maximum* var. *trichoglume* cv. Petrie (green panic), *P. coloratum* var. *makarikariense* cv. Pollock and *Cenchrus ciliaris* cv. Biloela to applied nitrogen (Ivory and Jacobsen 1971, 1972; Jacobsen and Ivory 1973) are relevant. The data indicate that the rainfall is sufficient to support a greater plant growth than the natural soil nitrogen will allow. This could lead to a decline in soil nutrients in the presence of a vigorous plant such as *C. ciliaris*. It also indicates that benefit could result from the addition of a pasture legume. Although a study of deterioration in introduced pasture production would include a variety of soil types, the Oc21 solodics are important because they occur in the higher rainfall areas.

Ploughing of *C. ciliaris* swards is a recognized method of increasing the density of the stand and of stimulating growth. The effect of this practice on the rate of use of soil nutrients and on long term productivity should be included in this study.

With the present land use, existing moderate levels of soil phosphorus are satisfactory for plant and animal requirements. Under a more intensive production system with higher levels of animal removal, deficiencies may become apparent. A response to phosphorus is recorded in glasshouse trials for the dominant soil type in this group (Wall *et al.* 1971–72).

Agronomically the soils are suitable for winter cereals and have the advantage of a level surface which can be worked soon after rain. To their detriment, they are erodible and hard-setting. In comparison with the cracking clays, the capacity to store water is limited by both texture and depth. Prediction of soil moisture changes through a water balance technique would facilitate the study of cropping in this marginal environment.

Buffel grass is heavily grazed when growing in areas occupied mainly by poorer quality native species. The extent of this utilization is shown by the recently enclosed area on the left.

When ungrazed, buffel grass will accumulate a good bulk of useful carry-over dry matter.

Argemona mexicana and *A. ochroleuca* sp. *ochroleuca* (Mexican poppy) are problem weeds which develop on these soils with the autumn planting of forage oats. *Emex australis* (spiny emex) is a weed of similar soil types in the Roma-Wallumbilla area (Paull and Stirling 1972). Although both succumb to herbicide treatment, the influence of crop-pasture rotation on weed population should be considered.

Group 6. Red earth—Poplar box-mulga woodland. This is a heterogeneous area of red earth soils and further classification should be attempted at an early stage in any research programme. Two distinct production situations occur. These are separated by the Balonne and Moonie Rivers which approximate to the 500 mm annual isohyet. The higher rainfall type to the east occurs on My3 soils while that to the west is predominantly My5 soil association.

Eucalyptus populnea is common throughout, while *Acacia aneura* (mulga) can be absent in the east and increase in importance in the west. *Eucalyptus melanophloia, Geijera parviflora* (wilga) and *Callitris columellaris* are important associated species in some areas. Where *A. aneura* is dominant with the *Eucalyptus* spp. as emergents only, a separate group (Group 7) has been defined. Native pastures are sparse with *Thyridolepis mitchelliana* (mulga grass) and *Aristida* spp. most conspicuous, *Aristida* spp. increasing with heavy grazing. Shrub species such as *Eremophila mitchellii* and *Cassia nemophila* (birdseye), although a problem in the eastern parts of this group, are less prominent in western areas.

Production alternatives. The higher rainfall area can produce winter forage crops in favourable seasons (figure 6) despite the relatively low range of available soil moisture. West of the Balonne River, some cultivation for woody weed control occurs and forage oats are planted. In both situations, the crop is used to improve the nutritional status of breeding and growing cattle. In the western parts, introduced pastures are more reliable than forage crops and will ultimately replace these. As economic conditions have permitted, there has been some activity in land clearing. While this increases available dry matter, low value *Aristida* spp. have often increased. *Cenchrus ciliaris* has been observed to compete with *Aristida leichhardtiana* on this soil-vegetation group.

The lower fertility and annual rainfall of the group are expressed not only in lower carrying capacities but also in the type of animal product. While cattle breeding percentages are moderately high (70%), the growth rate of young cattle is slower than the average for the study region and the normal product marketed is a store steer. Lambing percentages (58%) are sufficient to provide replacement sheep, while a satisfactory level of wool production can be maintained at low carrying capacities.

Common production systems. The typical property of the western part of this soil-vegetation group was one of 10 000 ha with no cultivation, carrying 1 000 adult ewes and 1 260 wethers. Cattle numbers totalled 200, of which 90 were breeders. In the eastern part, properties were smaller, production was more intensive and some forage crop was planted. Throughout the area, there was little introduced pasture although primary producers were aware of *C. ciliaris* and most properties had some plants around homesteads, stock yards, grids and fence lines.

Limitations of production and avenues of investigation. A high proportion of the plant biomass is unavailable and much of it unacceptable to animals and has little apparent resource value in a grazing system. Tree poisoning and ring-barking can increase native pasture. However, because of the poor type

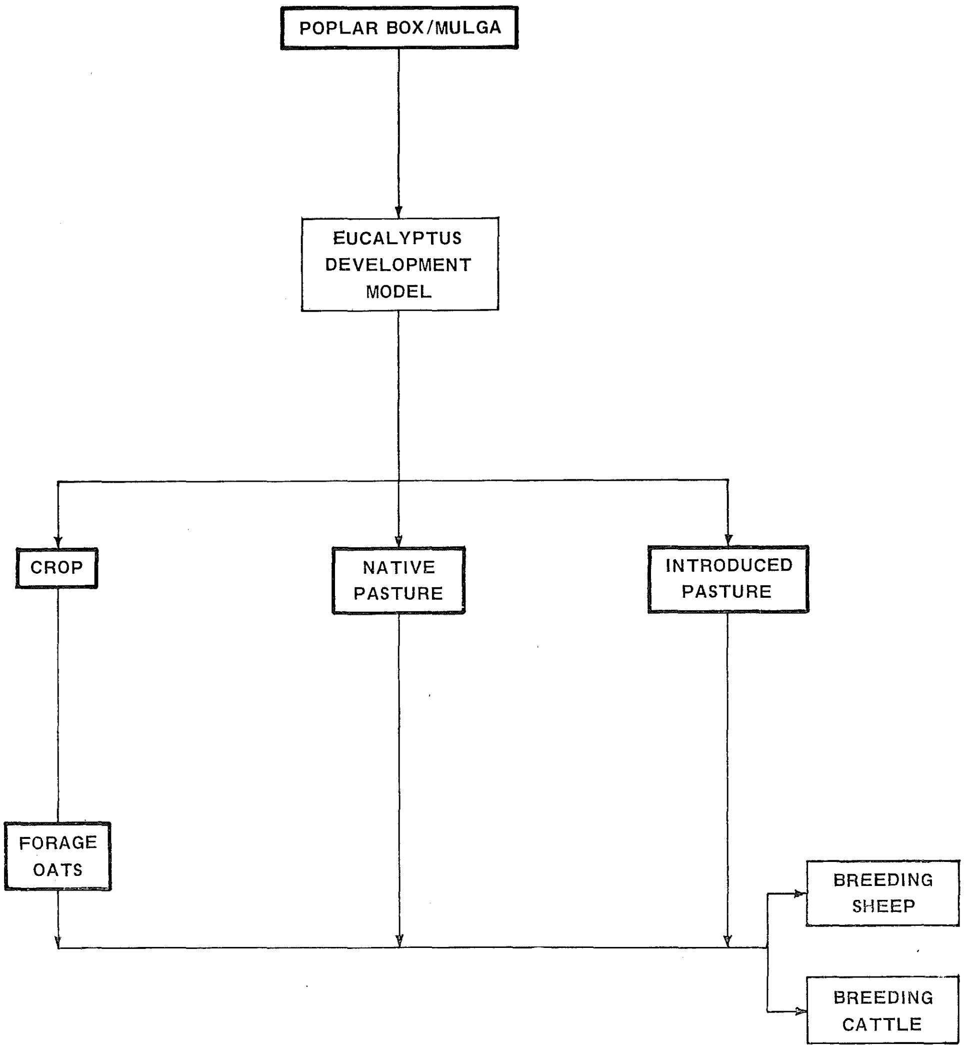


Figure 6.—Production alternatives for poplar box-mulga woodland.

of native species and the low water-holding capacity of the soil, frequent short periods of dry matter shortage will continue. As with Group 5, there is a need for an adapted pasture species which will provide a bulk of carry-over dry matter. Yields of the order of 1 700 to 2 200 kg ha^{-1} are reported for unfertilized *C. ciliaris* on this soil-vegetation type (Ebersohn 1971), and the quality of its carry-over material is high. Consequently an increase in *C. ciliaris* is anticipated; the rate of expanson will depend on economic factors. Cultivation is not generally available as an aid to introduction, but local experience indicates that broadcasting *Cenchrus* either before or after land clearing can result in satisfactory establishment. The processes involved in this practice should be studied. In particular, the influence of sowing time and seeding rate on the rate of colonization should be determined.

The early productivity of *C. ciliaris* may not be maintained. Its production trend will depend on available moisture, rate of mineralization of nitrogen and rate of removal of plant or animal product. It is unlikely that any of the legume species at present available will be productive in a pasture on these lands. Consequently, the study of production trends in modified woodland communities sown to *C. ciliaris* should be initiated. In addition, the long-term effects of modification of the tree layer on the stability of the woodland ecosystem should be considered before extensive land clearing takes place.

Conception rates in cows are high (Strachan 1971) despite low soil fertility. It has been suggested that animals obtain their mineral requirements through access to pastures growing on more fertile soil types. More intensive development will lead to restriction of animal movement, and factors such as low soil phosphorus will become more important. The current studies of faecal phosphorus (Weller and Plasto 1973) and phosphorus supplementation (Plasto and Weller 1973) may quantify this aspect of cattle nutrition in the area.

Two important poisonous plants occur in parts of this group. They are *Ipomoea calobra* (Weir vine) causing Weir vine poisoning in sheep and cattle and *Pimelea trichostachya* (spiked rice-flower) which causes St. George disease of cattle. In areas containing *I. calobra* management involves a light grazing pressure, the early recognition of symptoms in affected animals and moving all stock to pasture free from the plant. Herbicide screening trials have been carried out (Queensland Department of Lands 1972–73) and 2,4-D amine in water is an effective control when correctly applied (L. J. Percy personal communication). Labour, however, is an expensive component of this practice and a generally applicable control is not likely unless woodland vegetation is cleared for pasture development, at which time control treatments can be applied more rapidly.

Outbreaks of St. George disease occur mainly on properties located on the poorer red sandy soils (Stevens 1954). Control of the *Pimelea* plant is unlikely in a pastoral system and management of stock offers the major remedy at present. Continuing research aims at isolating the toxic principle involved and this may ultimately lead to the development of an antidote.

Group 7. Red earth—mulga-eucalyptus shrubland. This group occupies a very small part (133 000 ha) of the western section of the Balonne Shire. However, to the west of the study area and east of the Warrego River, dense shrublands of *A. aneura* occur on red earth soils. These receive 400 to 500 mm of rainfall annually. Research for the group is conducted from the Charleville Pastoral Laboratory and, where appropriate, will be discussed in relation to the programme at that centre.

A. aneura is the major woody species while *Eucalyptus* spp. are often present in the canopy or occasionally as emergents (Galloway *et al.* 1974). Of these *E. melanophloia* and *E. populnea* are the most prominent. In the shrub layer, *Eremophila* spp., *Cassia* spp. and *Dononaea* spp. can often form dense stands (Boyland 1973). The surface reaction of the soil is acid with levels most commonly in the range of pH 5 to 6. A range of soil textures and surface conditions is encountered and these influence the water relations to a major extent. Water-holding capacities are generally low and run-off is high on shallow sloping soils (Dawson compiler 1974).

Production alternatives. The area has traditionally been one of wool growing and sheep breeding. Under very low stocking rates, sparse grass and herbage, leaf fall and browse provide a low, safe and sometimes uneconomical level of production in which the fodder shortage situation is infrequent. With

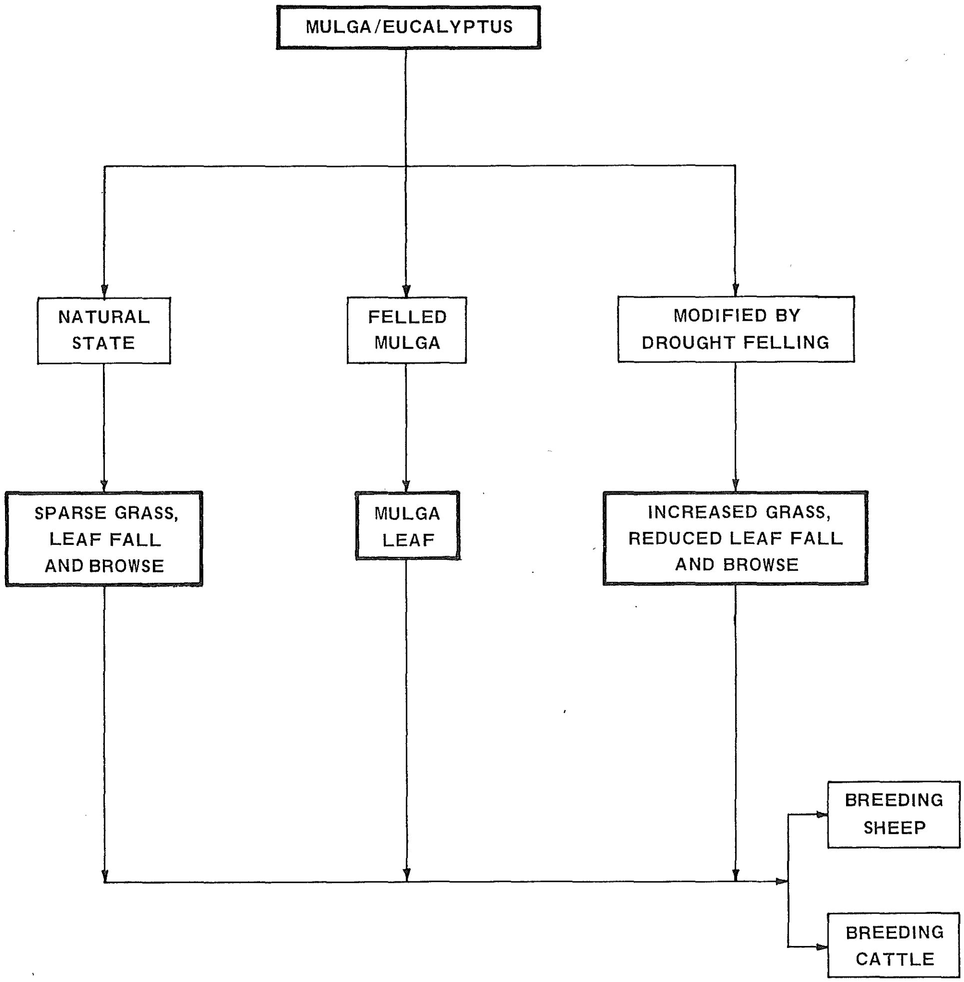


Figure 7.—Production alternatives for mulga-eucalyptus shrubland.

more stock, usually to offset an unfavourable economic situation, shortages of dry matter are frequent. In this situation the feeding of *A. aneura* becomes part of the normal production system rather than a drought strategy (figure 7).

When the mulga community is associated with some of the more heavily grassed open woodland communities, cattle are bred and store steers marketed. Since the depression in the wool industry, even those properties with predominantly shrubland have run some cattle in an endeavour to diversify production, and this trend has increased the pressure on scarce dry matter resources.

Low rainfall, low soil fertility and low water-holding capacity have prevented diversification into cropping, and this has limited the methods available for the introduction of exotic pasture species. Some *Cenchrus ciliaris* development, mainly in stump holes formed during tree pushing, has taken place. Broad-scale land clearing has been attempted commercially but the practice is neither common nor generally accepted.

COMMON PRODUCTION SYSTEMS. Wool production is the major source of income, with sheep breeding providing replacement sheep and allowing a moderate culling rate. Some cattle breeding is practised and store steers produced. The typical property in the Paroo shire was 20 000 ha in size, had 3 000 ewes and 1 500 wethers and ran 240 head of cattle, of which 140 were mature breeders and heifers (Australian Bureau of Statistics 1971-72). Although some forage cropping had been attempted, the total area of cultivation was small.

LIMITATIONS TO PRODUCTION AND AVENUES OF INVESTIGATION. In this area, *A. aneura* often grows in tree form, so densely that it prevents or seriously limits the growth of ground vegetation (Everist 1972). Although a valuable edible species, the quantity of plant is in excess of even frequent drought requirements. Thus, in dense shrubland, a large proportion of the tree population must be considered a woody weed. While, in times of cheaper labour, selective thinning may have been practised, clearing on a face, either to provide drought fodder or for land development, is the only feasible approach to vegetation modification today. Increases in herbage yield following tree thinning are reported (Beale 1970; Beale and Burrows 1970; Beale 1971; Beale 1973). However, there are problems associated with land clearing such as increases in undesirable plants (*Aristida* spp.), uncontrolled regrowth and mass germination of *Acacia aneura* and the increased possibility of fire which is harmful to *A. aneura* survival.

The drought insurance role of *A. aneura* seems to be best served by reserving a predetermined amount of shrubland. Sufficient meteorological data are available to determine drought probabilities, and a regression equation of the amount of leaf material on *A. aneura* trees of different stem diameter has been calculated (Burrows and Beale 1970). From an assessment of the probable frequency and duration of drought and the number of stock on a property, the size of fodder reserve for a given level of risk can be determined.

Modification of the community form seems necessary if increased herbage yield is to be achieved. The effect of land clearing on animal production and the effect of sheep and cattle grazing following clearing on seedlings and surviving plants of *A. aneura* and *Eucalyptus* spp. should be investigated. In favourable rainfall years, *A. aneura* will actively recolonize and again influence herbage production. The palatability of *A. aneura* is discussed by Melville (1947), Everist (1949) and Holland and Moore (1962). It seems that the grazing pressure of sheep and cattle might be used to keep this legume both within the reach of grazing animals and under control. Intake studies examining what species are grazed, when, and in what manner, will assist in the development of management systems for modified *A. aneura* communities.

The possible consequences of broad-scale land clearing on a mulga community are considered in figure 8 and some avenues by which regrowth might be contained are indicated. Additional mechanical inputs such as slashing, rolling or repulling should be examined as means of maintaining a shrub community.

If the input necessary to maintain *A. aneura* in a shrub form is not commercially acceptable, then the maintenance of variable aged stands should be considered. These may be: 1. recently pulled land with increased herbage yield and persistent plants of *A. aneura;* 2. land where seedling *A. aneura* is above the grazing height of animals and thus out of control; and 3. dense *A. aneura* shrubland as a fodder reserve block. The areas could be rotated in a long-term cycle.

Land clearing has been attempted on a commercial scale in mulga-eucalyptus shrubland.

An advantage of the slower, labour-intensive methods of land development is that scattered shade and fodder trees can be preserved.

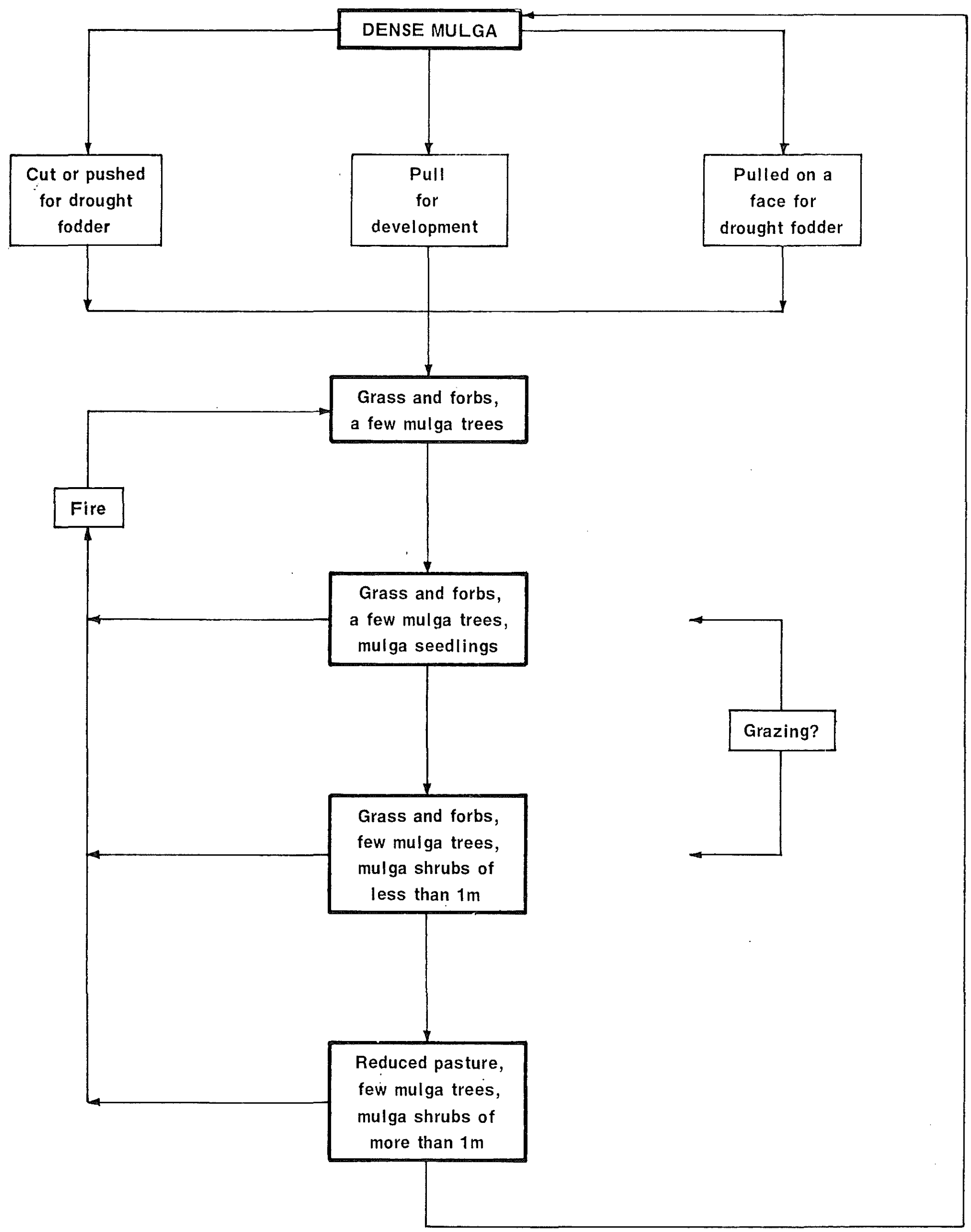


Figure 8.—Hypothetical development plan for mulga-eucalyptus shrubland.

Although animal production will increase as a result of land clearing, there remain many deficiencies in the modified system. Many native species are fibrous and of low quality and contribute little to high animal performance. Land clearing presents suitable conditions for the introduction of exotic species, these conditions being expensive to achieve by other means. *Cenchrus ciliaris* is the most suitable of the existing species and its rate of colonization and productivity should be measured. The current screening and field testing of grass, forb and shrub species should also be pursued.

Group 8. Shallow loamy soil—bendee shrubland. Small areas (91 000 ha) of predominantly shallow gravelly red earths occur on deeply weathered landscapes in the Condamine–Maranoa basin, the major occurrence being north-east of St. George. They occur on crests and upper slopes in gently undulating to rolling terrain (Galloway *et al.* 1974). *Acacia catenulata* (bendee) is the major woody species and occurs as open forests with sparse ground cover. The soils are shallow and infertile, outcrops of stone are common and the range of available moisture is poor.

PRODUCTION ALTERNATIVES. The predominant land use is extensive sheep grazing, these animals making best use of the sparse ground vegetation and leaf fall. Carrying capacity is one dry sheep to 8 ha (Tiller 1971) and wool cuts are low. Although some cultivation has been attempted, the area is basically unsuitable for permanent cropping. Only small areas are suitable for clearing and these may or may not be seeded to *C. ciliaris*. Following this development, large increases in carrying capacity occur which then decrease with gradual regeneration of woody species (Tiller *loc. cit.*).

GENERAL. No specific production systems have been developed for this group because rarely is a property confined to this type of country. Productivity is low and the more productive alternatives can be applied on only a small proportion of the area. The limitations to dry matter production are the same as those presented for Group 7 but shallow soils, rock outcrops and topographical features make the area unsuitable for all but limited development.

As the areas are often high in the landscape and act as watersheds for adjacent land units, their disturbance should be viewed with caution. Detailed investigations of the changes that occur following land clearing seem unwarranted on a soil-vegetation group of such limited extent.

Group 9. Shallow loamy soil—ironbark woodland. The soils of this group are shallow and stony, commonly referred to as skeletal soils or lithosols. They occur as low hills and dissected low ranges. Although scattered throughout the central and eastern parts of the Condamine–Maranoa basin, their area is not large, totalling only 204 821 ha. The vegetation is open forest with *E. drepanophylla, E. melanophloia, E. populnea* and *Callitris columellaris* in the tree layer and areas of *Acacia* spp. prominent in the shrub layer. The chief grasses are *Aristida* spp. though these may be accompanied by ephemerals after effective rainfall.

PRODUCTION ALTERNATIVES. The soils are unsuitable for agriculture and little development has taken place. Outcrops of this soil-vegetation group are normally left as shelter areas and timber reserves, although some hardwoods have been cut commercially. In the east, much of the group is contained in State Forests. Some ring-barking has been practised but because of the shallow stony soil and the risk of erosion, this is minimal. Extensive grazing of the coarse grasses, browse shrubs and ephemerals by sheep and cattle is the main form of land use.

GENERAL. Because this soil-vegetation group provides useful watershed conditions for adjoining land units and because of the risk of accelerated erosion, development should not be encouraged.

Group 10. Alluvial soil—eucalyptus woodland. The importance of this group of frontage soils is increased by the availability of irrigation water from Coolmunda Dam and the proposed supply from the Glenlyon Dam on Pike Creek (map 1). The tree species are typical of the location, including *E. camaldulensis* and *E. microtheca* on the rivers and *E. populnea* and *E. melanophloia* in the less frequently flooded sites. *Bothriochloa decipiens* and *Stipa verticillata* (slender bamboo grass) are common. Isbell (1957) divides this formation into younger terraces and levees and older terraces and levee slopes. The former are subject to seasonal inundation while the latter are covered by extreme floods.

PRODUCTION ALTERNATIVES. This group has favourable climatic conditions for cropping. Both winter and summer crops have been grown and the figure describing these practices for the brigalow lands is relevant. Because of its position as a frontage group, land use normally involves a combined use of this and the adjoining land units. Soils are moderate to high in fertility, but water penetration is a problem on the recent alluvial soils. Crops described in the irrigation section for Macintyre Brook are relevant to this area.

GENERAL. Because of the limited area of this group and the fact that it seldom occupies the major part of a property, production system diagrams have not been developed. Flooding restricts development on the lower terraces. Some ring-barking to improve the grazing potential and full development to allow cultivation have occurred on higher areas.

SUMMARY OF RECOMMENDATIONS

The production limitations described in the previous section open the way for discussion of research avenues aimed at increased or sustained production. Not all problems will yield to research effort at present. In some situations, only components of the problem are considered in the short term. Some practices may appear to have unfavourable economic implications in the light of existing market conditions. However, the aim should be to understand the biological mechanism; a decision as to the economic value of a practice can not be made without this information.

Group 1. Gilgaied clay and clay loam—brigalow and brigalow-belah forest. (a) The use of optimizing techniques such as linear programming to determine the combination or combinations of enterprises for maximum economic rewards is indicated for Groups 1, 2 and 3.

(b) The development of a model which incorporates the various sources of dry matter in a simulation of crop and animal production is required for the same groups. Experimentation with this model will indicate the influence of dry matter source on stability of production under fluctuating seasonal conditions. It will also highlight areas of data relevance and deficiency and provide a framework for research planning.

Some component research which will contribute to this simulation is indicated under the appropriate fields below.

CROPPING. (a) Studies of those cultural practices which result in a minimum depth of dry soil in the cultivation zone and in maximum soil moisture storage are required.

(b) The development of a model to simulate wheat growing is part of the major systems analysis study described above. Experimentation with this model will quantify the effect of time of planting on wheat yield and crop loss due to frost.

(c) Varietal and/or population studies of forage oats, sunflower, grain sorghum and pulse crops are required to provide the recommendations for extension services. Such studies should be co-ordinated with existing regional trials where available.

(d) A study of the changes in soil nitrogen is indicated where cropping and intensified animal production have replaced a forest vegetation. Research should indicate at what duration of crop or pasture production significant yield and quality declines occur. The ability of legumes to contribute to the maintenance of fertility should be determined.

(e) While a range of summer-growing forage crops is available, systems of utilization for maximum plant and animal production have not been examined locally.

NATIVE AND INTRODUCED PASTURES. (f) Native pastures are, and will remain for some time, the major source of forage for grazing animals. The species which are selected by sheep and cattle, their community dynamics, their seasonal contribution to the total dry matter production and their quality, should be determined.

(g) While introduced grasses overcome deficiencies of bulk in native pastures, they only partly overcome the quality deficiency. Increased animal performance resulted when annual *Medicago* spp. were combined with introduced grasses on brigalow lands. The methods of incorporating legumes in introduced and native pastures require investigation. Their contribution to pasture quality and dry matter production should be measured.

(h) Study of the establishment of pasture grasses both alone and in the presence of companion plants should be pursued.

SHEEP AND CATTLE. (i) The investigation of low growth rates of weaner sheep and poor wool growth on some gilgai country is required.

(j) Animal production measurements are required for sheep on forage crop and crop residue, sheep and cattle on introduced pasture managed as deferred grazing, and sheep and cattle on introduced pasture managed as a major component of a 'feed year' system.

(k) Study of the factors responsible for variation in animal performance on forage oats will provide a sound basis for economic analysis of crop fattening practices.

Group 2. Flooded clay—coolibah open woodland. (a) The use of remote sensing techniques to record water distribution for floods of recorded heights and the development of methods for interpreting such data will provide a basis for flood management.

(b) Studies of the establishment, productivity and management of *Panicum coloratum* on occasionally flooded lands in the higher rainfall areas are indicated.

(c) Monitoring endoparasite populations of sheep to determine the optimum frequency of drenching will provide a sound basis for recommendations.

Group 3. Undulating clay—Mitchell grass grassland. (a) Investigation of the influence of management practices on the composition and long term production of *Astrebla* pastures of the grassland (Group 3) and open woodland (Group 2) communities is required.

Group 4. Solodic—cypress pine-bull oak forest. The major work on this group is being conducted by officers of C.S.I.R.O. stationed at Cunningham Laboratory. It has been established that improved plant growth will be achieved by correcting soil nutrient deficiencies and by introducing improved pasture species. The measurement of animal production at different levels of input is in progress. Some additions to the present programme are suggested.

(a) Measurement of the performance of cattle from weaner weight onwards on modified grazing lands will allow small areas of developed forest to be utilized together with existing cattle breeding systems.

(b) Precise delineation of soil units throughout the cypress pine-bull oak solodics will provide the means of applying research results most effectively.

Group 5. Solodic—poplar box-sandalwood woodland and Group 6. Red earth—poplar box-mulga woodland. These soil-vegetation groups are both *E. populnea* dominant and since their development philosophies and problems are similar, types of investigations common to both are indicated. Duplication of sites is required, however, because of texture differences in the profiles, and lower rainfall and phosphorus in Group 6.

(a) Measurement of changes in botanical composition, production from each class of plant (tree, shrub, grass and herb), and soil water and nutrient levels following modification of *Eucalyptus* dominant vegetation is required.

(b) The influence of fire, animal, chemical and mechanical factors on woody species regrowth (predominantly *E. populnea* and *Eremophila mitchellii*) resulting from modification of the woodlands should be determined.

(c) Measurement of the ability of *Cenchrus ciliaris* to complement the dry matter production of native pastures will provide the basis for extension planning and effective promotion of this species.

(d) To anticipate the long-term effect of land-clearing and species introduction on total pasture production, studies of the rate of mineralization and removal of scarce nutrients are required. Such studies should also quantify pasture decline speculations.

(e) The probability of obtaining profitable forage oats yields on arable light textured soils (Group 5) is required. A simulation technique involving a soil water equation, planting criteria, the influence of applied nutrients on dry matter production and the length of grazing period, could be employed.

(f) The introduction of *C. ciliaris* to cleared non-arable woodland (Group 6) should be studied. The influence of seeding before or after clearing, the effect of month and rate of seeding and the rate of colonization should be considered.

(g) It is unlikely that any of the legumes at present available will be productive on Group 6 lands and, consequently, a search for legumes is indicated. The productivity of the annual *Medicago* spp. should be measured on Group 5 lands.

Group 7. Red earth—mulga-eucalyptus shrubland. In this region, it is assumed that the optimum pasture will contain a predominance of native species. The study of these is emphasized and studies of introduced species and cropping systems given lower priority. Because of the multiple roles which *Acacia aneura* can play in providing drought fodder, leaf fall and browse, research should aim at studying the plant in its various forms. Work at the Charleville Pastoral Laboratory has studied the plant as a drought fodder and in its capacity to provide leaf fall, but not as a browse shrub. As a continuation of existing research the following studies are recommended—

(a) Fodder reserve requirement for sheep based on drought probabilities and the production of edible leaf by *A. aneura* shrubland should be determined.

(b) Changes in the components of production following land clearing and study of the pattern of re-establishment and growth of *A. aneura* under the influence of sheep and cattle grazing, should be measured.

(c) The species of plants and parts of plants eaten by animals at different times of the year should be identified.

(d) Direction will be given by (c) to autecological studies which aim at examining germination, establishment, growth pattern and life span of important species.

(e) Existing species introduction and testing should be continued, and promising species distributed in modified landscapes and degraded communities.

Group 8. Shallow loamy soil—bendee shrubland and Group 9. Shallow loamy soil—ironbark woodland. Because of the location of these groups in the upper part of the landscape, it is recommended that the vegetation remain undisturbed to avoid erosion and siltation.

Group 10. Alluvial soil—eucalyptus woodland. Located along Macintyre Brook and the Dumaresq River, this group has access to water from the Coolmunda Dam and will, in future, receive water from Glenlyon Dam. Investigations at the Inglewood Field Station of the Queensland Department of Primary Industries are relevant. Current research on soils of low permeability, high value horticultural crops, small crops and intensive animal production systems should be pursued.

Regional studies

Some studies apply to more than one soil-vegetation group and are discussed in this section.

(a) LAND USE PRACTICES. 1. Land use can change quickly particularly in the eastern half of the study region. Consequently, crop statistics measured through established census avenues provide information too long after the event to be of value to marketing and supply authorities. The ERTS system employing remote sensing techniques can provide current information on land use and on aspects of land management. Techniques for monitoring condition and trend in pasture could be developed to advantage. The potential of such a system should be fully investigated at a local level and the costs and benefits of developing receiving facilities determined at a national level.

2. The value of rural statistics as collected by the Australian Bureau of Statistics is not fully realized when these are presented for shire areas. As the data are collected on a property basis, they can be organised into any defined areas. The soil-vegetation groups used in this project which combine soil associations and vegetation types with similar agricultural potential would be more useful.

(b) ANIMAL PRODUCTION. 1. An investigation of animal losses and management practices associated with dystocia in cattle is in progress. Such a study should progress to an economic assessment of the losses and costs associated with the disorder. The need for an investigation into the importance of management practices in combating this condition is indicated by interview data.

2. An investigation of the economic loss caused by eye cancer in cattle will provide stimulus to further study of the causes and remedies of this condition.

3. Although known to be present in the area, no study has been made of the occurrence of, nor economic loss caused by, the infertility diseases of sheep and cattle. Such an investigation would indicate whether there is a need for eradication programmes.

4. Despite the long history of wool production in the area, precise production data for sheep are not published. For accurate economic and systems analysis, data on animal growth rate, wool production and reproductive performance related to the major soil-vegetation types and for defined conditions of climate and management are required.

(c) AGRICULTURE. The shift in land use from predominantly sheep to predominantly cattle which occurred in the early 1970s allowed perennial grasses and shrubs to make a greater contribution to total production compared with annual species. The management implications of this and its influence on pasture trend should be considered.

(d) PESTS. 1. *Animal pests.* Pigs and foxes are accused of causing reductions in lambing percentages while pigs are also a problem in grain crop areas. A study of the habits, diets and, where necessary, controls for these animals is indicated.

2. *Plant pests.* There are a number of plant pests besides *Eucalyptus populnea* and *Eremophila mitchellii* which are sufficiently prominent to be classed as weeds in some areas. These include *Eremocitrus glauca* (limebush), *Acacia harpophylla, Cassia nemophila* (birdseye), *Opuntia tomentosa* (tree pear) and the herbaceous plants *Salvia reflexa, Ipomoea calobra* and *Pimelea* spp. Cultivation, where applicable, will suppress all of the tree and shrub species. Weedicides should be studied for their effectiveness against *S. reflexa* and *I. calobra* although *I. calobra* will not be treated on a large scale until clearing of the vegetation occurs.

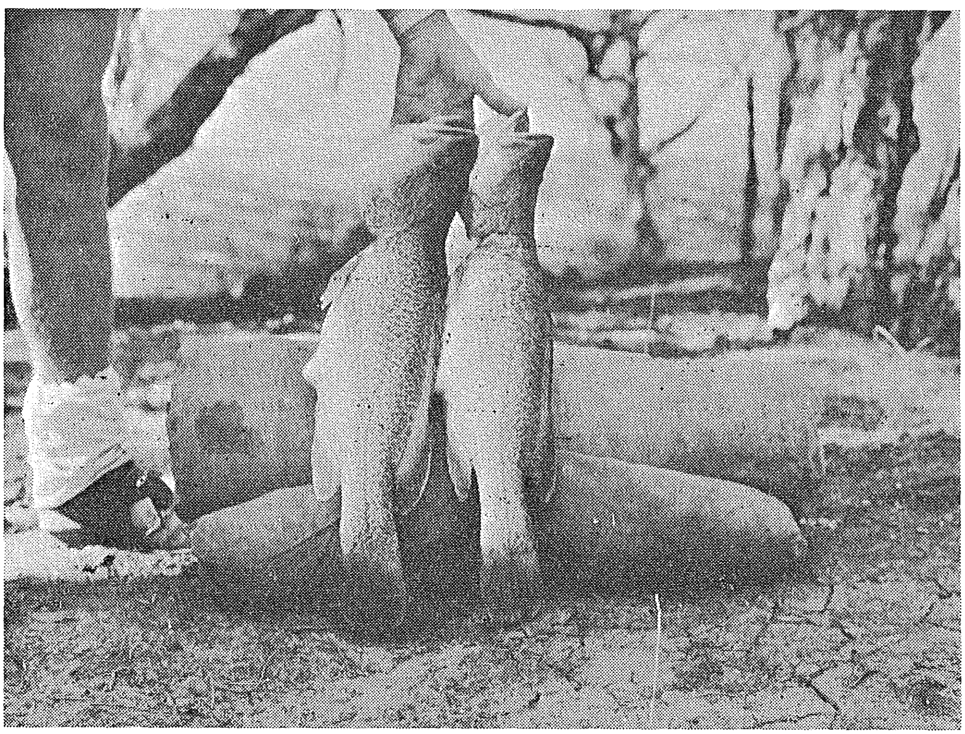
(e) RECREATION AREAS. The Condamine-Maranoa basin is well within the range of people from coastal and sub-coastal south-eastern Queensland who are seeking recreational areas. Investigation into the recreational potential of the area is required.

1. In the short term, people will use national parks and Crown lands associated with reserves and rivers. This will impose a pressure on the fauna and flora, and management principles will be required for their preservation.

2. In the long term, land-owners will employ recreation as a form of land use for commercial gain. Investigations into the profitability and management factors in this form of land use are required.

3. The rivers of the Condamine-Maranoa basin are used for non-commercial fishing and yield *Plectroplites ambiguus* (yellowbelly or golden perch) and *Maccullochella macquariensis* (Murray cod). Controlled breeding and restocking with these species should be investigated. The appearance of *Cyprinus carpio* (European carp) in the rivers of the area is reported. The influence of this species on indigenous fish and the possibility of its control or exploitation require investigation.

There are few major towns in the Condamine-Maranoa basin. St. George is the second largest.



Murray cod (Maccullochella macquariensis) *are one of the favoured species caught in the permanent rivers of the area.*

PRIORITIES

The Condamine-Maranoa basin in southern Queensland has a higher potential productivity than other areas west of the Great Dividing Range because of its higher rainfall reliability. Within the area, the major existing research efforts are confined to the brigalow lands (Group 1), the cypress pine-bull oak solodics (Group 4) and the mulga-eucalyptus shrublands (Group 7). These comprise the eastern and western sections of the Condamine-Maranoa basin. While the Group 1 investigations have application on Groups 2 and 3, work on Group 7 does not apply to the woodlands of Groups 5 and 6. This large area (3 million hectares) of solodic poplar box-false sandalwood woodland (Group 5) and red earth poplar box-mulga woodland (Group 6), referred to as 'red country', is largely unresearched, except for trial sites at Morocco and Wycanna holdings. Current research on the brigalow, solodic and mulga lands will generate further work.

The increased productivity which could result from further investigations on cleared brigalow forest will be much less than that achieved by the original clearing. In the cypress pine-bull oak solodics, the returns from research will not be realized until a major change in economic conditions occurs. In the mulga country, as with some work in the brigalow lands, research aims at preventing deterioration of the resource rather than at extracting higher productivity.

In the 'red country', commercial ventures and limited research have shown that increased pasture growth results when the *Eucalyptus* dominant woodland is cleared. It is in these soil-vegetation groups that the potential returns from research are high, and the priority for new programmes should be centred here. The return will be: 1. from increased animal production on the more fertile areas with better moisture relations; and 2. from protection of some *Eucalyptus* woodlands where disturbance can lead to deterioration of the ecosystem. Research should aim at quantifying soil and plant changes associated with land clearing, and disclose the important factors in controlling woody species. Studies of the productivity and management of *Cenchrus ciliaris* are also indicated. Nutrient recycling studies will indicate those nutrients most likely to be implicated in long-term yield declines in pasture. Legumes could contribute to the production and grazing value of pastures in these groups and introduction and/or breeding programmes are warranted. Agronomic investigations aimed at determining the cropping potential of the higher rainfall and higher fertility sections of the 'red country' are required.

Next in importance is the study of the reliability of production on clay soils in the Condamine-Maranoa basin. The eastern part of the region is not subject to excessive drought occurrence (Everist and Moule 1952). The central part (Surat-St. George) is unusual in producing successful crops on arable soils on the one hand and recording some periods of major stock loss and frequent periods of short term loss of animal production on the other. With this conflict, it is difficult to determine whether production units should be drought-oriented or production-oriented or a compromise between both. To measure the influence of the available sources of dry matter on the stability of production, a systems analysis study is proposed for Groups 1, 2 and 3.

Native pasture investigations have received a low priority in the past. However, on clay soils, they contribute the major part of the animals' diet and should be included in new programmes. On brigalow lands, quantification of the growth rate, quality and use of important species will be required to simulate animal production effectively. On Groups 2 and 3, studies of condition and trend in the *Astrebla* grassland are indicated by deterioration in the perennial component and invasion by weed species.

In the mulga-eucalyptus shrubland, identification of the species making the major contribution to animal nutrition, on both virgin and cleared shrubland, will give direction to other aspects of the research programme. The productivity, regrowth characteristics and management of cleared shrubland in the presence of grazing animals should be priority studies.

Fields of research involving animals are not all restricted to particular soil-vegetation groups. Two important ones are the incidence of dystocia and eye cancer. The losses in breeding herd efficiency and revenue and the direct costs associated with both should be determined as a priority.

Productivity measurements for sheep and cattle grazing deferred pasture and forage crops should be determined. Specific production data for sheep on the more important soil-vegetation groups is an important deficiency. An understanding of the reasons for different levels of reproduction and wool growth on adjacent soil-vegetation groups could lead to improved husbandry practices.

With multi enterprise properties, the problem of what proportion of resources to allocate to each arises. Economic analysis involving optimizing techniques should be applied to provide guidelines for extension officers. The analysis should be repeated whenever major changes occur in the cost-value relationship.

A REGIONAL FACILITY

Land use in the southern brigalow lands and the 'red country' is transitional between the specialized crop production of the Darling Downs and the pastoral activities of the mulga region. As such, it diversifies into both cropping and pastoral pursuits. Will it then assume the research philosophy of the mulga region (drought-oriented with conservation of the native species) or that of the Darling Downs (production-oriented with high specialization)? On the basis of climatic analysis, the southern brigalow lands should be production-oriented but with a view to integration of the available alternatives of production, not to specialization. The 'red country' is more drought-prone but is well situated to apply a range of drought mitigation technology.

Because of this difference in production philosophy, a separate research group should be established whose charter would involve researching the 'red country' and co-operating in existing and proposed research on the southern brigalow lands. While this group could operate from outside the area, because of the magnitude of the work and because the area lies 250 km from existing facilities, efficiency would be increased by establishing a new facility either within or close by the area.

The 'red country' is included in the southern parts of Booringa and Bungil shires and the shires of Bendemere, Warroo and Balonne. This is a total of approximately 6 million hectares and a large part of the Roma Statistical Division. The centres available for location of a research group are St. George and Roma. St. George (population 2 200) is close to extensive areas of 'red country' and to a major irrigation development. However, while not as centrally located, Roma has the advantages of size (population 5 900), and situation on major communication links and an established extension facility. Roma is therefore preferred.

The advantages of close contact between research and extension personnel are recognized. The present situation is deficient in that Roma has a major extension facility operating with a minimum of research support. Charleville has an extensive research facility which is linked with a district office whose duties are largely regulatory. There is little chance of feedback of information between these two centres and efficiency is lost in both groups. This could be overcome in the Condamine–Maranoa region by establishing a facility at Roma (the Roma Technical Laboratory) whose charter would involve: 1. investigation into plant and animal production for the 'red country' and associated grassland communities; and 2. to provide an extension service to the region. In this development, a research group would link with the present extension group to form a regional technical laboratory. Proximity of staff would allow a free flow of information on situation analysis and problem definition on the one hand and on research findings as they develop on the other. Programme planning in the conceptual phase would involve officers from both extension and research groups.

This regional unit would require sufficient area to accommodate administration, extension, regulatory and research staff with office, laboratory, glasshouse and storage facilities. Although this could be achieved on the present site of the Roma Court House, the future expansion of all Government Departments would then be restricted. An alternative arrangement would be to establish separate facilities for the Department of Primary Industries on the outskirts of Roma.

Field research sites would be located with regard to soil type-rainfall variations. These need not be permanently staffed but should contain sufficient equipment for sampling and shelter for officers during periods of field work. Co-operation with the institutions active in research on the brigalow lands would add to the value of this regional facility.

The Roma Technical Laboratory would bring together a team of sufficient numerical strength to attract the advantages of technical support and equipment usually associated only with research units in major cities. It would also create the opportunity for the successful operation of a research-extension-production relationship critical to the optimum use of resources.

PART 3

DESCRIPTION OF RESOURCES

CLIMATE

CLIMATIC INFLUENCES. The following statement of climatic influences has been provided by the Regional Director, Bureau of Meteorology, Brisbane—

'The six shires considered in the project incorporate areas of the meteorological districts of Darling Downs East, Darling Downs West, Maranoa and Warrego, and with only minor topographical variations can be generally treated as a climatic entity. However, the comparative proximity of the eastern boundary of the evaluation area to the normal path of the moist south-easterly winds leads to a higher rainfall and generally less extreme temperatures in the east than in the more westerly parts.

'The summer rainfall pattern is controlled by high pressure systems (anticyclones), which move across the Great Australian Bight, and the equatorial (monsoonal) trough and associated low pressure belt which lie across the tropical north of Australia. Under this pressure distribution, moist tropical air permeates well inland and thunderstorms and rain periods occur.

'In winter, the equatorial trough moves north of the equator, allowing centres of intense mid latitude high pressure to cross the continent between 25°S and 30°S. The accompanying dry, stable air mass commonly brings fine and cool to mild days, although heavy frosts are a fairly normal occurrence over much of the area. At the same time, the southern cyclonic circulations (Antarctic lows) penetrate the southern sector of the continent. It is not unusual for a cold front to extend northwards from these centres, transporting the cold but comparatively moist air to at least the southern areas of Queensland. The resulting rainfall leads to the winter peak of the bimodal rainfall pattern.'

RAINFALL. The climatic features map (map 3) contains isohyets of mean annual, mean winter (April to September inclusive) and mean summer (October to March inclusive) rainfall for southern Queensland. The annual isohyets were extracted from unpublished isohyet maps prepared by the Queensland Irrigation and Water Supply Commission for a 50 year period from 1920 to 1969, while those for summer and winter were prepared in collaboration with the Bureau of Meteorology, Brisbane. The variation in the location of these isohyets between seasons and the annual total is less than might be anticipated. The summer isohyets, while parallel to the coast in coastal areas, progressively develop a north-west/south-east aspect inland. The winter isohyets are generally parallel with the coast but north of the Condamine–Maranoa basin vary in response to influence from the Great Dividing Range. The annual isohyets run in an approximate north-north-west/south-south-east direction with local influences prominent. The range in mean annual rainfall is approximately 450 to 650 mm. Median monthly rainfall is lower than mean monthly rainfall on all occasions for all centres, while some median annual rainfall figures (Dalby, Tara, Inglewood and Dirranbandi) closely approximate the annual mean (table 1). This is the normal relationship where short intervals of rainfall records are examined (Bureau of Meteorology 1975).

The proportion of winter to summer rainfall increases to the south (table 2). All centres located north of latitude 28°S (Surat, Tara, Millmerran, Charleville, Roma and Dalby) have 35% or less of their mean annual rainfall in winter while those to the south of this parallel (Bollon, Dirranbandi, St. George, Goondiwindi and Inglewood) have 36% or more of their rainfall during this period.

Analysis of rainfall records for the Condamine–Maranoa basin or part of it has been carried out by Isbell (1957), the Bureau of Meteorology (1961), Wheatley (1969) and Galloway *et al.* (1974).

Rainfall variability (the mean deviation from mean annual rainfall expressed as a percentage) is low (less than 25%) for only a small part of the total area of Queensland (Dick 1958). However, a large part of this area of low variability occurs in the Condamine–Maranoa basin (map 3). On the average, rainfall in the Condamine–Maranoa basin is approximately one-third less variable than in comparable areas in other parts of Queensland (table 3).

The frequency of 'wet' and 'dry' months has been determined using calculated precipitation/evaporation values and theoretical requirements for effective rainfall (Everist and Moule 1952). On this basis, Goondiwindi, Surat and Dalby record very low frequencies of drought of more than four 'dry' months' duration (table 4). Roma has experienced approximately twice as many droughts of such duration. Dirranbandi, Bollon and St. George record much higher frequencies and are comparable with Charleville, but these are still less than the traditionally droughty areas such as Longreach, Winton and Cloncurry. The implication of this very low and moderate drought frequency is discussed in terms of research and extension philosophy in Part 2.

TABLE 1

MEAN (a) AND MEDIAN (b) MONTHLY RAINFALL (mm) FOR 11 CENTRES IN SOUTHERN QUEENSLAND

Centre	Years of Record	Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Bollon	86	1885–1973	a. 59	54	51	30	31	32	27	24	26	35	35	52	454
			b. 53	34	28	18	19	20	21	14	16	23	24	42	426
Dirranbandi	83	1888–1973	a. 58	54	51	30	33	35	28	22	26	33	39	50	461
			b. 44	35	32	18	20	26	20	15	19	25	27	39	476
St. George	91	1881–1973	a. 71	63	54	31	35	35	32	26	28	38	43	52	506
			b. 54	42	35	17	22	24	26	17	22	27	30	39	481
Surat	92	1881–1973	a. 74	77	61	31	32	40	41	28	31	49	48	71	580
			b. 61	48	49	25	21	27	29	19	21	33	31	67	544
Tara	61	1912–1973	a. 82	67	64	34	33	39	37	27	27	55	63	86	612
			b. 64	43	49	27	24	32	32	17	18	48	53	67	616
Goondiwindi	94	1879–1973	a. 79	69	59	34	40	42	41	34	38	48	59	71	613
			b. 64	53	39	26	32	30	35	27	32	39	47	61	604
Millmerran	72	1900–1973	a. 93	78	62	32	36	43	38	33	34	60	65	83	654
			b. 78	65	53	19	26	30	33	33	29	50	55	72	661
Inglewood	90	1883–1973	a. 86	73	60	33	41	44	42	34	41	57	66	81	656
			b. 61	58	42	24	30	33	36	27	36	48	65	69	658
Charleville	82	1874–1973	a. 73	66	75	34	29	20	23	20	24	41	37	58	495
			b. 59	61	63	21	22	13	12	10	10	22	24	42	410
Roma	98	1870–1973	a. 81	76	65	32	35	36	37	26	33	49	54	68	590
			b. 64	57	47	21	25	24	24	18	18	39	39	57	556
Dalby	101	1870–1973	a. 86	77	68	35	32	42	41	30	40	57	70	93	669
			b. 78	58	56	30	23	30	34	21	33	50	57	77	674

Source: Derived from data published by the Bureau of Meteorology in Monthly Climate Data—Surface, Australia.

TABLE 2

PERCENTAGE OF RAINFALL RECEIVED DURING APRIL TO SEPTEMBER AT 11 CENTRES IN SOUTHERN QUEENSLAND

Centre	%
Bollon	37
Dirranbandi	38
St. George	37
Surat	35
Tara	32
Goondiwindi	37
Millmerran	33
Inglewood	36
Charleville	33
Roma	33
Dalby	33

TEMPERATURE AND RADIATION. Maps of solar radiant energy incidence have been developed for Australia (Hounam 1963). These show (map 3) that for the Condamine–Maranoa region in midsummer (January) solar radiation becomes more intense moving from north-east to south-west. In midwinter (July), the radiation isopleths for Queensland are generally latitudinally oriented and intensity of solar radiation in the Condamine–Maranoa region increases from south to north.

Average temperature measurements show only slight variations between centres (table 5). The table lists the towns of Bollon, St. George, Surat and Goondiwindi within the evaluation area and for comparison Charleville, Roma and Dalby.

TABLE 3

PERCENTAGE VARIABILITY OF ANNUAL RAINFALL FOR 11 CENTRES, CONTRASTED WITH THREE CENTRES WHERE DISTANCE FROM THE EASTERN COAST IS COMPARABLE BUT LOCATED IN CENTRAL QUEENSLAND

Centre	% Variability	
Bollon	29	Compare with Longreach—37% variability
Dirranbandi	28	
St. George	28	
Roma	27	Compare with Alpha—33% variability
Surat	24	
Tara	19	Compare with Emerald—25% variability
Goondiwindi	20	
Millmerran	18	
Inglewood	19	
Charleville	35	
Dalby	20	

Source: Calculated from data published by the Bureau of Meteorology in Monthly Climate Data—Surface, Australia.

TABLE 4

FREQUENCY OF DROUGHT OF DURATION OF MORE THAN 4 MONTHS IN 58 YEARS (1894–1951) AND MONTH OF COMMENCEMENT

—	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Bollon	1	0	3	3	4	0	2	2	0	2	3	5	25
Dirranbandi	3	1	1	6	3	1	3	1	1	2	2	7	31
St. George	3	0	2	4	3	1	1	1	2	3	2	4	26
Surat	0	0	0	1	2	0	1	0	1	1	1	1	8
Goondiwindi	1	0	0	1	2	0	1	0	1	0	0	1	7
Charleville	0	1	2	3	2	4	2	1	1	5	5	4	30
Roma	0	0	0	0	3	0	4	1	1	2	1	5	17
Dalby	0	1	0	0	2	2	1	1	1	0	0	0	8
Longreach	2	1	0	3	2	5	8	5	4	3	10	0	43
Winton	2	0	0	1	7	6	10	2	6	5	10	0	49
Cloncurry	0	1	0	2	3	19	14	3	3	4	2	1	52

Source: Everist and Moule (1952).

TABLE 5

AVERAGE MAXIMUM, MEAN AND MINIMUM TEMPERATURES (°C) FOR SUMMER*, WINTER* AND WHOLE YEAR FOR SEVEN CENTRES IN SOUTHERN QUEENSLAND AND SUNDRY LOCALITY INFORMATION FOR THESE CENTRES

—		Bollon	St. George	Surat	Goondiwindi	Charleville	Roma	Dalby
Elevation (m)		185	117	250	220	294	308	345
Distance inland (km)		560	470	405	310	680	430	180
Latitude (degrees and minutes South)		28°02′	28°03′	27°10′	28°30′	26°25′	26°32′	27°11′
Average Maximum	summer	34·8	34·8	34·4	33·8	35·9	34·3	31·7
	winter	19·7	19·6	20·2	19·2	24·9	20·6	19·7
	year	27·8	27·7	27·9	27·0	29·2	28·1	26·4
Average Mean	summer	27·7	27·7	27·1	26·5	28·5	26·9	24·8
	winter	12·3	12·6	12·7	12·4	13·2	12·7	12·4
	year	20·4	20·5	20·3	19·9	21·3	20·3	19·1
Average Minimum	summer	20·6	20·6	19·7	19·3	21·0	19·6	17·8
	winter	5·0	5·6	5·1	5·7	5·3	4·7	5·0
	year	13·0	13·3	12·7	12·7	13·4	12·5	11·8

Source: Average temperatures—Bureau of Meteorology (1956).

NOTE.—* Summer is taken as the months December, January and February.

† Winter is taken as the months June, July, August.

Roma to the north of the region has the lowest average minimum temperatures in winter and Goondiwindi in the south has the lowest average maximum temperatures in winter. Average summer temperatures increase with distance inland, reflecting the increasing incidence of solar radiation from east to west at this time of year. Thus Dalby in the east experiences the lowest and Charleville in the west the highest average temperatures in summer.

TABLE 6

AVERAGE NUMBER OF DAYS PER MONTH RECORDING TEMPERATURES IN EXCESS OF 32·2 °C (a) AND 37·8 °C (b) FOR FOUR CENTRES IN THE CONDAMINE–MARANOA BASIN

Centre:	St. George[1]		Goondiwindi[2]		Roma[2]		Dalby[2]	
—	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
Jan	24	9	21·4	4·6	23·1	8·4	15·0	2·0
Feb	18	3	16·3	1·2	19·0	3·0	10·2	0·6
Mar	13	1	12·7	0·2	14·9	1·1	6·0	0·1
Apr	1	..	0·7	0·1	2·7	0·1	0·7	..
May	..	..	0·1	..	..	..	..	..
Jun	..	..	..	..	..	..	..	..
Jul	..	..	..	..	..	..	..	..
Aug	..	..	0·1	..	0·2	..	..	..
Sep	1	..	0·1	..	1·9	..	0·5	..
Oct	7	..	3·7	..	8·6	0·8	3·2	0·1
Nov	16	3	12·6	1·7	16·7	2·9	8·8	0·5
Dec	23	7	20·1	5·3	22·6	7·3	15·2	1·7
Total year	103	23	88·7	13·1	109·7	23·6	59·6	5·0

Source: [1] Wheatley (1969).

[2] Bureau of Meteorology (1961).

TABLE 7

AVERAGE NUMBER OF DAYS PER MONTH OF FROST OCCURRENCE

Centre	LH	Apr	May	Jun	Jul	Aug	Sep	Oct	Year
Bollon	L	0·3	1·7	—	—	—	1·0	0·1	
	H		0·6	3·6	3·9	3·1	0·1		11·3
St. George	L	0·8	4·2	5·4	3·1	0·5	0·2		
	H		0·1	1·8	2·4	0·6			4·9
Surat	L	0·2	1·7	—	—	—	1·4		
	H		0·6	5·0	4·1	3·3			13·0
Goondiwindi . .	L	0·1	0·5	4·8	4·9	5·1	0·7		
	H			1·9	1·4	1·2	0·1		4·6
Charleville	L		1·1	5·9	7·1	4·5	1·0		
	H		0·1	2·8	2·5	1·7	0·1		7·2
Roma	L	0·2	2·0	—	—	—	3·0	0·3	
	H		0·6	6·8	6·2	4·3	0·5		18·4
Dalby	L	0·3	1·9	—	—	—	2·1		
	H			4·2	4·3	3·7	0·5		12·7

Source: Foley (1945).
Legend: L = light frost, screen temperature between 0 and 2·2 °C.
H = heavy frost, screen temperature 0 °C or less.
NOTE.—For months where there are more than three days of heavy frost, entries under light frosts have been omitted.

The average numbers of day per month recording temperatures in excess of 32·2°C and 37·8°C have been used to demonstrate the occurrence of heat waves (table 6). Incidence of such heat-waves varies from year to year, being less in wetter years because of the modifying effect of cloud and rain-bearing winds (Skerman 1956). Periods of high temperature are not uncommon in the Condamine–Maranoa basin but are not excessive when compared with conditions in central and north Queensland. Heat-waves become more common with distance inland and to the north of the region.

The occurrence of frost in the region shows no clear trend with relation to elevation, latitude or distance inland (table 7). Roma and Dalby have the shortest frost-free period; St. George and Goondiwindi have the greatest number of frost-free days with first frosts occurring, on average, later than for other centres, and last frosts occurring earlier (table 8).

EVAPORATION AND HUMIDITY. Few direct measurements of evaporation are available for centres in the Condamine–Maranoa basin. Average daily evaporation figures recorded at the Inglewood Research Station (Queensland Department of Primary Industries) show that the amount of evaporation in summer is more than twice that in winter (table 9).

Histograms of evaporation (map 3) have been constructed from calculated values developed by Russell (personal communication 1973) who used isohyets and evaporation isopleths to interpolate values for intermediate centres. There is a considerable increase in average annual evaporation from east to west (1 396 mm at Warwick to 2 185 mm at Charleville) (table 10).

TABLE 8

FIRST AND LAST FROSTS OF THE SEASON AND AVERAGE FROST-FREE PERIOD

Station	Years of record		First frost			Last frost			Average frost free period (days)
			1	2	3	1	2	3	
Bollon	1913–43	L	May 27	21	Apr 3	Sep 5	14	Oct 10	263
		H	Jun 17	26	May 7	Aug 14	9	Sep 13	
St. George	1913–43	L	May 28	16	May 1	Aug 26	12	Sep 16	274
		H	Jun 19	14	May 10	Aug 4	13	Sep 2	
Surat	1908–43	L	May 22	22	Apr 24	Sep 5	10	Oct 12	259
		H	Jun 12	19	Apr 24	Aug 12	9	Sep 4	
Goondiwindi	1908–43	L	May 31	12	Apr 17	Aug 29	10	Oct 16	274
		H	Jun 30	20	May 19	Aug 3	21	Sep 13	
Charleville	1908–43	L	May 30	14	Apr 22	Aug 29	13	Oct 2	273
		H	Jun 17	11	May 26	Aug 11	16	Sep 13	
Roma	1908–43	L	May 21	14	Apr 17	Sep 18	12	Oct 12	244
		H	Jun 8	12	May 2	Aug 20	11	Sep 22	
Dalby	1908–43	L	May 18	15	Apr 17	Sep 13	9	Oct 1	246
		H	Jun 17	11	May 8	Aug 23	12	Sep 16	

Source: Foley (1945).

Legend: L = light frost, screen temperature between 0 and 2·2°C

H = heavy frost, screen temperature 0°C or less

1 = average date of first and last occurrence (for ten year period 1930–1939)

2 = mean deviation from average date (days)

3 = recorded date of first and last occurrence

TABLE 9

AVERAGE DAILY EVAPORATION (MM) FOR MONTHLY INTERVALS RECORDED AT THE INGLEWOOD RESEARCH STATION, WHETSTONE

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1964 ..	6·9	6·1	4·0	3·3	2·0	1·3	1·6	2·0	2·6	3·8	5·5	7·6
1965 ..	7·5	6·3	6·1	4·3	3·0	1·8	2·0	2·3	3·3	5·3	8·0	4·6
1966 ..	6·1	5·6	5·6	3·8	2·3	1·8	1·8	2·0	2·8	4·3	5·6	5·1
Daily average ..	6·8	6·0	5·2	3·8	2·5	1·6	1·8	2·1	2·9	4·5	6·3	5·8

Source: Records, Inglewood Research Station 1964 to 1966.

Relative humidity is higher in winter than in summer in the study area (table 11). This is contrary to the pattern in northern inland areas of Queensland where summer and early autumn are the periods of highest humidity: Richmond has 57% average index of mean relative humidity in March and 36% in September. The higher humidity in winter is a reflection of the southerly winter rainfall influence.

WIND. Although there is considerable variation between centres, the chief winter wind influence is southerly (S.W. to S.E.) (map 3) while in summer the greatest percentage of winds is from a northerly direction (N.W. to N.E.).

However, winds may come from any direction at any time of year. Wind speeds in the area are generally low, frequency of occurrence per year of average wind speeds of less than 13 km per hour being 69% for Goondiwindi, 75% for Dalby and 87% for Roma (Bureau of Meteorology 1961). The greatest frequency of low wind speeds occurs in winter. Strong wind gusts are most likely to accompany thunderstorms.

THUNDER DAYS. Thunderstorms bringing heavy rain or hail as well as strong wind gusts occur in October, November and December. The number of thunder days decreases with distance westward from the range in the Darling Downs region and southward from the Great Dividing Range north of Roma and Miles (map 3). Hail can be expected one year in three in the south-east, with the likelihood decreasing to the west and north.

DAYLIGHT HOURS AND CLOUDINESS. The Queensland Department of Primary Industries' Inglewood Research Station is the only centre in the region which records sunshine hours. Although cloudiness is greater in summer than in winter, sunshine hours are also greater in summer (table 12) because of the longer period of daylight.

Generally there is more cloud in the afternoon than in the morning (table 12). Conditions are least cloudy in the late winter and early spring. There is some trend to less cloud to the west and south.

TABLE 10

MONTHLY AND ANNUAL AVERAGE EVAPORATION (MM) FOR ST. GEORGE, WARWICK AND CHARLEVILLE

—	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
St. George													
No. of years ..	35	35	36	34	35	35	35	35	34	34	33	33	
Evaporation ..	266	219	200	142	94	64	63	90	137	194	229	256	1 954
Warwick													
No. of years ..	42	40	42	44	44	45	42	42	44	44	41	43	
Evaporation ..	177	146	143	105	75	53	55	70	98	136	163	176	1 397
Charleville													
No. of years ..	46	46	47	47	47	46	46	44	45	46	47	47	
Evaporation ..	282	236	212	164	113	77	81	109	160	214	256	281	2 185

Source: Derived from data published by the Bureau of Meteorology in Monthly Climate Data—Surface, Australia (between 1921 and 1973).

TABLE 11

AVERAGE INDEX OF MEAN RELATIVE HUMIDITY EXPRESSED AS A PERCENTAGE FOR SEVEN CENTRES IN SOUTHERN QUEENSLAND

Centres	Years of Record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Bollon ..	25	48	52	55	59	62	68	69	63	53	53	47	49	55
St. George ..	29	45	51	51	55	61	66	65	58	51	47	46	47	52
Surat	28	56	57	61	63	68	70	69	64	59	57	56	56	61
Goondiwindi ..	29	54	56	58	63	65	68	66	63	57	53	52	56	58
Charleville ..	29	44	47	50	52	59	65	61	53	47	42	42	43	49
Roma	26	51	54	56	58	57	66	64	57	52	48	48	50	55
Dalby	30	59	61	64	65	67	70	68	63	59	49	54	57	61

Source: Bureau of Meteorology (1956).

TABLE 12

AVERAGE DAILY CLOUDINESS, EXPRESSED IN EIGHTHS OF THE SKY COVERED (9 A.M. AND 3 P.M.) AND AVERAGE DAILY SUNSHINE (HOURS) AT INGLEWOOD RESEARCH STATION, SHOWN FOR MONTHLY INTERVALS

Centre	Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Bollon .. 1957–73	9 a.m. 3 p.m.	2·4 3·7	2·0 3·4	2·4 3·4	1·8 2·7	2·3 2·9	2·2 2·7	1·9 2·3	1·8 2·2	1·3 2·2	2·2 2·9	2·0 3·1	2·4 3·6	2·1 2·9
St. George .. 1962–73	9 a.m. 3 p.m.	2·6 3·9	2·8 3·6	2·7 4·1	2·1 3·3	2·4 3·4	2·7 3·2	2·3 2·3	2·1 2·9	1·7 2·6	2·4 3·3	2·2 3·4	2·4 4·1	2·4 3·3
Surat 1962–73	9 a.m. 3 p.m.	2·8 4·1	2·3 3·5	3·0 4·2	1·8 3·6	2·4 3·0	2·5 2·4	1·9 2·1	2·1 2·9	2·1 2·6	2·0 3·0	2·1 3·4	2·8 3·6	2·3 3·2
Goondiwindi .. 1957–73	9 a.m. 3 p.m.	2·2 3·4	2·2 3·5	2·1 3·4	1·8 2·8	2·0 2·8	2·7 3·2	2·3 2·7	1·8 2·3	1·6 2·3	1·9 2·7	2·3 3·3	2·3 3·7	2·1 3·0
Charleville .. 1957–73	9 a.m. 3 p.m.	2·8 4·5	2·8 4·5	2·6 4·0	2·3 3·5	2·9 3·4	2·8 2·8	2·1 2·4	1·7 2·2	1·4 2·1	2·1 3·1	2·3 3·7	2·4 4·2	2·4 3·4
Roma 1957–73	9 a.m. 3 p.m.	3·2 4·4	3·2 4·4	3·1 4·7	2·1 3·6	2·7 3·3	2·5 2·9	2·0 2·4	2·0 2·5	1·5 2·4	2·4 3·2	2·2 3·7	2·5 4·3	2·5 3·5
Dalby 1957–73	9 a.m. 3 p.m.	3·4 4·0	3·3 4·1	3·0 4·0	2·4 3·5	2·5 3·4	3·0 3·6	2·4 3·0	1·8 2·6	1·8 2·6	2·4 3·0	2·9 3·5	2·9 3·9	2·6 3·4
Inglewood (9 year average) Hours of sunshine		9·25	9·45	8·30	8·60	7·37	7·05	7·30	8·05	8·75	9·11	9·72	9·10	..

Source: Derives from data published by the Bureau of Meteorology in Monthly Climate Data—Surface, Australia.

SOILS

The soils of the region (map 4) have been described in the terms used in the Atlas of Australian Soils, Sheet 3 (Northcote 1966) and Sheet 4 (Isbell *et al.* 1967), each of which covers part of the Condamine–Maranoa basin. In addition, the relevant families as described by Galloway *et al.* (1974) are shown for most mapping units. The Northcote (1971) classification is shown for each mapping unit. The reader is referred to the original publications for further information.

Although 35 of the mapping units employed in the Atlas of Australian Soils are present in the evaluation area, only seven of these individually include more than 300 000 hectares (table 13). These are the CC17, CC20, My3, My5, Oc21, Ro4 and Va24 groups and they account for three-quarters of the study area.

DESCRIPTION—SOILS WITH UNIFORM TEXTURE PROFILES (*U*). B10, B12 (*Uc1.2*). 89 901 ha. Sand soils of minimal development-siliceous sands. The major area of B10 (52 940 ha) occurs along the Maranoa River north-west of St. George. To the west and associated with red earths are discrete areas of B12 (36 961 ha). The former are low dunes, sandy banks, or flat sandy rises slightly elevated above the surrounding clay plains and often related to functional or non-functional drainage lines. The latter are dunes and sandy plains with some dunes. The appropriate or approximate equivalent name is a siliceous sand (Stace *et al.* 1968).

Galloway *et al.* (1974) have placed the B10 association in the uniform sandy soils group where it contains 26% of Fa family and 26% of Fb with the duplex soils Dh (8%), Di (8%) and Dj (14%) as minor families. The major families are described as a red sand (Fa family) and yellow and brown sands (Fb family). Soil reaction is acid to neutral. The B12 association is also grouped with the uniform sandy soils where it contains 65% of Fa family and 25% of Fb.

AB2 (*Uc5.2*). 6 133 ha. Sand soils with weak horizon formation—deep red sands with an earthy fabric. Minor areas of this group occur within the My5 association in the western part of the Balonne shire. They are described as gently undulating sandy plains with an occasional low dune.

Galloway *et al.* (1974) have grouped the AB2 unit with the uniform sandy soils, and its description is the same as that shown for B12.

Fz1, Fz2, Fz3, Fz7 (*Um1.4*). 296 014 ha. Loamy soils of minimal development—shallow dense loamy soils. The major area of Fz1 (91 193 ha) occurs to the north-east of St. George. Scattered smaller areas of Fz2 (114 920 ha) occur throughout the brigalow lands while the occurrence of Fz3 (88 126 ha) is predominantly in the east where it is associated with a large area of duplex soils. The area of Fz7 (1 775 ha) is minor. The Fz1 soils are described as hills, ranges of hills, low hilly ridges, or dissected tableland remnants (mesa, butte or cuesta forms) with shallow loams usually containing or covered by siliceous gravel, with many rock outcrops and boulders of siliceous or ferruginous materials. The Fz2 are low hills and stony ridges, some mesa and butte-like residuals with shallow mostly stony soils; and the Fz3 soils are low hills and dissected low ranges, often with mesa or butte-like remnants where the chief soils are shallow stony loamy soils. Stace *et al.* (1968) refer to these soils as red earths.

TABLE 13

AREA OF MAPPING UNITS (HA) AND DESCRIPTION OF DOMINANT SOILS IN THE CONDAMINE–MARANOA BASIN

Map Unit	Description	Area	Totals
1. Soils with Uniform Texture Profiles			
	Sand soils of minimal development		
B10	Siliceous sand	52 940	
B12	Siliceous sand	36 961	89 901
	Sand soils with weak horizon formation		
AB2	Sand with an earthy fabric	6 133	6 133
	Loamy soils of minimal development		
Fz1	Coherent and shallow loamy soils	91 193	
Fz2	Coherent and shallow loamy soils	114 920	
Fz3	Coherent and shallow loamy soils	88 126	
Fz7	Coherent and shallow loamy soils	1 775	296 014
	Loamy soils having an A_2 horizon		
LM1	Porous peds evident in B horizon	54 554	54 554
	The cracking clays		
CC17	Deep, self mulching	862 703	
CC19	Deep, self mulching	96 358	
CC20	Deep, self mulching	1 070 753	2 029 814
MM1	Brown, self mulching	121 860	
MM2	Brown, self mulching	45 032	
MM4	Brown, self mulching	109 432	276 324
	Total		2 752 740
2. Soils with gradational texture profiles			
	Red earths		
My1	Neutral reaction trend	40 351	
My2	Neutral reaction trend	40 512	
My3	Neutral reaction trend	774 900	
My4	Neutral reaction trend	92 646	
My5	Neutral reaction trend	1 089 153	2 037 562
	Grey earths		
Mq1	Alkaline reaction trend	11 944	
Mq2	Alkaline reaction trend	67 790	79 734
	Total		2 117 296
3. Soils with contrasting (duplex) texture profiles			
	Hardsetting loamy soils with red clayey subsoils		
Oc21	Alkaline reaction trend—sporadically	791 524	
Oc22	bleached A_2 horizon: pedal subsoils	16 463	807 987
	Hard setting loamy soils with brown clayey subsoils		
Rt1	Neutral reaction trend—sporadically bleached A_2 horizon	28 891	28 891
Ro3	Alkaline reaction trend—whole coloured	189 972	
Ro4	subsoil—sporadically bleached A_2 horizon	499 383	689 355
	Friable loamy soils with brown clayey subsoils		
Rz1	Neutral reaction trend—sporadically bleached A_2 horizon	36 639	36 639
	Hard setting loamy soils with yellow clayey subsoils		
Si2	Alkaline reaction trend—sporadically	150 590	
Sl2	bleached A_2 horizon	6 779	157 369
	Hard setting loamy soils with mottled yellow clayey subsoils		
Va24	Alkaline reaction trend—bleached	337 818	
Va28	A_2 horizon	14 526	352 344
	Sandy soils with mottled yellow clayey subsoils		
Wa13	Acid reaction trend—bleached A_2	161 242	
Wa15	horizon: pedal subsoils	6 133	167 375
	Hard setting loamy soil with dark clayey subsoils		
HG1	Alkaline reaction trend—sporadically	125 895	
HG2	bleached A_2 horizon	58 428	184 323
	Total		2 424 283
	Total for evaluation area		7 294 319

Galloway *et al.* (1974) consider that the most prominent members of this group are massive earths with 35% Eg family and 10% Ea family. They consider that the shallow loamy soils of Gb family (skeletal soils) comprising 35% of the area, are the minor type. The Eg family are described as shallow red earths, generally gravelly and acid throughout while the Ea family are neutral to acid loamy red earths.

LMI (*Um4.3*). 54 554 ha. Loamy soil having an A_2 horizon—porous peds evident in B horizon. Small areas of these soils occur along the Dumaresq River and Macintyre Brook east of Goondiwindi and on the Weir River. They occur in the form of river terraces and levees.

Surface soils are slightly acid to neutral and calcium is the dominant exchangeable metal cation (Isbell 1957). Available phosphorus is high (45–90 p.p.m.) while total nitrogen, soluble salt and chloride contents are low. The related great soil group is a regosol (Isbell *loc. cit.*).

CC17, CC19, CC20 (*Ug5.24, .25*). 2 029 814 ha. Cracking clay soils—grey, self-mulching, deep. Of the cracking clays the CC19 (96 358 ha) are only an isolated occurrence in the extreme west of the Balonne Shire. The most extensive areas of CC17 (862 703 ha) soils occur along the Balonne, Moonie, Macintyre and Barwon Rivers below St. George, Nindigully and Goondiwindi respectively. They occur as plains of slightly gilgaied cracking clays associated with major and minor functional and non-functional drainage-ways.

The CC20 (1 070 753 ha) soil association occurs as a broad north-south sweep across the Condamine–Maranoa basin, broken frequently by outcrops of My3, Fz1 and Fz2 and areas of Ro4, HG1 and HG2 soil associations. These cracking clays also occur to the east and west of the major area as isolated areas in Va24 and My5 soils respectively. They are commonly referred to as the grey soils of heavy texture although Stace *et al.* (1968) consider the appropriate or approximate equivalent name to be grey clays.

The following analytical data of CC17 and CC20 soils is reported by Isbell (1957). Soil reaction for the CC17 group is slightly alkaline to neutral throughout the profile. Clays of the surface 15 cm are almost fully base saturated with calcium as the dominant exchangeable cation and magnesium also prominent. Exchangeable sodium reaches significant levels in some profiles (up to 10% of total exchangeable metal cations). Chloride content is high, below 30 cm, as are total soluble salts. Organic carbon and total nitrogen are both low and the C:N ratio ranges from 10 to 15. Available phosphorus ranges from 15 to 30 p.p.m. in the surface soil.

The CC20 soils are strongly gilgaied and the vertical interval between puff and depression may be as great as two metres although more commonly it approaches one metre. Soil reaction is variable but commonly is alkaline at the surface of both puff and depression and rapidly changes to acid often at a shallow depth. The clays of alkaline (or sometimes neutral) reaction are 80 to 90% saturated but the exchangeable hydrogen of the acid horizon is only 30% of the total exchangeable cations and seems insufficient to explain the low pH values recorded. Where soils are alkaline, free carbonate occurs and calcium is the dominant exchangeable metal cation but exchangeable magnesium becomes dominant with acid reaction. Sodium may be a prominent part of the total exchangeable metal ions (up to 30%). Chloride and total soluble salt are normally high while the C:N ratio ranges from 8 to 10 for the puff with the depression slightly higher. Available phosphorus figures are low to very low except in certain depression profiles. Less than 10 p.p.m. P is often recorded for all sections of the profile.

Galloway *et al.* (1974) have shown the CC20 soils as a mosaic of gilgaied Ca family (40%) and non-gilgaied Cb family (10%) with duplex soils (Da, Db; 8 to 10%), brown and grey-brown soils (Bb, 6%; Bc, 8%) and/or loamy red earths (Ec, 12%; Eb, 8%) as minor families. The Ca family are very deep, mainly grey clays with pH neutral at the surface, alkaline between 60 and 90 cm and grading to medium to very strongly acid in the lower profile. The Cb family are only moderately deep to deep grey, brown or reddish brown soils, alkaline at or near the surface and acid beneath.

The CC17 and CC19 associations contain 70% of Ce family and 20% Be (Galloway *et al. loc. cit.*). The Ce family, formed on alluvium, are very deep grey and brown medium to heavy clays, neutral to mildly alkaline at the surface and becoming strongly alkaline below 30 cm depth. Their phosphorus status is fair to very high (20-200 p.p.m.); calcium and magnesium are the dominant and subdominant exchangeable metal cations respectively. The Be family are brown and grey-brown soils formed on alluvium.

MM1, MM2, MM4 (*Ug5.32, .34, .37*) 276 324 ha. Cracking clay soils—brown, self mulching. Major occurrences are of MM1 (121 860 ha) in the vicinity of Talwood, MM4 (109 432 ha) east of Surat and MM2 (45 032 ha) south of the Glenmorgan-Meandarra road. As a group, they are gently undulating or undulating cracking clay plains except for the latter where linear gilgai occurs on slopes; very slight to moderate microrelief occurs on MM4 and MM1 soils respectively. Commonly included with the grey and brown soils of heavy texture (Stephens 1962), Stace *et al.* (1968) refer to them as grey or brown clays.

The MM1 soils have neutral to alkaline reaction at the upper levels and become extremely acid at depth (Isbell 1957). Calcium is the dominant exchangeable metal cation in the upper section and magnesium at depth. Total soluble salts and chloride are high below 30 cm and available phosphate low. Linear gilgai can be present in the MM2 and MM4 soils (Isbell *loc. cit.*) and the soil reaction may be neutral to slightly acid in the depression whereas elsewhere moderately alkaline conditions exist. Calcium is the dominant exchangeable metal cation and sodium is usually present in significant amounts in all but the surface horizons. Available phosphorus is fairly low in the slope soils (17 p.p.m. or less) but high in the grey soils of the valley floors (40 to 50 p.p.m.).

Galloway *et al.* (1974) subdivided the major area of MM4 soils east of Surat into two types, the major part a loamy duplex soil described with the Ro4 soil association and the remainder a cracking clay of Cc family (65%) with brown and grey-grown soils of Bd and Bf families (12% and 11% respectively) as minor types. The cracking clays of the Coomrith-Inglestone area (MM2) are similarly subdivided while the MM1 soils of the area south-west and north of Talwood are shown as loamy duplex soils.

The Cc family occurs mainly on undulating Mitchell grass 'downs'. The soils are self-mulching with linear gilgai present and depth ranging from 65 to 150 cm, the deeper soils occurring generally on lower slopes. Soil reaction is neutral to mildly alkaline at the surface and strongly alkaline below 30 cm. Analytical data show medium to high cation exchange capacity and 100% base saturation with calcium and magnesium dominant, and very low to medium available phosphorus (8-30 p.p.m.).

SOILS WITH GRADATIONAL TEXTURE PROFILES (*G*). My1, My2, My3, My4, My5 (*Gn2.12*). 2 037 562 ha. Red earths, natural reaction trend (no A_2 horizon present). The red earths are in the western part of the Condamine-Maranoa basin and occupy relatively small areas scattered throughout. Minor types My1 (40 351 ha) and My4 (92 646 ha) are extensive to the west of the evaluation area. My2 soils (40 512 ha) occur as ridges in the area between the Balonne and Moonie Rivers. My5 (1 089 153 ha) occupy large areas of Balonne Shire while My3 (774 900 ha) have major occurrences east of the Balonne and Moonie Rivers. The My1 soils are described as gently to strongly undulating tablelands, tableland remnants, and plains broken by some steeper hilly areas; the My2 soils are undulating ridges broken by broad flat valleys; the My3 are gently undulating plains with occasional high ridges and cuesta-like scarps; the My4 are gently undulating plains with dunes and occasional low stony ridges; and the My5 are plains with occasional low dune ridges. The name red earth is accepted by most workers.

The My3 soils are acid throughout (Isbell 1957). The total exchangeable metal cations are low with calcium predominant but magnesium may show a rise with depth and sodium is low throughout. Total soluble salts and chlorides are fairly low as is total nitrogen. Available phosphorus is low in all horizons (10 p.p.m.).

Galloway *et al.* (1974) have classified the My3 and My2 soils as composed mainly of Ea family (up to 75%), gravelly loamy red earths with some occurrence of gravelly red and yellow earths and duplex soils. The My5 association are predominantly Eb family (58-67%), loamy red earths, with some deep red sandy soils of Fa family (15%). The My1 and My4 soils are poorly represented in the Condamine-Maranoa basin and no attempt has been made to relate them to the soil map presented in the Balonne-Maranoa report.

Of the seven families which make up the massive earth group, the most important are the gravelly loamy red earths with neutral to acid reaction (Ea) and the loamy red earths with neutral to acid reaction (Eb). The former have profiles generally more than 90 cm deep and they contain, on average, 10 to 20% of fine gravel (6 to 25 mm in diameter) consisting of fragments of ferruginized sedimentary rocks. Chemical properties vary and in one profile soil reaction was acid throughout with calcium and magnesium co-dominant in the exchange complex and available phosphorus was very low at 5 p.p.m. In another, the soil reaction was mildly alkaline in the subsoil with magnesium dominant and sodium subdominant. The Eb family are similar but are gravel-free, more than 100 cm deep, medium to slightly acid at the surface and grading to neutral or mildly alkaline at depth.

Mq1, Mq2 (*Gn2.83*). 79 734 ha. Grey earth, alkaline reaction trend. Small areas of Mq1 (11 944 ha) and Mq2 (67 790 ha) soils occur in the south-west of the Condamine-Maranoa basin adjoining red earth and cracking clay associations. The former are described as very gently undulating plains with some dunes and the latter as plains with mostly moderate to strong gilgai microrelief or numerous sink-hole depressions.

Galloway *et al.* (1974) consider that the cracking clays are the dominant type in this association and classifies them with a predominance of families Ca and Cb which have been described previously.

SOILS WITH CONTRASTING (DUPLEX) TEXTURE PROFILES (*D*). Oc21, Oc22 (*Dr2.33*). 807 987 ha. Hard-setting loamy soils with red clayey subsoils—sporadically bleached A_2 horizon, pedal subsoils (alkaline reaction trend). Extensive areas of Oc21 (791 524 ha) occur between the Maranoa and the Balonne Rivers and in association with a range of soils in a band from Glenmorgan to Mungindi. They are described as very gently undulating plains or occasional low flat terraces fringing drainage lines. The area of Oc22 (16 463 ha) is minor. These soils are commonly referred to as solodic soils.

The soil reaction of the A horizon is usually neutral but there is commonly a rise in pH to 8 or slightly higher in the B horizon (Isbell 1957). Calcium is the dominant exchangeable metal cation in the former and magnesium may rise to dominance in the latter horizon. Exchangeable potassium is high in the A horizon as is the chloride content. Available phosphorus is variable at the surface and ranges from 20 to 110 p.p.m while values at depth show a marked drop.

Galloway *et al.* (1974) consider that the Oc21 soil association can be subdivided into clay soils, brown and grey-brown soils, red earths and deep red or yellow sandy soils leaving as the predominant texture contrast type the sandy or loamy duplex soils (Dh, 30%; Di, 30%; Dj, 10%) with deep cracking clays (Ce, 10%), and sandy or loamy duplex soils (Dh, 16%; Di, 14%; Dj, 13%) with loamy alkaline red earths (Ec. 40%). Thus, in that area between the Balonne and Maranoa Rivers, large areas mapped as Oc21 association are shown as cracking clays and massive earths, with duplex soils as minor families only. West of Talwood the Oc21 soils have been remapped as massive earths, but east of the Moonie River they are mapped as the cracking clays referred to above. The Dh family are thin soils, slightly acid to neutral in reaction at the surface and moderate to strongly alkaline subsoil, 100% base saturated with calcium dominant and magnesium subdominant. Available phosphorus is high at 57 p.p.m. The Di soils also have 100% base saturation, predominantly with calcium and magnesium and high available phosphorus (60 p.p.m.). The Dj are less fertile with neutral to slightly acid subsoils. The calculation of the area of Oc21 soil association (table 13) was based on Sheets 3 and 4 of the Atlas of Australian Soils (Northcote 1966; Isbell *et al.* 1967) and will thus vary from that shown by Galloway *et al.* (*loc. cit.*).

Rt1 (*Db1.32*). 28 891 ha. Hard-setting loamy soils with brown clayey subsoils, sporadically bleached A_2 horizon (neutral reaction trend). A limited area of this association occurs along the Maranoa River. It is described as level or very gently undulating alluvial plains fringing major drainage lines and is another of those grouped under the common name of solodic soils.

Galloway *et al.* (1974) consider the major soil type to be medium to heavy clays with 70% of Ce (deep soils) and 20% of brown and grey-brown soils of Be family. They are subject to overflow flooding of varying frequency, depth and duration and have been described under CC17 soil association.

Ro3, Ro4 (*Db1.33*). 689 355 ha. Hard-setting loamy soils with brown clayey subsoils, sporadically bleached A_2 horizon (alkaline reaction trend). The location of the Ro3 (189 972 ha) soils is between the Balonne and Moonie Rivers. The Ro4 (499 383 ha) soils are distributed throughout the cracking clay soils. The former are described as plains or low levee-type rises associated with both functional and non functional drainage lines and the latter as gently undulating plains with hard alkaline brown soils. Both are commonly referred to as solodic soils.

In the Ro4 soils the A horizon ranges from slightly acid to neutral reaction, the B horizons are neutral to moderately alkaline but in the deeper subsoils below 127 cm pH values commonly drop to give strongly acid conditions (Isbell 1957). Calcium is normally the dominant exchangeable metal cation in both A and B horizons. Magnesium and sodium, particularly the latter, show an increase in the B horizon. The chloride and total soluble salt contents are low in the A horizon but increase with depth. The C:N ratio is of the order of 10. Available phosphorus ranges from low to moderate in the A horizon (13 to 40 p.p.m.), but is generally very low in the B horizon (10 p.p.m.).

Galloway *et al.* (1974) list the Ro3 types with sandy or loamy duplex soils (Dh, Di, Dj families) and deep cracking clays soils (Ce family) described previously (Oc21). Boundaries for the Ro4 association have been extensively modified. Many soils of this description are included with the cracking clays and many soils previously grouped as cracking clays now appear in this group. The unit is described as loamy duplex soils containing 22% Da and 16% Db families with gilgaied (Ca, 18%) and non-gilgaied (Cb, 16%) cracking clay soils. The Da family have thin loamy surface horizons over dark reddish brown to dark brown, strongly alkaline, medium to heavy clay subsoils; profiles are generally more than 90 cm deep. Reaction in the surface horizons is medium acid to neutral, and this grades from strongly alkaline to moderately acid in the deeper layers of some profiles. Base saturation is 100% predominantly with calcium and magnesium but sodium comprises 30 to 40% of the exchange capacity at depths below 36 cm. The available phosphorus is low in the surface horizons ranging from 15 to 20 p.p.m. These soils commonly occur in catenary sequences or in mosaics with gilgaied clays (Ca family described previously) and in places they intergrade with the solodized solonetz and related soils of Dd and De families described elsewhere (Va24, 28).

Rz1 (*Db3.32*). 36 639 ha. Friable loamy soils with brown clayey subsoils, sporadically bleached A_2 horizon (neutral reaction trend). A small area of this association occurs south of St. George. It is described as undulating sandy plain fringing drainage lines and with prominent elongate sandy dunes.

Galloway *et al.* (1974) described the dominant member of this group as a deep red or yellow sandy soil (Fa, 26% and Fb 26%) and they include the duplex soils (Dh, 8%; Di, 8% and Dj, 14%) as minor types. The major families have been described with the B10 and B12 associations and the minor ones with the Oc21 soils.

Si2 (*Dy2.33*). 150 590 ha. Hard-setting loamy soils with yellow clayey subsoils, sporadically bleached A_2 horizon (alkaline reaction trend). The occurrence is associated with the Balonne and Weir Rivers. Soils are described as plains or low levee-type rises associated with both functional and non- functional drainage lines and are solonetz soils.

Galloway *et. al.* (1974) include this association with the Oc21 type suggesting that its major components are of Dh, Di and Dj families which have been described previously.

S12 (*Dy2.43*). 6 779 ha. Hard-setting loamy soils with yellow clayey subsoils, bleached A_2 horizon (alkaline reaction trend). One occurrence, located at Yelarbon, is of curiosity value only and is described simply as a plain. It is one of the solodic soils and other descriptions are not available from the area.

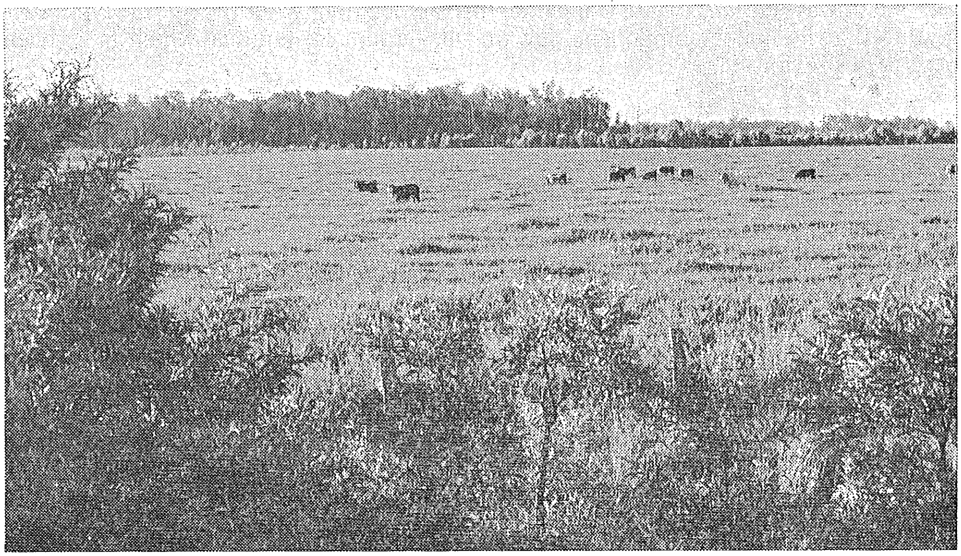
Although the surface reaction is moderately alkaline the remainder of the profile is strongly alkaline at pH 10 and higher (Isbell 1957). Magnesium is the dominant exchangeable metal cation in the A_1 horizon. In the A_2, sodium shows a sharp rise while calcium and magnesium remain constant. In the B_2 horizon both calcium and sodium show a marked rise with sodium occupying 46% of the total exchangeable metal cations. Chloride and total soluble salt contents show an increase to a maximum in the B_{22} horizon, but are not unduly high. Available phosphorus is low in the A horizon but increases in the B_2 and lower horizons.

Va24, Va28 (*Dy3.43*). 352 344 ha. Hard-setting loamy soils with mottled yellow clayey subsoils, bleached A_2 horizon (alkaline reaction trend). Extensive areas of Va24 (337 818 ha) and some Va28 (14 526 ha) association occur predominantly in the eastern part of the Condamine-Maranoa basin. The former are described as gently undulating plains of hard alkaline and neutral, yellow, mottled soils and the latter as undulating ridges and some gently sloping plains. Both groups are commonly referred to as solodized solonetz.

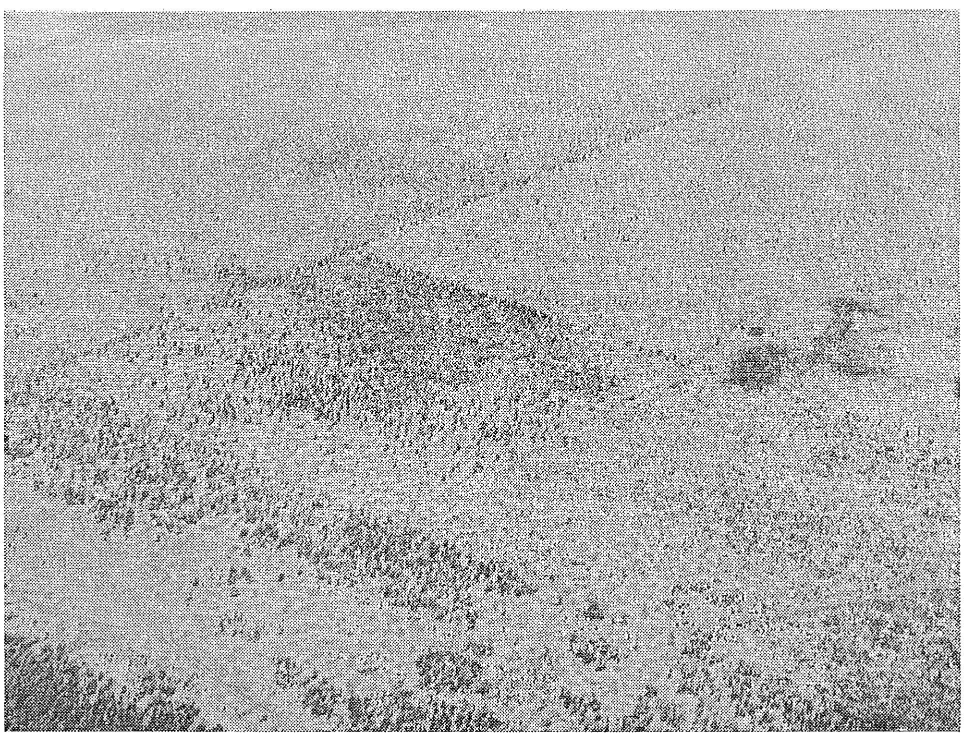
The A_1 horizon is usually strongly acid (pH 5.5) while the A_2 is acid but variable and the reaction changes from acid to alkaline in the B horizons (Isbell 1957). Magnesium is the dominant exchangeable metal cation and may range up to 70% of the total metal ions in the B_{21} horizon. Exchangeable sodium shows a marked rise with depth while exchangeable calcium is very low in the B horizon. Chloride and total soluble salts are low in the A and may show a small rise in the B horizon while total nitrogen and available phosphorus are low and low to very low respectively.

Galloway *et al.* (1974) classified these duplex soils with columnar structure to Dd family (27%) and De family (26%) with some deep red sandy forest soils of Fd (11%) family. The soils of Dd family have thin sandy or loamy surface horizons, generally with a pale-coloured or bleached A_2 horizon over clayey, strongly alkaline subsoils with columnar structure. Base saturation is 100% with calcium and magnesium co-dominant. The De soils are similar to the Dd type but they have strongly acid to mildly alkaline reaction in the subsoils. They also have low exchange capacity and magnesium and sodium are the dominant and subdominant cations respectively in the lower subsoil. The Fd family are uniform sandy soils formed on transported material and neutral to medium acid throughout.

Wa13, Wa15 (*Dy5.41*). 167 375 ha. Sandy soils with mottled, yellow, clayey subsoils, bleached A_2 horizon, pedal subsoils (acid reaction trend). Occurring predominantly in the upper and middle sections of the Weir River, the Wa13 (161 242 ha) soils are more prominent than the Wa15 (6 133 ha), only one area of which is present in the north. The larger group are described as flat to gently sloping plains with occasional undulating sandy ridges while the



Cattle fattening on forage oats is an important enterprise in the brigalow country.



The distinctive pattern of gilgai microrelief which is characteristic of the southern brigalow country.

minor group are moderate to strongly undulating lands with occasional low mesa-like hills. These soils are commonly referred to as yellow podzolic soils and solodic soils.

Soil reaction is acid throughout, often strongly so, but occasionally it may become alkaline in the deep subsoil (Isbell 1957). The B horizon clays are unsaturated. Magnesium is by far the dominant exchangeable metal cation and with sodium (fairly high) forms 90% of the total exchangeable metal cations. Chlorides and total soluble salts are usually negligible although they may show a slight accumulation in the deep subsoils. Total nitrogen and available phosphorus are low.

HG1, HG2 (*Dd1.33*). 184 323 ha. Hard-setting loamy soils with dark, clayey subsoils, sporadically bleached A_2 horizon (alkaline reaction trend). The more prominent HG1 (125 895 ha) association occurs along the Moonie River with some areas just to the north of Goondiwindi while the HG2 (58 428 ha) group occur between Goondiwindi and Talwood. They are described as plains associated with both functional and non-functional drainage lines the only difference being in the minor associated soils. They are grouped with the solodic soils.

Related to the belah soils, the HG group usually has a slightly more acid A_1 horizon (Isbell 1957). The B_{21} is slightly acid while the B_{22} is normally alkaline. Calcium is the dominant exchangeable metal cation in the A horizon and magnesium in the B. Exchangeable sodium shows an appreciable rise in the B horizon (up to 20% of the total exchangeable metal cations). The chloride and total soluble salt contents are very low in the A horizons but show some accumulation in the B and deeper horizons. The C:N ratio ranges from 10 to 14. Available phosphorus is normally low.

Galloway *et al.* (1974) have treated this soil association in a similar manner to that of the Oc21 type by subdividing and reallocating the soils to clay soils, red earths, sandy soils and duplex soils.

Land use factors

THE GILGAI MICRORELIEF. The deep gilgaied clay soils occupy 47% of the total brigalow area of Queensland (Isbell 1962). This area is largely contained in Tara and Waggamba shires and areas immediately to the north. Gilgais vary greatly in spacing and shape but tend to be reasonably uniform over limited areas (Isbell *loc. cit.*). Normal, melon-hole, stony, lattice, linear or wavy and tank gilgai are described (Stace *et al.* 1968). Approximately twice this number have been defined by van Dijk (unpublished data) who used gilgai formation as a criterion for soil-land component mapping in an area approximating Tara shire (map 2).

The origin of the gilgai formations is still a matter for debate. Hallsworth, Robertson and Gibbons (1955) studied the gilgaied soils of New South Wales and concluded that the distinguishing feature of these soils was contained in their swelling pattern on wetting, this being related to clay content, exchange capacity of the clay and amount of sodium on the exchange complex. Isbell (1957) found that this theory did not hold for Queensland soils and suggested that a consistent feature of gilgai soils in Queensland was the extremely acid (pH 4.0–5.0) conditions in the subsoil. Stace *et al.* (1968) consider that the gilgai morphology is formed by the forcing upwards of large blocks of soil which have broken away from the subsoil.

The gilgai surface causes land use restrictions particularly when cultivating and planting operations are delayed by ponded water. Where the vertical interval between puff and depression approaches 2·0 m, the land is suitable only for native or ash-sown, introduced pasture species. With gilgais of the order of 1·0 to 1·5 m, forage cropping may be practised, but not grain cropping.

SALINITY. The tentative map of Northcote and Skene (1972) shows broad areas of saline and sodic soils and two categories of sodic soils cover approximately half of the Condamine–Maranoa basin. The first of these is the alkaline, strongly sodic (exchangeable sodium percentage 15 or more) and sodic (exchangeable sodium percentage from 6 to 14) soils with clay surface texture, uniform texture profiles and with intergrades to both saline and normal soils. The second is of similar characteristics but formed on duplex soils. The authors point out that, in general, soils with defined saline and sodic properties comprise more than 50% of the soils present in the areas mapped.

The distribution of salt-affected soils is available for the principal land systems and land units of the Balonne–Maranoa area (Galloway *et al.* 1974). Although the occurrence of these soils is sporadic in some landscapes, levels of electrical conductivity of 4 to 12 mmhos cm^{-1}, exchangeable sodium of 10 to 50% and chloride of 400 to 3 400 p.p.m. have been recorded.

WATER-HOLDING CAPACITY. While the brigalow soils are generally deep, some of the solodic soils have very shallow topsoils and thus retain little moisture for plant growth. Soil moisture measurements are available for many of the soils of the Condamine–Maranoa basin (Isbell 1962; Reeve, Isbell and Hubble 1963; Dawson 1972*b*; Galloway *et al.* 1974). A summary of this information is presented.

The clay soils of the brigalow lands, flooded plains and open grasslands are capable of storing 0·17 to 0·21 cm cm^{-1} of depth. The weakly solonized brown clay loams which commonly occur in association with the brigalow soils, store in the order of 0·13 to 0·17 cm cm^{-1} of depth. However, moderate levels of exchangeable sodium and soluble salts affect permeability and availability of moisture on this soil type.

The solodized solonetz with cypress pine-bull oak forests have hard-setting, thin, clay loam surface soils with low storage capacity. Where the deeper sands occur, infiltration is satisfactory but moisture retention is low. The available moisture range is 0·04 to 0·08 cm cm^{-1} of soil. The hard-setting loamy solodic soils of the poplar box-false sandalwood woodlands have reasonable depth but a narrow range of available moisture, of the order of 0·13 cm cm^{-1} of soil.

The red earths of the poplar box-mulga woodlands and the mulga-poplar box shrublands have low water storage capacities. Because of their location in the more arid westerly areas, their cropping potential is very low. The range of available moisture is approximately 0·04 cm cm^{-1} of soil. The shallow, loamy soils of the bendee and ironbark country are unsuitable for cultivation although the available moisture capacity is moderate. The alluvial soils carrying eucalypt woodland, east of Goondiwindi, have available moisture of 0·08 to 0·13 cm cm^{-1} of soil but very low infiltration rates of 2·5 mm per hour.

VEGETATION

The vegetation of the region is diverse and, before 1950, had been described and/or mapped by a number of authors (Diels 1905; Domin 1911; Taylor 1918; Swain 1928; White 1930; Prescott 1931; Herbert 1932; McTaggart 1936; Blake 1938; Everist 1949). With the aid of photointerpretation, a far greater accuracy of community identification was made possible and works by Isbell (1957), Skerman (1959), Holland and Moore (1962), Johnson (1964), Dawson (1972*b*), and Galloway *et al.* (1974) contribute to our knowledge of parts of the evaluation area.

The most recent land use studies provide detailed descriptions of vegetation for the northern and western parts of the area (Dawson *loc. cit.*; Galloway *et al. loc. cit.*) and, in conjunction with the work of Isbell (*loc. cit.*) and Johnson (*loc. cit.*) have been used to prepare a summary description of vegetation corresponding with the soil-vegetation groups outlined in Part 1. A composite vegetation map (map 5) has been prepared from the work of the first three of these authors and that of Moore and Perry (1970). A tabulated comparison of communities as presented by the first three authors is also included (table 14). In reading this table, it should be remembered that not all communities are repeated in each area and different methods of classification have been employed by each author. Isbell largely followed the nomenclature of Beadle (1948). Dawson followed the system of classification devised by Specht (1971) while Galloway *et al.* showed groups basically equivalent to the formations of Beadle and Costin (1952).

Description

GROUP 1. GILGAIED CLAY AND CLAY LOAM—BRIGALOW AND BRIGALOW-BELAH FOREST. Three growth forms of *Acacia harpophylla* (brigalow) are recognized (Johnson 1964). 'Sucker' brigalow occurs when damage is caused to either the aerial or lateral roots of the plant. 'Whipstick' brigalow consists of a dense, usually uniform layer of plants which have developed from brigalow forest due to some disruptive influence or through mass germination of seed. 'Tall' or 'virgin' brigalow occurs in communities which vary from closed layered to open grassy forest. Johnson (*loc. cit.*) described nine types of virgin communities according to the other species of trees and shrubs which are prominent within them. Of these, six types occur in the study area.

Brigalow-Wilga community. Layered forest with *A. harpophylla* in the canopy and *Geijera parviflora* (wilga) usually dominant in the understorey. *Casuarina cristata* (belah) is commonly associated in the communities of southern Queensland where every gradation from pure *A. harpophylla* to pure *C. cristata* occurs. Other commonly associated species are *Heterodendrum diversifolium* (scrub boonaree), *Apophyllum anomalum* (broom brush), *Eremocitrus glauca* (limebush) and *Myoporum deserti* (Ellangowan poison bush) while *Melaleuca bracteata* and *M. lanceolata* (tea trees) occur in some areas. Distribution of this community is wide and it occurs on both gilgaied and sedentary clay soils.

Brigalow-belah community. This is co-dominant over large areas in southern Queensland and forms a layered forest often with *G. parviflora* dominant in the understorey. The shrub and ground flora is similar to that of the brigalow-wilga community.

TABLE 14

A COMPARISON OF PLANT COMMUNITIES AS DESCRIBED FOR OVERLAPPING SECTIONS OF THE CONDAMINE–MARANOA BASIN BY GALLOWAY *et al.* (1974), DAWSON (1972) AND ISBELL (1957)

Galloway *et al.*	Dawson	Isbell
Grassland		
Astrebla	No equivalent	No equivalent
Open	No equivalent	No equivalent
No equivalent	Blue grass grasslands	No equivalent
Low Open Woodland		
Atalaya hemiglauca and *Flindersia maculosa*	No equivalent	No equivalent
Acacia harpophylla	No equivalent	No equivalent
No equivalent	No equivalent	Tea-tree-spinifex
Open Woodland		
Eucalyptus microtheca	No equivalent	Coolibah-boonarie-myall-Mitchell grass
E. orgadophila	No equivalent	Other parkland
E. melanophloia	Silver-leaved ironbark, poplar box, shrubby woodland	Silver-leaved ironbark-poplar box-narrow-leaved ironbark
E. populnea	Poplar Box, shrubby open woodland (without *Astrebla*)	Myall-boonarie
No equivalent	No equivalent	Sandalwood-wilga-tea-tree-*Disphyma australe*
Angophora melanoxylen	No equivalent	No equivalent
A. costata	No equivalent (does occur but grouped elsewhere)	No equivalent
E. tessellaris	Rough-barked apple, cypress pine, poplar box, Queensland blue gum, tumble-down gum, shrubby woodland	Tumbledown gum-cypress pine
	Cypress pine, layered open forest	Sandridge
No equivalent	Bendo tall open shrubland	No equivalent
Woodland		
E. largiflorens	No equivalent	No equivalent
E. populnea		
with *Callitris columellaris*	Cypress pine, layered open forest (partly equivalent)	Cypress pine-bull oak
with *Casuarina luehmannii*	Bull oak, layered open forest (partly equivalent)	
with *Acacia aneura*	No equivalent	No equivalent
with *A. harpophylla*	No equivalent	No equivalent
with *Eremophila mitchellii*	Poplar box, shrubby woodland	Popular box-sandalwood-wilga
Grassy woodland of	Poplar box, grassy woodland (partly equivalent)	No equivalent
Eucalyptus melanophloia		
with *C. columellaris*	Silver-leaved ironbark, poplar box, shrubby woodland	No equivalent
with *A. aneura*	No equivalent	No equivalent

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with *C. luehmannii*	Silver-leaved ironbark, poplar box, shrubby woodland	No equivalent
Grassy woodland of *E. drepanophylla*	No equivalent	No equivalent
with *C. columellaris*	Narrow-leaved ironbark, layered open forest	Cypress pine-bull oak
	Cypress pine, layered open forest	
	Dusky-leaved ironbark, layered open forest	No equivalent
with *C. luehmannii*	Narrow-leaved ironbark, layered open forest	Cypress pine-bull oak
	Bull-oak, layered open forest	
Grassy woodland of	Narrow-leaved ironbark, layered open forest	Poplar box-narrow-leaved ironbark
	Spotted gum layered open forest	No equivalent
Casuarina cristata	No equivalent	No equivalent
E. thozetiana	No equivalent	No equivalent
E. microcarpa	Gum-topped box, layered open forest	No equivalent
E. saligna	No equivalent	No equivalent
Mixed eucalypt community	No equivalent	No equivalent
No equivalent	Molly box, shrubby open forest	Mallee box-poplar box
No equivalent	No equivalent	Poplar box-silver-leaved ironbark-apple
No equivalent	No equivalent	Narrow-leaved-ironbark-spinifex
Open Forest		
Callitris columellaris	Cypress pine layered open forest	Cypress pine-bull oak
A. aneura	No equivalent	No equivalent
A. harpophylla	Brigalow open forest	Almost pure brigalow
	Brigalow, belah, wilga, shrubby open forest	Mixed brigalow-belah
Casuarina cristata	Belah, open forest	Almost pure belah
A. cambagei	No equivalent	No equivalent
A. catenulata	Acacia open forest (bendee)	No equivalent
A. shirleyi	No equivalent	No equivalent
A. microsperma	No equivalent	No equivalent
No equivalent	Acacia open forest (currawong)	Lancewood
No equivalent	Black tea tree, tall open shrubland	No equivalent
No equivalent	No equivalent	Wattle
Tall Open Forest		
E. eugenioides	No equivalent	No equivalent
Closed Scrub		
Semi-evergreen vine thicket	No equivalent	No equivalent
Fringing Communities		
E. microtheca	Fringing forest of river red gum and coolibah	Fringing forests
E. camaldulensis		
E. tereticornis	No equivalent	No equivalent

Brigalow-sandalwood community. Where conditions are not suited to the development of brigalow-wilga or brigalow-yellowwood communities, *Eremophila mitchellii* (sandalwood) may become dominant in the understorey. These communities may form the transition zone between brigalow-wilga and brigalow-poplar box communities. Small areas are found throughout the brigalow region.

Pure brigalow communities. Throughout the brigalow belt, low-layered or grassy brigalow forests occur. *Acacia harpophylla* dominates the canopy while the shrub layer, if present, is very scattered. Ground vegetation is usually grass dominant (with chiefly *Paspalidium* spp.) and this may be sparse depending on the density of the tree layer and seasonal conditions.

Brigalow-eucalyptus communities. Of three communities, the brigalow-poplar box community which is transitional between open *Eucalyptus populnea* (poplar box) forest and various brigalow communities is most prominent. The shrub *Eremophila mitchellii* becomes more common as the *Eucalyptus populnea* approaches dominance. Of lesser importance are communities where *E. thozetiana* (mountain yapunyah) occurs in mixed stands with *A. harpophylla* and communities containing *E. pilligaensis* (mallee box) which occur in some parts of the Goondiwindi district.

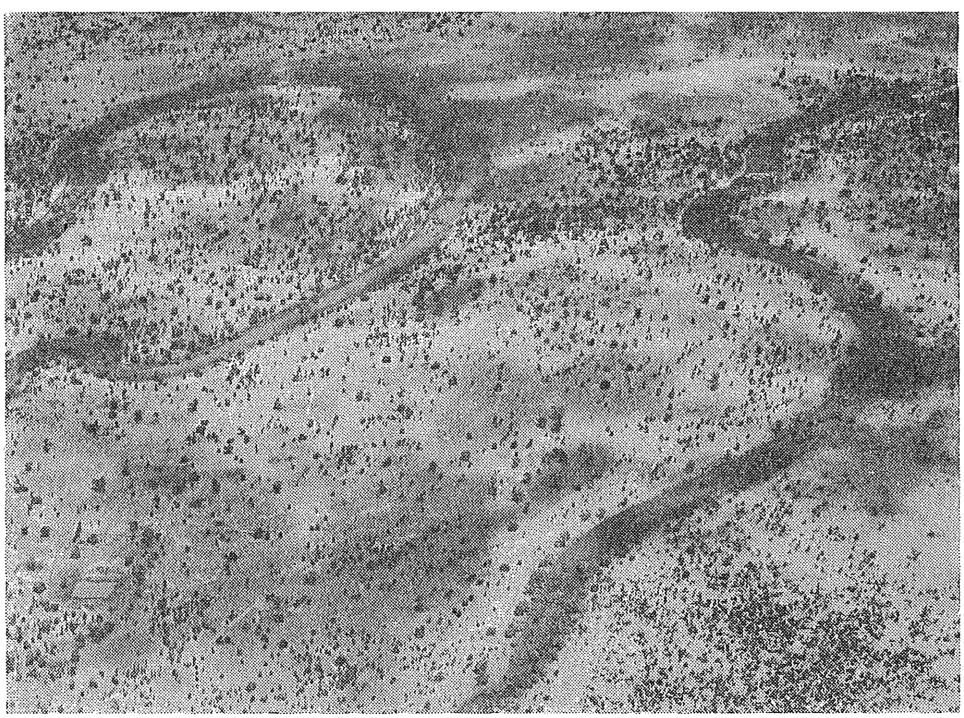
Brigalow-acacia communities. Several species of acacia are found in association with *A. harpophylla*, the most important being *A. cambagei* (gidyea). This species occurs along the 500 mm isohyet (and in some drier regions) on the western margin of the brigalow lands. *A. omalophylla* (yarran) forms mixed scrubs on the margins of some brigalow-wilga communities. *A. aneura* (mulga) is occasionally associated with *A. harpophylla* on the eastern fringe of the mulga shrublands.

Three brigalow communities were described by Isbell (1957). These were almost pure *A. harpophylla*, mixed *A. harpophylla-C. cristata* and almost pure *C. cristata*. Isbell (*loc. cit.*) suggested that the ground cover in all of these communities was fairly sparse, the major grasses being *Paspalidium caespitosum* (brigalow grass) and *P. gracile* (slender panic) while the most important small shrubs and herbaceous plants were *Carissa ovata* (currant bush), *Rhagodia parabolica, Salsola kali* (soft roly-poly), *Bassia quinquecuspis* (prickly roly-poly), *B. tetracuspis* (brigalow burr), *Atriplex semibaccata* (creeping saltbush), *Chenopodium trigonon* (fishweed) and *Maireana brevifolia* (cotton bush). In damper situations, *Carex rhytidocarpa* (a sedge), *Cyperus bifax* (downs nutgrass), *Diplachne parviflora, Marsilea drummondii* (nardoo) and *Leptochloa digitata* (cane grass) occur. In more open communities, *Enteropogon acicularis* (curly windmill grass), *Chloris truncata* (windmill grass), *C. divaricata* (slender chloris), *Sporobolus caroli* (fairy grass), *Eragrostis leptostachya* (paddock love grass) and *E. parviflora* (weeping love grass) are found. The annual medics, *Medicago minima* (small woolly burr medic) and *M. polymorpha* (burr medic), and *Senecio platylepsis* may develop in good seasons.

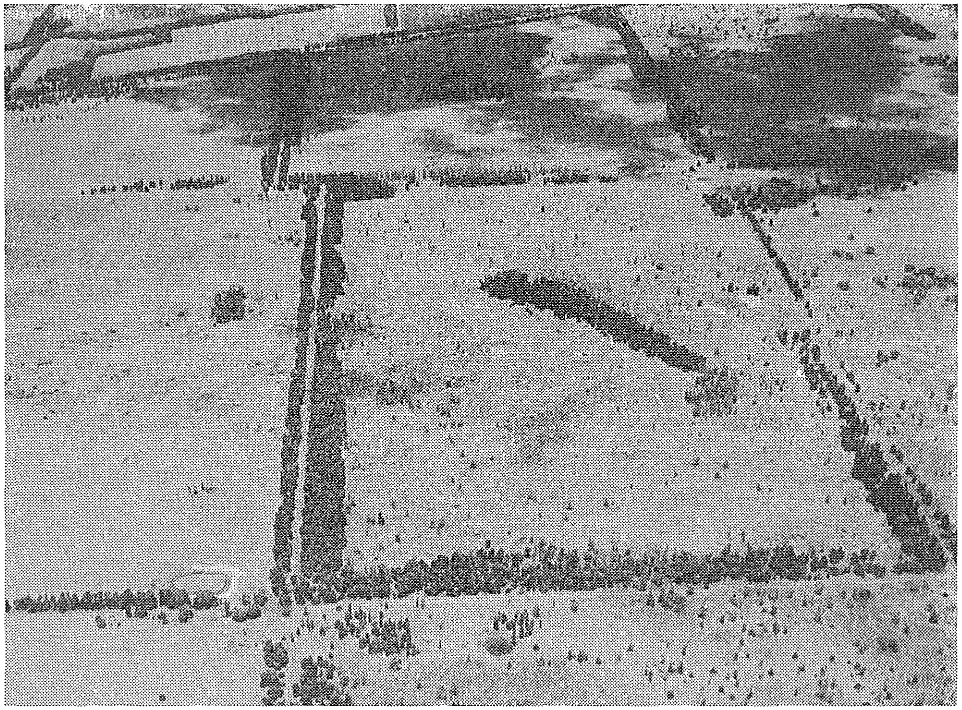
In addition to *Paspalidium, Enteropogon, Leptochloa, Sporobolus* and *Cyperus* species, Johnson (1964) records *Aporuellia australis, Abutilon oxycarpum* (a flannel weed), *Rhagodia nutans* (berry saltbush), *Enchylaena tomentosa* (ruby saltbush), *Cheilanthes distans* (rock or mulga fern), *Ancistrachne uncinulata* (hooky grass), *Sporobolus mitchellii* (creeping rat's-tail grass), *Sida spinosa* (spiny sida), *Commelina lanceolata* and *Plumbago zeylanica* in southern brigalow communities.

Galloway *et al.* (1974) suggest that *Acacia harpophylla* open forest predominates in the east and north east of the Balonne-Maranoa, is replaced by *Casuarina cristata* open forest in the centre of the region and this species is replaced by open forests of *A. cambagei* in the south-west. The species recorded for the brigalow community and for the belah community are basically similar to those shown by Johnson (1964). Species associated with *A. cambagei* are *C. cristata, Eucalyptus microtheca* (coolibah), *Eucalyptus largiflorens* (black box), *Eremophila mitchellii* and *Geijera parviflora.* The ground flora is composed mostly of forbs such as *Bassia* spp. and *Enchylaena tomentosa* while grasses such as *Tripogon loliiformis* (five-minute grass), *Paspalidium gracile* and *Enteropogon acicularis* occur.

GROUP 2. FLOODED CLAY—COOLIBAH OPEN WOODLAND. *Eucalyptus microtheca* is the principal species on these fine textured soils (Galloway *et al.* 1974), some of which are subject to occasional flooding. Associated trees are *E. populnea, E. largiflorens, Casuarina cristata* or *Acacia pendula* (myall). *E. camaldulensis* (river red gum) develops in fringing communities. Shrubs do not usually occur but in areas of flooding *A. stenophylla* (river myall) and *Eremophila bignoniiflora* (creek wilga) occur while *Muehlenbeckia cunninghamii* (lignum) inhabits waterlogged localities. *Astrebla lappacea* (curly Mitchell grass) is the dominant species in the ground cover with associated *Paspalidium jubiflorum* (Warrego summer grass) and *Thellungia advena* (coolibah grass). *Dichanthium* spp. (blue grasses) and *Cyperus bifax* may occur in wetter areas. *Panicum*



Flood country on the Macintyre River west of Goondiwindi.



Cleared brigalow-belah forest with shade lines and patches remaining.

decompositum (native millet) is common in areas subject to flooding south of St. George. *Eragrostis setifolia* (neverfail grass), *Sporobolus mitchellii* and *B. tetracuspis* are associated species. With heavy grazing, perennial grasses disappear and *Bassia* species become more prominent.

Isbell (1957) writing specifically of the low-lying areas subject to fairly frequent flooding between the Macintyre and Weir Rivers records *Eucalyptus microtheca, Heterodendrum oleifolium* (boonaree) and *Acacia pendula* with occasionally *Casuarina cristata* and a ground cover of *Astrebla lappacea, Dichanthium sericeum* (Queensland blue grass), *Iseilema membranaceum* (small Flinders grass) and *P. decompositum.* On adjacent parkland communities, additional species are *Paspalidium globoideum* (shot grass), *Dactyloctenium radulans* (button grass), *Eriochloa pseudoacrotricha* (early spring grass), *Eulalia fulva* (silky browntop), species of *Chloris, Bothriochloa bladhii* (forest blue grass) and *T. advena.* The annual winter *Medicago* spp. also develop under favourable conditions.

GROUP 3. UNDULATING CLAY—MITCHELL GRASS GRASSLAND. This tussock grassland with occasional scattered *Eucalyptus microtheca, E. populnea, E. melanophloia* (silver-leaved ironbark) and *E. orgadophila* (mountain coolibah) and low shrubs such as *Acacia farnesiana* (mimosa bush) and *A. victoriae* (gundabluey) has a basal cover of the perennial species of about 3% (Galloway *et al.* 1974). *Astrebla* species occur in all stands with *A. lappacea* most commonly and *A. elymoides* (hoop Mitchell) and *A. squarrosa* (bull Mitchell) only occasionally present. Under heavy grazing *Aristida leptopoda* (white spear grass) increases while the *Astrebla* species decline. Other prominent species are *T. advena, Malvastrum spicatum* (malvastrum), *Panicum decompositum, Iseilema* spp., *B. Tetracuspis, Sporobolus mitchellii* and *Dichanthium* spp.

Associated with this grassland on fine-textured, sedentary soils near Surat and Roma are communities of *Atalaya hemiglauca* (whitewood). *Bauhinia carronii* (bauhinia) is an important constituent near Surat where there may be some *Acacia harpophylla.* The ground cover is similar to that of *Astrebla* grassland but when heavily grazed *Atriplex semibaccata* (creeping saltbush), *A. muelleri* (annual saltbush) and *Bassia tetracuspis* usually replace grasses.

Included in this soil vegetation group is the land type of the Coomrith-Inglestone area described as open woodland (occasionally woodland) of *E. orgadophila* with *E. populnea, C. cristata, Acacia harpophylla* and *G. parviflora.* Species characteristic of *E. populnea* and *E. melanophloia* woodlands such as *Aristida ramosa, Enteropogon acicularis* and *Ancistrachne uncinulata* predominate though *Dichanthium* spp. and *Astrebla* spp. do occur.

GROUP 4. SOLODIC—CYPRESS PINE-BULL OAK FOREST. Where *Callitris columellaris* (cypress pine) is dominant the soils are solods, solodic or solodized—solonetz with a sandy A horizon usually exceeding 30 cm. With a shallower A horizon and a heavier texture *Casuarina luehmannii* (bull oak) increases in importance. Associated tree species are prominent in both types and include *E. populnea, E. drepanophylla* (narrow-leaved ironbark), *Angophora costata* (rusty gum) and *E. dealbata* (tumble-down gum). The shrub layer is usually not prominent although on the sandy areas *Acacia conferta* may be common while occasionally *A. spectabilis* (Kogan wattle), *A. mollissima, Hovea longifolia* (purple bush pea), *Melichrus urceolatus* and *Dodonaea cuneata* (a wild hop) may occur. Ground cover can be sparse, the chief species being *Aristida caput-medusae* (many-headed wire grass), *A. ramosa,* the love grasses *Eragrostis leptostachya, E. elongata* (clustered love grass) and *E. lacunaria* (purple love grass) and *Chrysopogon fallax* (golden-beard grass).

Dawson (1972B) describes layered open forests of *Callitris columellaris* with *Acacia* spp., *Casuarina luehmannii* and *Eucalyptus drepanophylla* and *C. luehmannii* with *E. drepanophylla, Callitris columellaris* and *Angophora costata* for the lower slopes and plains in the topography.

GROUP 5. SOLODIC—POPLAR BOX-SANDALWOOD WOODLAND. The upper layer of this woodland is predominantly *E. populnea* with *E. melanophloia* the only other species of note (Galloway *et al.* 1974). Lower trees are not common, *Acacia excelsa* (ironwood) and *Heterodendrum oleifolium* occurring occasionally. The shrub layer is variable but dense stands of *Eremophila mitchellii* can occur. *G. parviflora* is common while *Canthium oleifolium* (myrtle tree) occurs only occasionally. Where the shrub layer is more than about 6 m tall, a lower shrub layer of *Carissa ovata, Cassia nemophila* (butter bush) and *Dodonaea attenuata* (hop bush) may occur.

The ground cover varies according to the density of the canopy but is often sparse. *Bothriochloa decipiens* (pitted blue grass) is the commonest species and *Enteropogon acicularis, Aristida ramosa* and *A. jerichoensis* (wire grass) also occur. On eroded areas, *Tripogon loliiformis* forms an extremely open ground cover.

Isbell (1957) describes the main species as *Eucalyptus populnea, Eremophila mitchellii* and *G. parviflora* and suggests that often much of the *E. mitchellii* is dead. Commonly associated species include *Atalaya hemiglauca, Acacia excelsa, Casuarina cristata, Eremocitrus glauca* and *Capparis mitchellii* (wild orange) with occasionally *Flindersia maculosa* (leopard wood) and *Cassia circinnata.* The ground flora contains chiefly *Chloris divaricata, C. truncata* and *Enteropogon acicularis* with occasionally *S. caroli, Dichanthium sericeum* and species of *Aristida and Eragrostis.* Also common in the community is *Calotis hispidula* (bogan flea) while, in some years, the annual winter medics *Medicago minima* and *M. polymorpha* may be prominent.

GROUP 6. RED EARTH—POPLAR BOX-MULGA WOODLAND. A range of relationships exists between the major species of this group (Galloway *et al.* 1974). East of the Balonne River, poplar box woodland with an understore of *Acacia aneura* is confined to the more arid upper slopes, but elsewhere it occupies all parts of the landscape. Farther east *A. aneura* is replaced by *Eremophila mitchellii. Eucalyptus melanophloia* and *E. intertexta* (forest gum) are occasional components of the upper tree layer while *A. aneura* dominates the lower tree layer. A shrub layer can be present and may contain *Eremophila mitchellii, G. parviflora, Cassia nemophila* and *E. glabra* (black fuchsia). The ground cover can be open, but will become denser in disturbed areas. *Thyridolepis mitchelliana* (mulga grass) and *Aristida jerichoensis* are widespread, the latter becoming denser on heavily grazed areas. Associated species are *A. leichhardtiana, B. decipiens, Enteropogon acicularis, Monachather paradoxa* (mulga oat grass), *Digitaria brownii* (silver spike grass), *Eragrostis lacunaria, Enneapogon gracilis* (a bottle washer grass), *Paspalidium constrictum* (belah grass), *Themeda australis* (kangaroo grass), *Eragrostis eriopoda* (woollybutt grass), *Bassia diacantha, B. convexula* (copper burr), *Hibiscus strutii, Sida brachypoda* and *Cheilanthes sieberi* (mulga fern). In places, heavy grazing followed by sheet erosion has produced a hard-setting soil surface bare of grasses and forbs except for *Tripogon loliiformis* and, in places, *Phyllanthus* sp.

A woodland community of *Eucalyptus melanophloia* with a lower storey of *Acacia aneura* also exists, usually on upper slopes where it sometimes grades into open forest of *Acacia catenulata* (bendee). It is similar in many respects to the poplar box-mulga community.

GROUP 7. RED EARTH—MULGA-EUCALYPTUS SHRUBLAND. These open forests are best developed on sandy or loamy red earths and grade into the poplar box-mulga group in the east (Galloway *et al.* 1974). Eucalypts, mainly *E. melanophloia* and *E. populnea* are often present in the canopy of dense stands of *A. aneura* (1 200 trees ha^{-1}), while *E. exserta* (bendo) and *E. terminalis* (western bloodwood) occur occasionally. Lower trees and shrubs are not common except *Eremophila mitchellii* and *Cassia nemophila.* Ground cover is sparse with *Thyridolepis mitchelliana* the most common grass. *Aristida jerichoensis, A. leichhardtiana, Eragrostis lacunaria, Paspalidium constrictum, M. paradoxa* and *Cheilanthes sieberi* are also widespread. Forbs such as *S. brachypoda* and *H. sturtii* are sometimes conspicuous.

GROUP 8. SHALLOW LOAMY SOIL—BENDEE SHRUBLAND. *Acacia catenulata* (bendee) communities occur on deeply weathered soils, usually on scarps (Galloway *et al.* 1974). The tree layer is dense and emergents *Eucalyptus populnea, E. melanophloia* and *E. drepanophylla* are common. *A. aneura* and rarely *A. aprepta* (Miles mulga) in the tree layer and *E. microcarpa* (green-leaved box), *E. thozetiana, E. trachyphloia* (brown bloodwood), *E. exserta* and *Cadellia pentastylis* (ooline) may also occur.

GROUP 9. SHALLOW LOAMY SOIL—IRONBARK WOODLAND. This occurs on mottled zone lateritic residuals, mainly in the east. The chief species are *E. melanophloia, E. drepanophylla, E. populnea* and *Callitris columellaris* (Isbell 1957). In some areas, low wattle 'scrubs' are prominent, *A. cunninghamii* (black wattle) being the dominant species. The ground cover consists mainly of *Aristida* species with occasionally *Themeda australis* (kangaroo grass).

GROUP 10. ALLUVIAL SOIL—EUCALYPTUS WOODLAND. The vegetation of the older terraces is woodland dominated by *E. melanophloia* and *E. populnea* with occasionally *Angophora floribunda* (rough-barked apple; previously *A. intermedia*) (Isbell 1957). In fringing forests, *E. camaldulensis, E. microtheca* and *E. tessellaris* (carbeen) may occur in addition to the above species. The grass cover consists mainly of *Bothriochloa decipiens* and *Stipa verticillata* (slender bamboo grass).

Factors influencing the development of plant communities

An expression of the increasing aridity in the Condamine–Maranoa basin from east to west is the change from *Acacia harpophylla* to *A. cambagei* on fine textured soils (Galloway *et al.* 1974). *A. aneura* is absent from semi-arid regions with a regular summer or winter drought (Nix and Austin 1973) and its distribution coincides with areas of positive but low evapotranspiration ratios, the optimal zone receiving less than 250 mm summer and less than 110 mm winter rainfall in eight years out of 10. Farmer, Everist and Moule (1947) had previously concluded that some winter rain was necessary for the best development of *A. aneura*.

Edaphic and topographic factors influence the distribution of plants within an area (Galloway *et al.* 1974). The occurrences of *C. columellaris* on deep sandy soils is the best example while the effect of soil texture can be seen with *A. aneura* and *Casuarina luehmannii* occurrence on medium textured soils and *A. harpophylla* and *A. cambagei* on fine textured soils. The absence of most trees from the grey and brown soils of heavy texture is often related to the effect of deep cracking and self mulching on tree establishment. Beadle (1948) considers *A. pendula, Astrebla lappacea, A. pectinata* (barley Mitchell) and *Iseilema membranaceum* as indicators of alkaline soils of heavy texture. Further he suggests that *E. intertexta* and *Aristida jerichoensis* are indicators of acid soils of light texture and that *E. populnea* is of no value as an indicator. The last species is an outstanding example of tolerance to a wide range of soil texture and reaction and, in New South Wales, it is consistent only in that it is confined to the summer rainfall zone where it occurs over a range from 250 to 675 mm (Beadle *loc. cit.*). Skerman (1948) reports the occurrence of *Eremophila mitchellii* on soils with a high percentage of sodium (greater than 10%). An exception to this is where it occurs with *Eucalyptus populnea* and *G. parviflora* when soil sodium is not usually high.

The effect of flooding on vegetation in the area is difficult to report because of limited data on the extent of the vegetation influenced by flood water. Flooding, however, causes the establishment, sometimes in dense stands, of *E. microtheca* and *E. camaldulensis,* the death of *Astrebla lappacea* and the development of ground flora containing such species as *Cyperus bifax, S. verticillata* and the shrub *Acacia stenophylla*.

Large areas of the world's grasslands are considered to be a fire sub-climax (Tothill 1971). Many such areas are at ecological equilibrium only in the presence of periodic burning and without this there is a general reversion to bush, scrub or forest. In southern Queensland, burning by the aborigines was replaced by the spasmodic burning by pastoralists and this has permitted the development of an understorey of woody weeds (Moore 1969; Galloway *et al.* 1974). The effect of fire on some woody species is known. *Callitris columellaris* and *Casuarina cristata* are susceptible to fire and, in many cases, it is difficult to determine in what quantities they originally occurred in some communities (Galloway *et al. loc. cit.*). The aerial parts of *A. harpophylla* are killed by fire but subsequent regrowth from root suckers can be very vigorous (Johnson 1964).

Fire enhances the germination of the seed of many woody species such as *Acacia* spp. (Moore 1969). It hastens germination in *A. aneura* when followed by soaking rain within a few months (Everist 1949). It is, however, not the only means of breaking dormancy in this species (Winkworth 1973). *A. aneura* vegetation is sensitive to fire and destruction of the canopy will allow rapid colonization by *Dodonaea attenuata* and *D. boroniifolia* (Holland and Moore 1962). Fire kills small *A. aneura* trees and the lower branches of more advanced trees (Everist, Harvey and Bell 1958).

The control of *Opuntia inermis* (prickly pear) by the insect *Cactoblastis cactorum* is an outstanding example of the modifying influences which can be applied to a plant species. Another example is the effect of the rabbit, which is considered to be one of the factors which caused deterioration of native pastures in north-western New South Wales (Moore 1969). It is concluded that they played an important role in early deterioration of mulga communities although much damage had already been done by sheep. For the Condamine–Maranoa basin, it is claimed that the rabbit exerted a control over *Eremophila mitchellii* and that shrub populations have increased since the number of rabbits decreased. Rabbits, however, prefer grasses and herbs and tend to eat all available stock feed before eating shrubs (Moore 1973).

The effect of sheep and cattle on vegetation is of major consequence. The grazing of shrub and tree species by sheep and cattle is conspicuous because of the development of well defined 'browse lines'. This effect has been observed to a marked extent in *A. aneura, Casuarina cristata, Callitris columellaris* and *A. harpophylla*. Landowners experienced in the management of green country (undeveloped forest country) suggest that good use can be made of species of low palatability (*A. harpophylla, Casuarina luehmannii*) by alternating stock between different types of vegetation. Sheep can have a major effect on the establishment of *Callitris columellaris,* and in *A. aneura* shrubland sheep will kill seedlings in all but the most favourable seasons (Burrows 1973).

Under heavy grazing, the *Astrebla* grasslands of the northern part of the Condamine-Maranoa basin show an increase in *Aristida leptopoda* at the expense of *Astrebla lappacea*. Changes in botanical composition, or at least in presentation of dry matter, have been suggested for native pasture when cattle replace sheep as the major grazing animal. Initially, perennial grasses make a greater contribution to total dry matter while shrubs, previously suppressed by sheep, develop largely free of disturbance. In poplar box-sandalwood and similar communities, heavy grazing can lead to the replacement of more palatable species by *Aristida* spp. (Galloway *et al.* 1974).

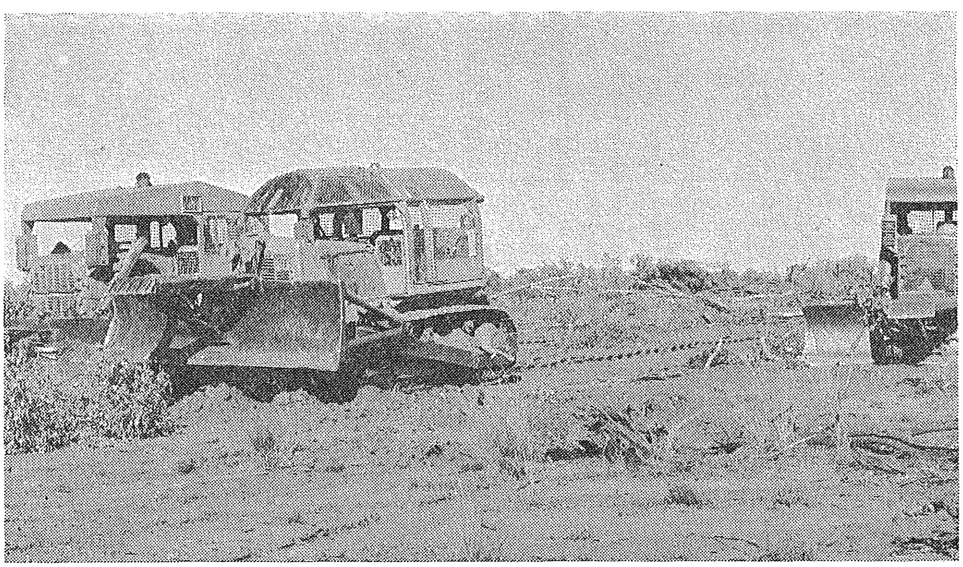
Most woodlands and forests have been modified by ring-barking. Some areas have been rung as many as three times and few areas have escaped the influence of the axe. It is significant that only in relatively small areas has this means of development led to a stable community, largely devoid of trees. The exception may be where repeated treatment has been possible, such as on small frontage selections. A logical alternative to ring-barking is the use of tree poisons applied to individual trees. The use of heavy machinery for land clearing has been the most spectacular means of modifying native vegetation. The widest application of this method has been in the brigalow and brigalow-belah forests. Arable lands carrying eucalypt-dominant vegetation have also been cleared as have some cypress pine-bull oak region communities. The most recent land clearing has involved non-arable lands including poplar box-sandalwood and poplar box-mulga woodlands and mulga-poplar box shrublands.

With progressive development to cultivation and annual cropping, the native vegetation has been successfully suppressed. Many native species have been killed by cultivation and would require re-establishment from seed to be a problem in any subsequent pasture phase. *Eremocitrus glauca* is a very persistent species because of its ability to sucker from roots up to 61 cm below the soil surface (Coaldrake 1970), but intensive cultivation for 5 to 6 years is reported by landholders to exert a large degree of control. Ploughing is also an effective control measure against *Acacia* and *Eucalyptus* species, *Eremophila mitchellii* and a wide range of minor shrub species.

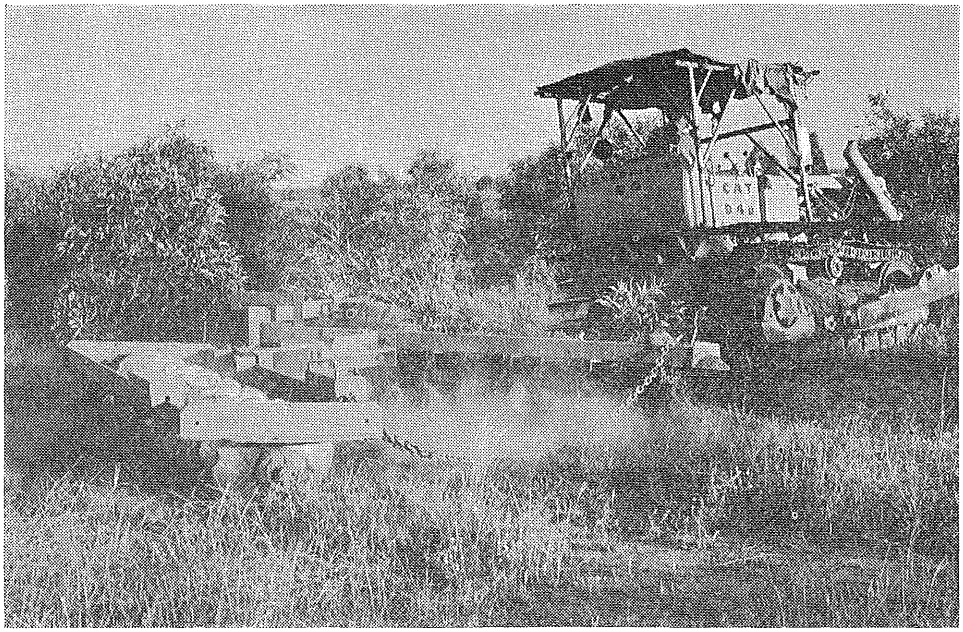
Methods of modifying vegetation

In agricultural areas, regrowth following land clearing is controlled by cultivation. In pastoral areas, the problem is more complicated and in many cases unresolved. Well-established systems are available for the successful development of brigalow and brigalow-belah communities both for pastoral and agricultural use and the eucalypt forests and woodlands are the main areas of concern. A description of the principles involved and the methods used in modifying these two vegetation types is given and the likely outcomes discussed.

BRIGALOW DEVELOPMENT. The carrying capacity of brigalow forest is about one steer to 20 hectares, largely due to the poor growth of herbs under the tree layer (Coaldrake 1970). The biomass of the tree layer is 293 t ha^{-1}



Heavy crawler tractors, either two or three, linked by chains, are employed in land clearing. Poplar box and mulga were the dominant trees in this woodland.



Regrowth of brigalow on gilgaied soils can be controlled by cultivation with heavy tandem disc harrows.

of dry matter of living and dead trees (Moore, Russell and Coaldrake 1967). As this is largely unavailable to the grazing animal, the potential for modification of the vegetation to achieve an increased level of animal carrying is apparent.

Skerman (1953) considered the development of the brigalow country as related to land use practices. With dairying, subsequent to the period when 'felling' of trees was practised, ring-barking was an effective control when followed by a period of some 5 years before the area was burnt. *Chloris gayana* (Rhodes grass) was sown in the ash of the burn and provided competition for sucker regrowth and a productive pasture. On sheep properties, ring-barking was the early method employed; it was found that sheep ate the young shoots of brigalow suckers when stocked at sufficiently high rates and when alternative forage sources were not available. With the development of suitable machinery, the techniques of land clearing were utilized and sheep again used to control regrowth. With this system, it was not possible to establish *C. gayana* and native species subsequently developed. On cattle properties, the development of the brigalow forest was most difficult because of the inability of cattle to control regrowth.

Methods of *Acacia harpophylla* land development have been reviewed with consideration of the effect of tree form, time of pulling, soil moisture, type of community and time of burning on suckering following clearing (Johnson 1964). *A. harpophylla* is very susceptible to 2,4,5-T (Johnson 1966) and a 60 to 90% reduction in sucker regrowth has been obtained by aerial spraying in late summer or autumn. A marked positive correlation exists between effectiveness of kill and soil moisture status when using 2,4,5-T in diesel distillate (Johnson and Back 1973). Aerial spraying is a satisfactory method for control of *A. harpophylla* regrowth on a pastoral holding. Burning, which stimulates suckering, can increase the effectiveness of subsequent spraying.

With the increase in cropping, cultivation, either by ploughing or by disc harrowing has become the chief means of controlling regrowth. Ploughing to 10 cm gives satisfactory control (Coaldrake 1967) there being no advantage in deeper treatment. The effectiveness of ploughing improves from a minimum in spring to a maximum in midsummer and early autumn, this pattern following closely the pattern of shoot growth (Johnson and Back 1973).

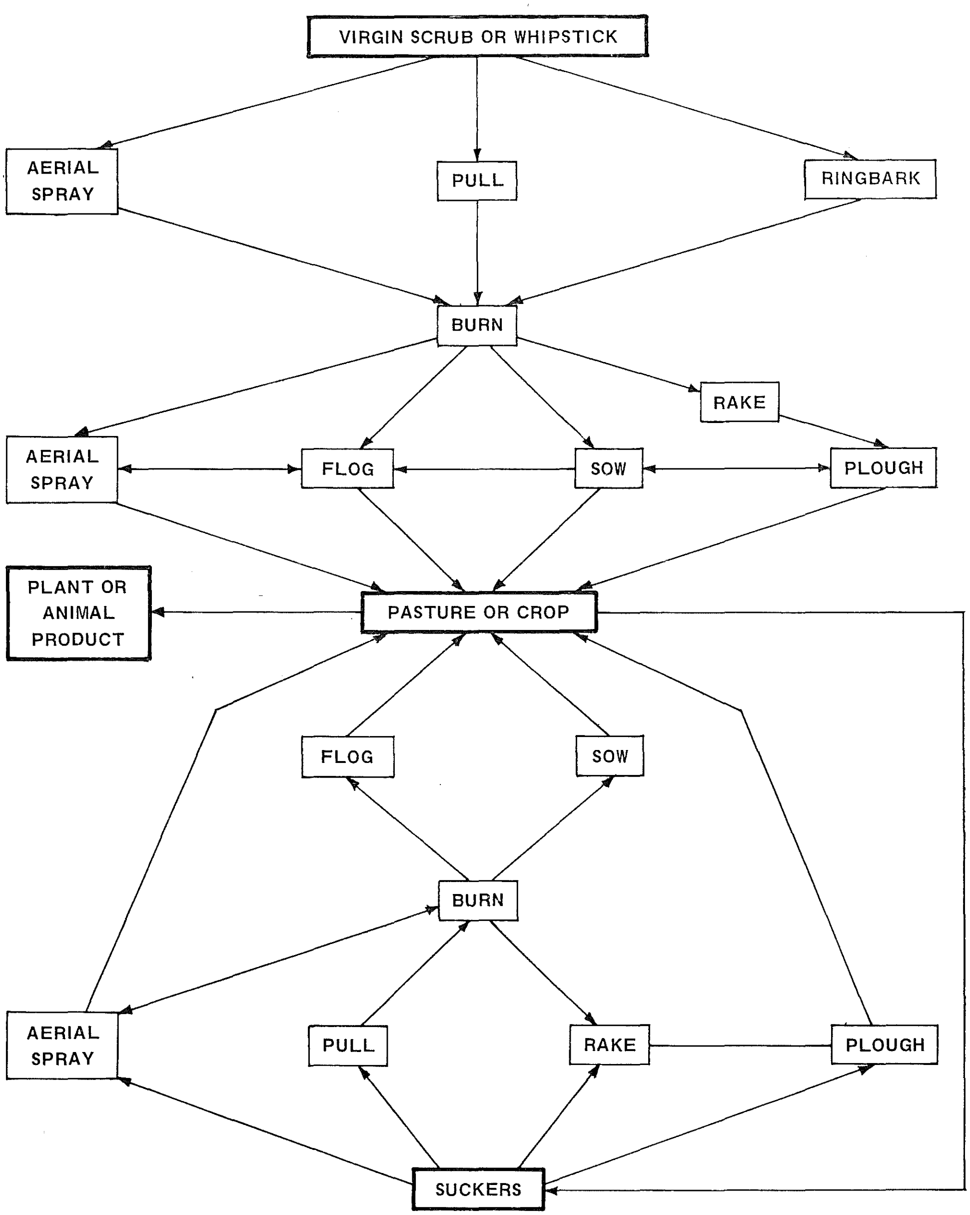


Figure 9.—Development practices for brigalow vegetation adapted from a programme suggested by Johnson (1964).

A model describing methods of handling brigalow communities has been prepared (Johnson 1964). In the light of present day practices, modifications have been made to this model but the basic form is retained as it considers development from both virgin and sucker stands (figure 9).

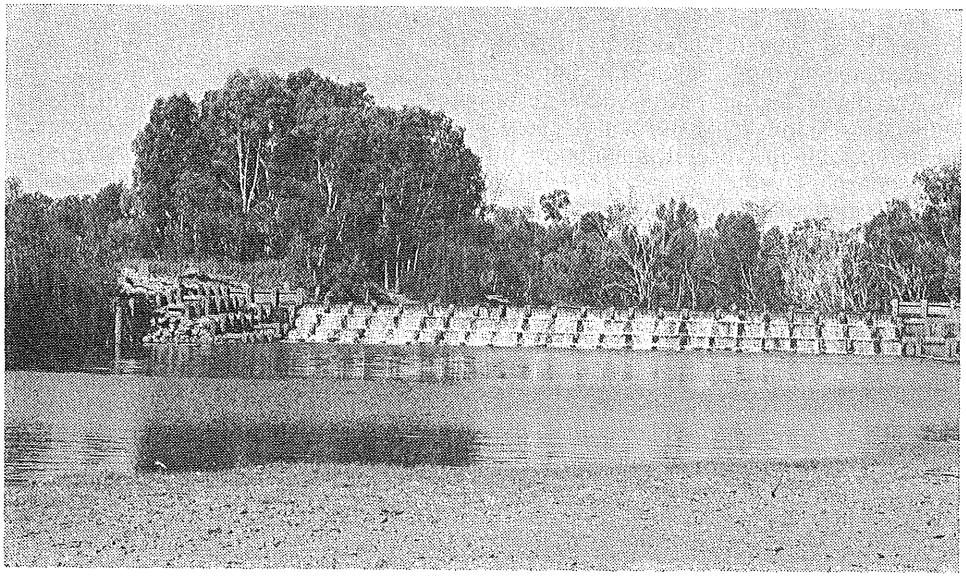
The most common present day practice for controlling *A. harpophylla* regrowth is to cultivate for 3 years. On non-arable land, although heavy grazing with sheep has been the method used to develop extensive areas of brigalow country (Skerman 1953), aerial spraying is now a preferred method. The former method caused loss of animal production and required a high level of managerial skill for the one to two seasons required for regrowth control.

EUCALYPTUS DEVELOPMENT. The effect of tree and shrub densities on the production of native grasses and herbs in woodland dominated by poplar box has been reported (Walker, Moore and Robertson 1972). Levels of herbage production of 820, 1 540 and 2 600 kg ha^{-1} were reported for untreated, ring-barked and chemically-treated woodland respectively. The subsequent response by woody weeds includes tree and shrub species and results from germination of seed and accelerated growth of established plants. Although both tree and shrub regrowth have been viewed with concern in the past, recent reports (Walker, Moore and Robertson *loc. cit.;* Moore and Walker 1974) state that, while maximum production of herbage in shrubby woodlands is obtained at a tree density of six or less per hectare, shrubs have a much lesser effect. At densities of 360 ha^{-1}, shrubs from 0·6 to 2·5 m in height had little effect on herbage production. Their regulation is still considered important, however, as they can be a hindrance to stock management and their continued development would ultimately influence herbage production. The long-term effects of suppressing these woody species have not been reported.

The earliest attempts to modify vegetation in Queensland were aimed at eucalypt forest and woodland. It is significant that few of these areas have remained as grassland and some have been 'treated' as many as three times. Practices which have been used to modify eucalypt vegetation are felling, ring-barking, chemical injection and land clearing. The first method is only of historical interest while ring-barking is still practised but at a greatly reduced scale because of labour costs. The removal of sucker growth is normally carried out twice at one-year intervals following the initial treatment. On occasions, the practice is not necessary.

An alternative method of thinning tree species is by the use of chemicals (Robertson 1965; Robertson and Moore 1972; Robertson and Pedersen 1973). Basal injections of 2,4,5–T and picloram singly and in combination (Robertson and Moore *loc. cit.*) effectively killed mature single stemmed trees of poplar box. Poisoning causes a much quicker visual response than ring-barking (Walker, Moore and Robertson 1972) and leaves on injected trees were brown and dry a month after treatment whereas 12 to 18 months elapsed before all leaves on ring-barked trees were dead. The herbage response followed the same pattern.

The major woody species which re-established from seed following thinning at Wycanna Woodland Experimental Centre (C.S.I.R.O.) near Talwood were *E. mitchellii, Cassia nemophila, Dodonaea viscosa* (sticky hop-bush), *Pimelea pauciflora* (poison pimelea) and *E. populnea* (Moore and Walker 1972). Lesser species were *Acacia oswaldii* (nelia), *Casuarina cristata, Maytenis cunninghamii, Myoporum deserti* and *Jasminum lineare*. Although basal bark spraying is effective in controlling *E. mitchellii* (Robertson 1965), other treatments have been investigated. Fewer woody plants regenerated on plots sown to introduced grasses



Glenarbon Weir is one of three weirs on the Dumaresq River which provide a total of 1 500 ml of water for irrigation.

(Moore and Walker *loc. cit.*), intermittent heavy grazing with sheep controlled seedling regeneration of *E. mitchellii, Cassia nemophila* and *D. attenuata* and burning 2 years after the initial timber treatment reduced the number of these three shrubs on ungrazed plots from 3 665 to 90 plants ha^{-1}. A combination of burning and grazing offered slightly greater benefits.

Ring-barking, although still practised, has largely been replaced by tree poisoning and land clearing.

With land clearing, large areas can be treated quickly and at a relatively low cost. The method lends itself to the development of agricultural land where subsequent burning, raking of timber and cultivation control the regrowth of woody species. For pasture land, clearing leads to a rapid response in grasses and herbs and the disturbance caused during land clearing can be used to advantage in the establishment of introduced pasture species. Quantitative data on the level of grass and herb response which result from land clearing are not available. The development of coppice shoots on broken stumps and lignotubers of *Eucalyptus populnea* and regrowth of woody plants from seed are difficult to regulate. Robertson and Pedersen (1973) applied chemical as a basal bark spray to poplar box and recorded best results with a mixture of 2,4,5–T and picloram.

A type of development, best described as 'interrupted development' has often been employed on eucalypt vegetation. Tree species are cleared as previously described and advantage taken of the flush of grass and herbage growth. Woody species are allowed to develop modified only by the influence of the grazing animal and an occasional fire. When regrowth develops sufficiently to suppress ground cover, the area is cleared again and the same sequence of events is repeated. The unavailability of a practical control measure or shortage of finance to allow the labour-intensive controls to be applied are suggested as the reason for this course of action. It is most common in those areas too dry for agricultural development.

Common practices employed in the modification of vegetation in which eucalypt is the dominant species, and the probable pasture responses, have been considered (figure 10). Where uncertainty exists about the outcome of a management practice, this is indicated by a question mark.

The practices of ring-barking and herbicide treatment successfully remove mature trees, but the problem of seedling and shrub regrowth remains. With land clearing, sucker, seedling and shrub regrowth can be handled through uninterrupted development involving burning, raking and ploughing but the outcome of other management treatments is uncertain. It is currently suggested that there may be an advantage in poisoning *E. populnea* before the land-clearing operation. This practice could assume greater importance on pastoral land if successful control of seedling regrowth through grazing and burning can be established on the wide range of land forms available.

HYDROLOGY

Surface water

Three river basins drain the Condamine–Maranoa region. These are the Border Rivers basin which includes the Macintyre–Dumaresq and Weir Rivers, the Moonie River basin, and the Condamine–Culgoa Rivers basin, which includes the Balonne and Maranoa Rivers (map 1). In turn, these form part of the Murray–Darling Drainage Division (Australian Water Resources Council 1971). Two of these basins, the Border Rivers and the Condamine–Culgoa, contribute more than 90% of the average annual discharge (table 15).

Average annual run-off has been estimated to be less than 2·5 cm for most of the region, and less than 1·25 cm for the western third (Anon. 1967). For the eastern portion, average annual run-off has been estimated at 2·5 cm (Bureau of Meteorology 1961). To conserve this run-off at the property level, there are numerous earth tanks and dams in or near creeks, gullies and depressions, especially in areas of clay soil and/or poor artesian water supply.

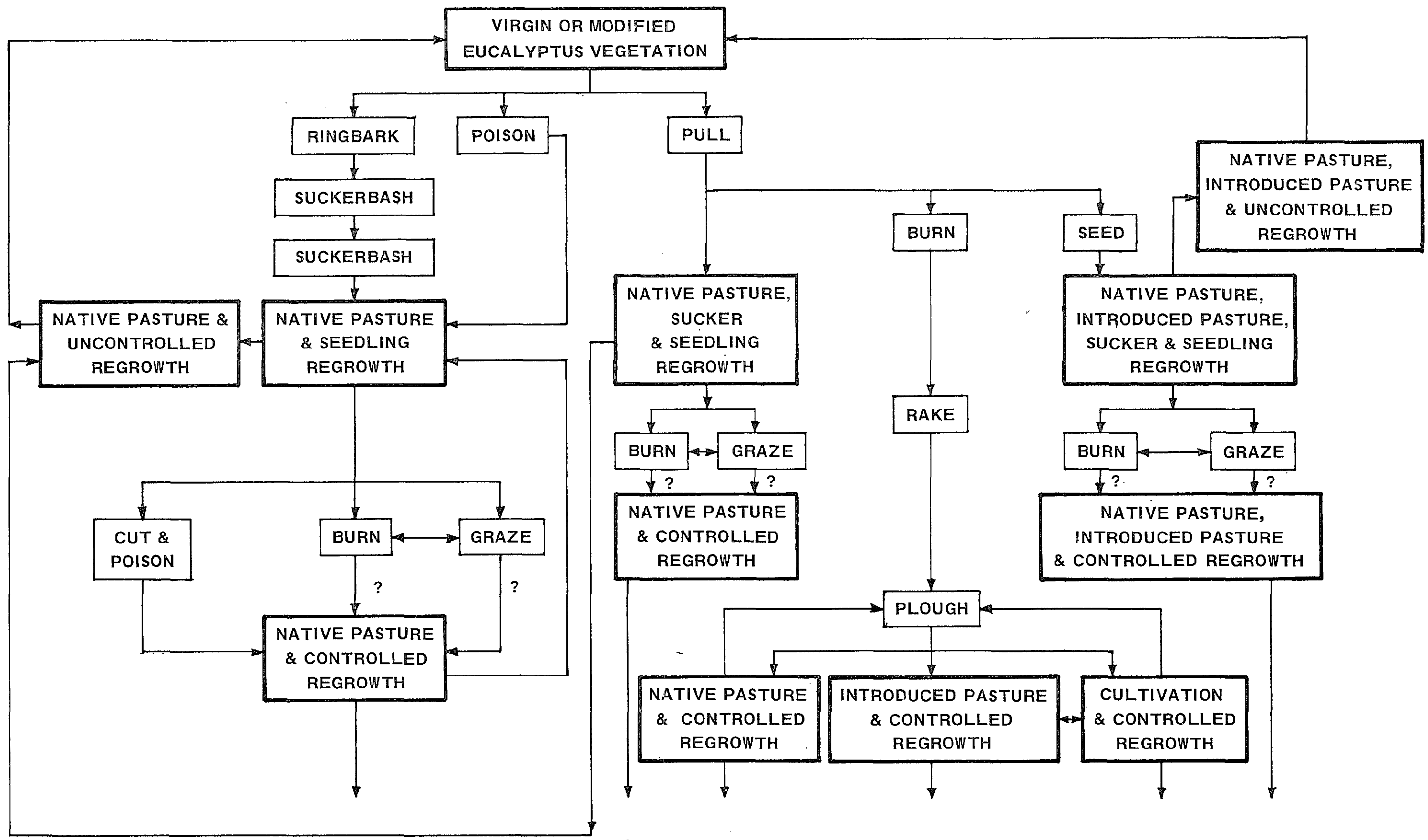


Figure 10.—Development practices for Eucalyptus *vegetation.*

TABLE 15

AVERAGE ANNUAL DISCHARGES OF THE RIVER SYSTEMS DRAINING THE CONDAMINE–MARANOA BASIN

River System	Gauging Station	Average Annual Discharge (Ml)
Moonie River basin	Gundablouie	215 250
Border Rivers basin	Bogabilla	1 143 390
Condamine–Culgoa Rivers basin	Kunreebree	1 611 300
Total		2 969 940

Source: Australian Water Resources Council (1965).

The major surface water storages which affect or will affect the Condamine–Maranoa region include the Coolmunda Dam, the Jack Taylor Weir, the E. J. Beardmore (Kajarabie) Dam and the Moolabah and Buckinbah Weirs, the Glenlyon Dam situated on Pike Creek and, to some extent, the Leslie Dam (stage I and the proposed stage II). There are a number of minor weirs in the region, mainly having a regulatory function (map 1). At present, the total storage capacity of these structures is 256 631 Ml (table 16). If the partly-constructed Glenlyon Dam and Leslie Dam stage II are included, the storage capacity becomes 557 661 Ml.

TABLE 16

STORAGE CAPACITY AND ASSURED SUPPLY OF MAJOR DAMS AND WEIRS RELEVANT TO THE CONDAMINE–MARANOA BASIN

Structure	Storage Capacity (Ml)	Assured Supply (Ml)
Jack Taylor Weir	10 086	
Kajarabie (Beardmore) Dam	100 368	63 960 for irrigation
Moolabah Weir	3 936	
Buckinbah Weir	5 105	
Coolmunda Dam	75 030	18 204 for irrigation
Chinchilla Weir	9 237	
Minor weirs	5 883	
Leslie Dam—stage I	46 986	3 198 for City of Warwick 12 915 for irrigation
Proposed and partly-constructed dams		
Leslie Dam—stage II	60 270	9 840 for irrigation
Glenlyon Dam	260 760	39 975 for irrigation in Queensland
Queensland share	130 380	
Total at present	256 631	
Total proposed	577 661	

Source: Irrigation and Water Supply Commission, Queensland (personal communication).

Water from the E. J. Beardmore Dam and the Jack Taylor Weir is reticulated to the irrigation area south-east of St. George. This irrigation project has been developed in two stages. The original 18 farms taken up in 1957, and a further two allocated in 1963, were irrigated by water pumped from the Jack Taylor Weir. Thirty-two additional farms are watered from the E. J. Beardmore Dam, completed in 1973, the water being reticulated largely by gravity via the Thuraggi watercourse and the Moolabah and Buckinbah Weirs.

Below St. George, the Balonne River divides into a series of effluent streams. In order to better distribute low flows in these channels, regulatory weirs have been built at four sites, three of which are in the study area and one is in New South Wales. These are designed to divert part of the water from the Culgoa River into the Balonne Minor and its more widespread system of effluent channels. They are located at the Culgoa–Balonne Minor bifurcation, the Balonne Minor–Donnegri Creek bifurcation and the Ballandool–Bokhara bifurcation in Queensland, and the Bokhara–Birrie bifurcation in New South Wales (Dumaresq–Barwon Border Rivers Commission 1971).

The Coolmunda Dam, completed in 1968, is situated on the Macintyre Brook below its junction with Bracker Creek (map 1). The water trapped by the dam is used to irrigate an area along the Macintyre Brook, extending into the project region as far as the junction of this watercourse with the Dumaresq River. (Queensland Department of Agriculture and Stock and Irrigation and Water Supply Commission 1963).

A partly-completed dam on Pike Creek will conserve water for irrigation along the Dumaresq–Macintyre River valley, such water to be divided equally between Queensland and New South Wales. At this stage, it is proposed to limit the assured supply of water to the area between the dam and Goondiwindi; below Goondiwindi, prospective irrigators would be required to rely on unregulated stream flow. The Leslie Dam is considered briefly in the groundwater section because it stores water which would otherwise pass through the evaluation area.

Surface water in the Condamine–Maranoa region is generally of satisfactory quality for irrigation. An exception existed with water from the Macintyre Brook used to irrigate tobacco in the Inglewood area. During periods of low water flow, high chloride content (average of more than 40 p.p.m.) lowered leaf quality (McNee and Skerman 1965). Subsequently, the construction of Coolmunda Dam has permitted control over the flow in Macintyre Brook thus preventing undue build-up of chloride concentration.

Although there were only 24 recorded floods at Goondiwindi town in the 70 years to 1961 (table 17), the Macintyre River is credited with an average of 2·8 floods per year which inundate at least the low lying parts of the river system (Bureau of Meteorology 1961).

Two types of flood warnings are issued by the Brisbane office of the Australian Bureau of Meteorology (Heatherwick 1974). For river basins on which detailed hydrological investigations have been carried out (Brisbane, Mary and Macintyre Rivers), flood forecasts involving river height predictions, on an average of 24 hours ahead, are issued. For the Macintyre River, these are related to river levels at Goondiwindi. On rivers for which these investigations have not been carried out, flood warnings are qualitative in nature and give only details of recorded rainfalls and river heights, forecast rainfalls and expected flooding in terms of minor, moderate and major degrees. The Condamine River system receives flood warnings only but is the subject of detailed investigations which will allow flood forecasting in the future.

Groundwater

The region derives supplies of groundwater from the Mesozoic aquifers of the Surat Basin a sub-basin of the Great Artesian Basin. There is also water in the alluvium adjacent to the Dumaresq River, but the supply of this is poor (Queensland Department of Primary Industries and Irrigation and Water Supply Commission 1969). Geologically, the Surat basin is a Jurassic—Cretaceous formation

TABLE 17

FREQUENCY OF FLOODING EXPRESSED AS ACTUAL NUMBER OF OCCASIONS ON WHICH FLOOD HEIGHTS HAVE BEEN EXCEEDED

River	Gauging Station	Years of Record	J	F	M	A	M	J	J	A	S	O	N	D	Total
Condamine ..	Condamine	36	5	11	5	1	1	3	3	2	..	1	3	3	38
Balonne	Surat	50	5	7	6	2	2	2	5	1	1	2	3	3	39
Macintyre	Goondiwindi ..	70	2	5	1	..	..	3	4	..	..	5	2	2	24

Source: Bureau of Meteorology (1961).
Note: Flood height is defined as the height of water at the gauge site at which the banks are overflowed.

overlying the southern part of the Permian–Triassic Bowen Basin (Casey 1968) and separated from the Eromanga Basin by the Nebine Ridge. The most productive aquifers lie within the Jurassic and Cretaceous sandstones, known in decreasing order of age as the Precipice Sandstone, Hutton Sandstone, Gubberamunda Sandstone and the Blythesdale Formation which includes the Mooga Sandstone. Water can also be obtained from the fossil wood beds, the Orallo Formation, of the Upper Jurassic sediments (Casey *loc. cit.*). The aquifers tend to increase in depth from north to south.

All aquifers decrease in productivity towards the south-eastern corner of the Great Artesian Basin, due to a lessening of porosity of most of the aquifers east of an irregular line between Muckadilla and Goondiwindi (Whitehouse 1954). As well, salinity of the water tends to increase in this direction. The Blythesdale Formation is the main aquifer exploited in the northern part of Tara Shire since it gives good stock supplies at quite shallow depths (Dawson 1972*b*).

Of a total of 339 artesian bores drilled in the study region, 256 continue to flow. Pumping supplies are normally available from those which have stopped flowing and from the numerous subartesian bores. Artesian bores in the eastern part of the Condamine–Maranoa are generally shallower (averaging 250 to 450 m), have lower flows (40 to 1 000 m^3 day^{-1}) and outnumber those in the western areas by 3·5 times. Of these bores, 80% are controlled to regulate their flow. The deeper artesian bores in the western part of the region average 600 to 1 000 m with some as deep as 2 700 m. They have much greater flows (1 200 to 2 200 m^3 day^{-1}) and only 30% are controlled.

The major proportion of the Great Artesian Basin has water quality of the order of 140 to 640 p.p.m. of total dissolved solids with levels up to 1 700 p.p.m. recorded in isolated situations (Ogilvie 1954). In the shires of Balonne and Warroo, total dissolved solids increase from 500 to 780 p.p.m. from west to east while in Waggamba and Tara shires higher levels are likely.

The question of diminution of flow of artesian waters appears to be less serious than was thought at one stage; the rate of diminution is lessening and there is a trend towards equilibrium (Eden 1969). Consideration of the total artesian flow over the State does not adequately represent the problem of diminution (Queensland Department of Co-ordinator General of Public Works 1954); for this purpose the Artesian Basin should be divided into hydrological groups, the bores in each presenting a similar behaviour pattern. Thus, the Surat geological basin corresponds to the Balonne hydrological group (Ogilvie 1954). The flow from bores in this group reached a peak in 1930, with a diminution rate in 1952 of 3% a year. By 1965, this had dropped to 1·12%; in the same period the average diminution rate for the State dropped from 2% to 0·57% (Eden 1969).

In the last 10 years, there has been a considerable amount of exploratory drilling for oil in the Condamine–Maranoa region. Non-productive wells are frequently converted to water bores should the owner of the property so desire. The oil companies line the bore to 122 m, the landholder then casing to the depth of the aquifer being tapped. The bore belongs to the oil company until their authority to prospect expires, when ownership reverts to the Crown. It is then sold to the landholder for a nominal sum. These bores usually tap good supplies in the Hutton and Triassic sandstones at depths normally out of the economic reach of pastoralists (Casey 1968). Bores obtained in this way, however, form only a small proportion of the total bores in the area, some 20 artesian bores having resulted from drilling in search of oil.

An area of intensive irrigation development exists to the east of the project region in the Brookstead–Cecil Plains area where water is drawn from Condamine River alluvium and by direct pumping from its two streams. A reduction in groundwater level in the alluvium has hastened interest in the construction of stage II of the Leslie Dam, water from which will be used both to substitute for and to augment groundwater supplies and also to experiment with artificial recharge of the groundwater aquifers. The presence of alluvium groundwater stimulated interest in other areas along the Condamine and a series of test bores was drilled between Surat and Condamine. However, little water was found, and it was concluded that the prospects for irrigation development were poor (Queensland Irrigation and Water Supply Commission personal communication).

GEOLOGY

Recent descriptions of the geology of the Condamine-Maranoa basin appear in the Bureau of Mineral Resources 1:250 000 Geological Series with explanatory notes. Relevant sheets are Surat (Reiser 1971), Roma (Exon 1971*b*), Mitchell (Exon 1971*a*) and Homeboin (Senior 1971).

The Surat report describes the physiography of the region as—1. Dissected plateaux and ridges of deep weathering profile, remnants of former pediplains developed on deeply weathered Lower Cretaceous sediments. These form a divide between the Condamine River in the east and the Balonne River in the west. 2. Rolling downs topography developed where erosion has stripped the weathered material and exposed unaltered Lower Cretaceous sediments from which grey and brown soils of heavy texture have developed (Isbell 1957). 3. Dissected terraces of partly consolidated Tertiary alluvium, localized along the courses of present-day streams as rounded hills and ridges above the level of the alluvial plains. 4. Alluvial plains of Quarternary age developed on alluvial fill in the valleys of the Balonne and Moonie River systems.

The physiography of the area to the west of the Balonne River is described in the Homeboin report (Senior 1971). An extensive depositional plain, consisting mainly of sandy soils, covers the larger part of the area. Claypans are common near the periphery of the sandplains.

In the eastern part of the study region are found Palaeozoic rocks and these are the basement of the Great Australian Artesian Basin. Mesozoic outcrops occur throughout the younger Quarternary sediments to the west, but the description of these is complicated by the lateritic influence which has affected nearly every post-Palaeozoic formation (Isbell 1957).

The Surat Sedimentary Basin underlies most of the Condamine-Maranoa basin. The stratigraphy of this formation has recently been described (Allen and Hogetoorn 1970). Geological age, rock units, thickness of sediments, lithology, environment of deposition and major hydrocarbon occurrence are tabulated by these authors (table 18). Name changes which have occurred in describing the sediments of this basin are included and this adds considerable clarity when comparing the work of various authors.

OIL AND GAS. There are three commercial oil fields in the Condamine-Maranoa basin—the Moonie, Alton and Bennett fields. The Moonie field is linked with Brisbane by an oil line (map 6) and oil is transported from the other two fields to this line.

Roma, the major gas-producing field just to the north of the study area, is also connected to Brisbane by a pipe line (Wallumbilla-Brisbane gas line) (map 6). Several gas fields are connected to this line including Bony Creek, Duarran,

TABLE 18

STRATIGRAPHY OF THE SURAT BASIN

Age	Rock Units	Thickness (max. m)	Lithology	Environment of Deposition	Major Hydrocarbon Occurrences	Comment
Cretaceous ..	Wallumbilla Formation	670	Shale with minor glauconitic sandstone; macrofossils	Marine	..	Previously named Roma Formation
	Bungil Formation ..	300	Sandstone and shale ..	Lacustrine and fluviatile	..	These four formations together comprise the Blythdale Group of Whitehouse (1955). The Mooga and Gubberamunda are important aquifers
	Mooga Sandstone ..	110	Quartzose sandstone ..	Fluviatile	..	
Jurassic ..	Orallo Formation ..	240	Sandstone, shale, and minor coal and bentonite; fossil wood	Lacustrine	..	
	Gubberamunda Sandstone	240	Quartzose sandstone ..	Fluviatile	..	
	Injune Creek Group	640	Shale, sandstone and coal	Lacustrine, fluviatile and paludal	Gas at Pleasant Hills	Lower part is formed by Walloon Coal Measures (= Birkhead Formation)
	Hutton Sandstone ..	240	Quartzose sandstone with interbedded shale and pebble-conglomerate	Fluviatile and minor lacustrins	Gas at Leichhardt	Important aquifer
	Evergreen Formation	180	Shale and sandstone			
	Evergreen Formation		Shale and oolitic chamositic sedimentary rock	Shallow marine? ..		
	Evergreen Formation — Boxvale Sandstone Member	30	Quartzose sandstone ..	Fluviatile	Oil at Conloi and at Roma	
	Evergreen Formation		Shale and sandstone ..	Lacustrine and fluviatile	Oil at Alton	
	Precipice Sandstone	150	Sandstone with minor shale		Gas at Roma; oil at Moonie, Alton, Roma and Bennett	Precipice on Roma Shelf is generally less than than 30 m thick
			Quartzose sandstone ..	Fluviatile		
Triassic Permian			Sediments of southern Bowen Basin			

Source: Allen and Hogetoorn (1970).

Grafton Range, Hope Creek, Pickanjinnie, Pine Ridge, Pringle Downs, Pleasant Hills, Raslie, Richmond, Tarrawonga, Wallumbilla South and Snake Creek. Timbury Hills and Yanalah gas fields are connected to the Roma power station.

Oil occurs in the Precipice sandstone at Moonie and Alton, and gas and minor oil occurs in the Precipice sandstone on the Roma Shelf where it is less than 30 m thick. The Evergreen Formation also carries some oil while the Hutton Sandstones and Injune Creek beds carry some gas (table 18) (Allen and Hogetoorn 1970).

Production of oil began in 1964 after the pipeline to Brisbane was completed. The initial recoverable reserves were approximately 3 498 000 m^3 and the production reached a maximum of 1 590 m^3 per day but declined to 636 m^3 per day by the end of 1969 (Allen and Hogetoorn *loc. cit.*). The Moonie oil line presently carries 200 m^3 a day of oil (Queensland Department of Mines personal communication).

Gas was first discovered at Roma in 1906 and the use of this for electricity generation began in 1961. The gas pipeline to Brisbane was completed in 1969. The recoverable reserves are currently 0.8×10^6 m^3. Both the gas and oil fields are regarded as only small fields.

POPULATION

The 1971 census showed that there were 23 773 people living in the six shires including Goondiwindi town. Of these, 40·6% lived on rural holdings, 53·3% in towns of more than 200 people and 6·1% in towns of less than 200 people (table 19). This compares with a total population of 1 823 362 people in Queensland, of which 9·5% lived on rural holdings, 83·4% in towns of more than 200 people, and 7·1% in towns of less than 200 people.

TABLE 19

POPULATION STATISTICS FOR THE CONDAMINE–MARANOA BASIN, FROM THE CENSUS OF 1971

Local Authority Area	Total Population	Population on rural holdings		Population in towns of more than 200 people		Population in towns of less than 200 people	
		No.	%	No.	%	No.	%
Inglewood	3 639	1 255	34·5	2 098	57·7	286	7·9
Millmerran	3 432	1 884	54·9	1 441	42·0	107	3·1
Waggamba	2 913	2 160	74·2	534	18·3	219	7·5
Tara	3 328	1 973	59·3	1 150	34·5	205	6·2
Balonne	5 354	1 540	28·8	3 208	59·9	606	11·3
Warroo	1 376	828	60·2	508	36·9	40	2·9
Goondiwindi Town	3 731	—	—	3 731	100·0	—	—
Condamine–Maranoa basin	23 773	9 640	40·6	12 670	53·3	1 463	6·1
Queensland	1 823 362	172 506	9·5	1 517 707	83·4	129 443	7·1

Source: Australian Bureau of Statistics (1973).

In Queensland since 1947, there has been a continuous increase in total population and a consistent trend to a declining proportion of this population living on rural holdings (table 20). In the Condamine-Maranoa basin, however, there has been a decline in population since 1961. At the same time, there has been no discernible pattern of change in the proportion of total population living

TABLE 20

TOTAL POPULATION AT YEAR OF CENSUS SHOWN, AND PERCENTAGE OF POPULATION LIVING ON RURAL HOLDINGS AT YEARS OF CENSUS BETWEEN 1954 AND 1971

Local Authority Area	Parameter	Year of Census				
		1947	1954	1961	1966	1971
Inglewood	Total population % on rural holdings	4 057 —	4 441 46·2	4 868 40·0	4 184 34·2	3 639 34·5
Millmerran	Total population % on rural holdings	3 012 —	3 473 57·7	3 423 56·3	3 512 55·8	3 432 54·9
Waggamba	Total population % on rural holdings	2 590 —	2 968 64·6	3 123 66·4	2 895 78·5	2 913 74·2
Tara	Total population % on rural holdings	2 278 —	3 149 56·0	3 558 55·3	3 525 57·0	3 328 59·3
Balonne	Total population % on rural holdings	4 404 —	5 527 34·7	6 105 34·0	5 849 33·3	5 354 28·8
Warroo	Total population % on rural holdings	1 385 —	1 652 50·9	1 774 53·4	1 573 60·1	1 376 60·2
Goondiwindi Town	Total population —	2 467 —	2 950 —	3 274 —	3 529 —	3 731 —
Condamine–Maranoa basin	Total population % on rural holdings	19 829 —	24 160 43·4	26 125 41·9	25 067 42·2	23 773 40·6
Queensland	Total population % on rural holdings	1 106 415 —	1 318 259 14·8	1 518 828 12·6	1 674 324 11·3	1 823 362 9·5

Source: Australian Bureau of Statistics (1947, 1954, 1961, 1966, 1971).

on rural holdings, although the effect of the development of brigalow areas can be seen in the increase from 1961 to 1971 in the shires of Tara and Waggamba. These figures reflect the essentially rural nature of the region, the only two major towns being Goondiwindi and St. George. These had populations of 3 731 and 2 184 respectively at the 1971 census. The towns of Inglewood, Tara, Dirranbandi and Surat had populations of between 500 and 1 000 people (map 7).

SERVICES AND FACILITIES

This section augments the information on services and facilities contained in map 6. Additional data are contained in appendices. Where not otherwise referenced, information has been obtained from the appropriate Government department.

ROADS. At 30 June 1972, the six shires had 13 655 km of sealed, other formed and unformed roads out of a total of 193 538 km in Queensland (Australian Bureau of Statistics 1968 to 1974), giving a proportion of 588 ha of land to every kilometre of road compared with an average of 893 ha km^{-1} for the State. The proportion of sealed road has almost doubled since 1966-67 (appendix 2).

No 'beef roads' exist or are planned for this region. However, various developmental roads have been and are being constructed. These and major roads are marked on map 1. Satisfactory road conditions allow for short travelling times through the area and from the area to Brisbane (table 21).

TABLE 21

ROAD DISTANCES AND TRAVELLING TIMES FROM MAJOR TOWNS TO BRISBANE

Towns	Distance (km)	Travelling Times (mins)
Inglewood	285	222
Goondiwindi	378	286
Meandarra	372	288
Surat	472	356
St. George	515	384
Bollon	631	460

Source: Commissioner of Main Roads (1974).

RAIL SERVICES. The six shires are served by four branch lines running to Glenmorgan, Cecil Plains, Millmerran and Texas, as well as the major South-Western line running through Inglewood and Goondiwindi to Dirranbandi (map 1). The main Western line to Cunnamulla and Quilpie (via Miles, Roma and Charleville) provides a service to the northern parts. The area has a total of 523 km of railway line, with 52 sidings, 30 of which have livestock yards (appendix 3).

Freight rates for wool do not increase uniformly with distance from Roma Street Station (appendix 3). They are reduced in the border regions to allow the railway to compete with interstate road carriers who are not liable for road permit fees.

AIR SERVICES. There are 13 Authorised Landing Areas (A.L.A.) in the six shires, as well as larger strips at Goondiwindi, Bollon, St. George, Dirranbandi, Mungindi and Tara. An A.L.A. has a minimum width of 60 m and is restricted to aircraft of 2 040 kg all-up weight. The larger strips can take aircraft of the size of the Fokker 'Friendship'. Ansett Airlines of Australia provide air services to Goondiwindi, St. George and Dirranbandi through a charter operator called 'Nationwide'. Both Goondiwindi and St. George have a non-directional beacon (a navigation aid) and runway lighting.

NEWSPAPER, RADIO AND TELEVISION SERVICES. The major newspapers distributed within the area are *The Sunday Mail, The Courier-Mail, Sunday Sun* and *Queensland Country Life*. *Queensland Country Life* is circulated to 75% of rural holdings in the six shires. Country newspapers which supply the area include the *Western Times, Chinchilla News* and *Murilla Advertiser, Dalby Herald, Goondiwindi Argus, Roma Leader, The Western Star, Balonne Beacon, Warwick Daily News, Texas and Inglewood News, Toowoomba Chronicle* and *Queensland Grain Grower.*

Five commercial and four national stations provide radio services for the area. The commercial stations are located at Warwick, Toowoomba, Oakey, Roma and Charleville, while the national stations are located at Dalby and St. George, with two at Brisbane. There are also specific shortwave services from Brisbane and Melbourne.

Mt. Mowbullan in the Bunya Mountains and Passchendaele Ridge, north of Stanthorpe are sites for national and commercial television transmitters; Mt. Mowbullan also has aircraft communication facilities. A microwave system which was completed in early 1974 carries national television programs to transmitters at Miles, Roma, St. George and Dirranbandi in addition to telegraphic information as far as Roma. A television link from Passchendaele carries television programs to a translator at Goondiwindi. The border regions also receive television broadcasts from New South Wales.

TELEPHONE SERVICES. There are currently 4 996 telephone subscribers in the six shires; 96% of telephones are connected through manual exchanges, although the conversion to automatic exchanges is in progress.

POSTAL SERVICES. Mail is delivered to 4 977 reception points; 3% of delivery services run once a week, 74% twice a week, 12% three times a week and 11% run six times a week. Towns on the South-Western railway line also receive mail services by rail. The six shires have 10 official and 22 non-official post offices.

EDUCATION SERVICES. There are 37 Government and seven non-government schools in the six shires, having a total of 5 549 pupils of whom 1 185 are secondary pupils (appendix 4). There are no agricultural colleges or tertiary institutions in the area.

HEALTH SERVICES. The six shires have 11 public hospitals with a total capacity of 326 beds (appendix 5).

POLICE AND JUDICIAL SERVICES. A total of 15 police stations, 16 Clerks of the Court and five bailiffs serves the six shires.

ELECTRICITY. The area is supplied with power derived from three sources and distributed by five electricity authorities (map 6). Millmerran is supplied by the Southern Electric Authority of Queensland (S.E.A.) and Tara Shire by the Dalby Town Council which obtains its electricity from S.E.A. Inglewood and

Waggamba shires are supplied by the North-West County Council of N.S.W. Electricity generated from local natural gas is supplied to Warroo shire by the Roma Town Council.

Compared with most of Queensland, the project area is well covered by single wire earth return transmission lines, a system used mainly in western rural areas because of the low cost with which it can cover vast distances. Areas in the Condamine-Maranoa basin not covered by this system include a corridor running north from St. George to Warroo Bridge then turning west-north-west, areas immediately to the west and north-east of Moonie, and the solodic country north of Tara.

STOCK ROUTES. An extensive system of stock routes is present throughout the Condamine-Maranoa basin. These are now largely unused by travelling stock because of the advantages of road transport. The main arteries may, however, be used for stock during times of drought.

ABATTOIRS. There are no abattoirs in the project area other than for local supply. The adjacent area has 17 abattoirs licensed to kill and process meat for export (table 22), four of which are in New South Wales and eight in either Toowoomba or Brisbane. There are another two abattoirs which do not have export licences.

TABLE 22

ABATTOIRS SERVING THE CONDAMINE–MARANOA BASIN

Location	Company
Cannon Hill	Metropolitan Public Abattoir Board
Dinmore	Bremer River Abattoir Pty. Ltd.
Dinmore	Dinmore Meat Works Pty. Ltd.
Murarrie	Thos. Borthwick and Sons (A'asia) Ltd.
Murarrie	Queensland Bacon Pty. Ltd.
Oxley	T. C. Hutton Pty. Ltd.
Ipswich	Ipswich District Abattoir Board (1)
Drayton	Toowoomba Public Abattoir Board
Willowburn	Darling Downs Co-op. Bacon Assn. Ltd.
Doboy	Darling Downs Co-op. Bacon Assn. Ltd. (1)
Beaudesert	Tancred Bros. Pty. Ltd.
Oakey	Oakey Abattoir Pty. Ltd.
Roma	Roma Meat Works Pty. Ltd.
Warwick	Warwick Bacon Co. Pty. Ltd.
Beenleigh	Teys Bros. (Wholesale) Pty. Ltd.
Inverell	North-West Abattoir Pty. Ltd.
Moree	Gwyder Valley (Abattoir) Country Canned
Tenterfield	Riverstone Meat Co. Pty. Ltd.
Wallangarra	Anderson Meat Packing Co. Pty. Ltd.

Source: Slaughtering and Meat Inspection Branch, Queensland Department of Primary Industries, Brisbane (personal communication).

NOTE: (1) Abattoirs without a licence to slaughter cattle for export.

CATTLE DIPS. There are four cattle dips on the Queensland-New South Wales border situated at Wallangarra, Texas, Keetah and Goondiwindi. These are controlled by the New South Wales Department of Agriculture. There are no dips on the border east of Wallangarra nor west of Goondiwindi. The project area is tick-free, but to the north and east lies the 'tick line'. This is a theoretical line incorporating a protective system of clearing and strategic dips, which separates the tick-infested and the tick-free areas. Only the more important clearing dips are shown on map 6.

STOCK SELLING YARDS. At least 17 sets of yards in or adjacent to the six shires provide stock selling facilities for the area. These have an approximate total capacity of 21 200 cattle and 132 000 sheep, with an annual throughput of about 220 500 cattle and 833 000 sheep (table 23). The more important yards are those located at Roma, Dalby and Boggabilla for cattle and at Dirranbandi, Dalby and Boggabilla for sheep.

TABLE 23

STOCK SELLING CENTRES WITHIN AND ADJACENT TO THE CONDAMINE–MARANOA BASIN

Shire	Town	Capacity	Annual Throughput
Inglewood	Inglewood	2 000 C	4 000 C
	Texas	2 000 C	4 500 C
Millmerran	Millmerran	600 C	3 000 C
	Millmerran	400 C	4 000 C
	Bringalily	400 C	2 100 C
	Karara	300 C	200 C
		8 000 S	10 000 S
Waggamba	Boggabilla (N.S.W.)	3 500 C	35 000 C
		20 000 S	150 000 S
Tara	Meandarra	10 000 S	7 000 S
		1 000 C	7 000 C
	Tara	10 000 S	—
		1 000 C	4 000 C
Balonne	St. George	400 C	700 C
	Dirranbandi	700 C	5 500 C
		40 000 S	60 000 S
	Thallon	300 C	1 500 C
	Thallon	600 C	2 000 C
Warroo	Surat	14 000 S	14 000 S
Outside	Roma	2 000 C	40 000 C
	Dalby	4 000 C	107 000 C
		30 000 S	592 000 S
		2 000 P	2 000 P
	Wallumbilla	2 000 C	N.A.
Total	..	21 200 C	220 500 C
		132 000 S	833 000 S
		2 000 P	2 000 P

Source: Veterina y Services Branch, Queensland Department of Primary Industries, Brisbane (personal communication).
Legend: C—Cattle, S—Sheep, P—Pigs.

WHEAT STORAGE. The total capacity of bulk storage for wheat within the study area in 1972-73 was 285 700 tonnes spread over 19 depots. This constituted 22·9% of Queensland's total bulk storage. As well, some of the area is served by depots along the main Western railway line. The major storages are in Waggamba, Millmerran and Tara shires (table 24). All bulk stores are sited along railway lines.

TIMBER MILLS. The study area has 20 timber mills, of which three are 'bush mills' and the rest are located in townships. All cut cypress pine exclusively.

Extension and Research Facilities

EXTENSION. At present, there are 11 extension officers of the Queensland Department of Primary Industries stationed within the study area, three of whom have regulatory functions with Veterinary Services Branch. The officers consist

TABLE 24

STORAGE CAPACITY OF WHEAT DEPOTS OF THE STATE WHEAT BOARD IN SIX SHIRES

Shire	Depot	Bulk Capacity (t)	
		1970–71	1972–73
Millmerran	Cecil Plains	24 800	26 700
	Yandilla	11 600	14 600
	Millmerran	19 400	31 300
	Pampas	3 300	3 900
	Horrane	—	4 100
	Nangwee	—	8 200
	Norwin	20 900	20 900
Inglewood	Inglewood	3 300	3 300
	Texas	6 000	6 500
Waggamba	Bungunya	7 100	7 000
	Goondiwindi	48 000	56 200
	Talwood	5 800	6 500
	Toobeah	12 300	13 100
	Yelarbon	17 200	13 700
Tara	Meandarra	18 400	26 600
	Glenmorgan	10 700	11 400
	Tara	8 500	8 500
	The Gums	4 900	10 100
Balonne	Thallon	12 300	13 100
Total of Six Shires		234 500	285 700
Total Queensland		1 056 100	1 249 000
Six Shires Storage as % of Queensland Storage		(22·2%)	(22·9%)

Source: State Wheat Board, Toowoomba (personal communication).

of a Sheep and Wool Adviser, a Beef Cattle Husbandry Adviser, an Agriculture Branch Extension Officer and a Stock Inspector stationed in St. George serving the Balonne Shire, and a Sheep and Wool Adviser, a Beef Cattle Husbandry Adviser, a Soil Conservationist, an Agriculture Branch Extension Officer and two Stock Inspectors stationed at Goondiwindi serving the Waggamba shire. There is also an Agronomist stationed at the Inglewood Field Station in the Inglewood Shire, who functions as both research and extension officer. The remainder of the study area is served by extension officers stationed outside its boundaries and 27 of these have responsibilities within one or more of the six shires.

Warroo Shire is served chiefly by officers from Roma. Those with responsibilities in this area on regulatory duties include two Veterinary Officers, two Stock Inspectors, and an Inspector and Field Assistant from Slaughtering and Meat Inspection Branch. Officers with extension responsibilities include a Husbandry Officer and an Adviser from Sheep and Wool Branch, two Beef Cattle Husbandry Advisers, an Agriculture Branch Extension Officer, an Agricultural Economist and a Regional Extension Leader from Extension Services Section. Facilities also exist for a Soil Conservationist.

Extension officers from Miles working in the Tara Shire include a Beef Cattle Husbandry Adviser, an Agriculture Branch Adviser, a Soil Conservationist and a Stock Inspector. A Veterinary Officer from Chinchilla also serves the shire, as do Sheep and Wool Advisers from Roma and Dalby.

Millmerran Shire is served by a Soil Conservation Adviser and Stock Inspector from Millmerran, a Pig Section Adviser, Sheep and Wool Adviser and an Agricultural Economist from Dalby and other officers from Toowoomba. Inglewood provides an Agriculture Branch Adviser and a Stock Inspector for Inglewood Shire, Warwick being the base for most of the other extension staff serving the area. Officers from Goondiwindi also work into this shire.

RESEARCH. Most biological research is conducted from outside the area, the only research stations lying within the study region being the Inglewood Field Station of the Queensland Department of Primary Industries at Whetstone, and the Pastoral Veterinary Centre of the University of Queensland at Goondiwindi.

The University of Queensland is chiefly involved in veterinary research while some civil engineering and economic studies are conducted from Brisbane. The Pastoral Veterinary Centre at Goondiwindi also provides a veterinary service to the community, a teaching situation for students, and research opportunity for graduate staff.

C.S.I.R.O. research officers from the Division of Tropical Agronomy who work in the study area are based at Cunningham Laboratory, Brisbane and at Cooper Laboratory adjacent to the Queensland Agricultural College at Lawes. Officers from the Canberra based Woodland Ecology Unit also have investigations in the region. Field experimental sites related to the soil-vegetation groups are located near Meandarra for Group 1 lands, near Kogan and Tara for Group 4 lands and near Talwood for investigations on Group 6 lands. Research aimed principally at the brigalow lands to the north of the Condamine–Maranoa basin is carried out at Narayen Research Station near Mundubbera.

The Queensland Wheat Research Institute at Toowoomba, under the auspices of the Queensland Department of Primary Industries, conducts research in the wheat lands (Groups 1 to 5) of Queensland. Field plots are located on private properties throughout the study area. Research in the Condamine–Maranoa basin concerned with beef cattle, crops, pastures and soils is conducted from the Queensland Department of Primary Industries office in Toowoomba. Departmental officers conduct pasture and crop research from Warwick, with plant breeding and selection carried out at Hermitage Research Station. The same organization conducts pasture research from the Charleville Pastoral Laboratory and crop research from Roma. Brisbane-based Husbandry Research and Pathology Branches of the Department also perform research which encompasses the study area.

In addition to the above, some research into problems of weeds found in the Condamine–Maranoa basin is carried out from Brisbane at the Alan Fletcher Laboratory of the Queensland Department of Lands.

LAND TENURE

About 70% of the Condamine–Maranoa basin is alienated (converted to freehold) or in the process of alienation compared with only 16% for Queensland (Queensland Department of Lands 1973–74). Land not held by freehold is leased under one of the tenures listed below (Fletcher 1963).

Pastoral Lease (P.L.).

a. Pastoral Holding
b. Pastoral Development Holding
c. Preferential Pastoral Holding
d. Stud Holding

Selection Tenure.

a. Agriculture Selection
  (i) Agricultural Farm* (A.F.)
  (ii) Perpetual Lease Selection (P.L.S.)

b. Settlement Farm Lease (S.F.L.)

c. Grazing Selection
  (i) Grazing Homestead Freehold Lease* (G.H.F.L.)
  (ii) Grazing Homestead (G.H.)
  (iii) Grazing Farm (G.F.)

d. Prickly Pear Selection* (P.P.S.) and Prickly Pear Development Selection* (P.P.D.S.)

Occupation License.

Other Leases (O.L.). These include Auction Purchase Freehold, Auction Perpetual Lease, Special Lease, Development Lease and Purchase Lease.

* These leases are open to alienation.

Of the various forms of lease selection (as opposed to freehold), the most common numerically are Perpetual Lease Selection, Agricultural Farm, Grazing Homestead Freehold Lease, Grazing Homestead and Grazing Farm. In terms of area, Grazing Homestead Freehold Lease and Grazing Homestead are the most prominent (table 25). Leases denoted as Other Leases are of comparatively small significance in the study region.

TABLE 25

APPORTIONMENT OF LEASEHOLD LAND IN THE CONDAMINE–MARANOA BASIN AND QUEENSLAND

Type of Lease	Condamine–Maranoa Basin (1)		Queensland (2)	
	% of Leasehold Area	% of Total Number of Leases	% of Leasehold Area	% of Total Number of Leases
P.L.	4·17	1·06	66·09	6·65
A.F. (3)	14·46	23·62	8·90	49·27
P.L.S.	6·86	32·53	1·44	23·90
S.F.L.	0·67	1·41	0·12	0·43
G.H.F.L. (3)	39·52	21·45	..	..
G.H.	25·64	11·48	14·82	10·17
G.F.	8·55	7·10	4·76	7·02
P.P.S. and P.P.D.S. (3)	0·10	0·55	..	..
O.L.	0·02	0·81	3·88	2·55

Sources: (1) Queensland Department of Lands (personal communication). Figures as at 30 June, 1974.
(2) Australian Bureau of Statistics 1971–72.
NOTE: (3) These leases are open to alienation. In the Queensland column they are grouped, and shown against A.F. Lease.

It is of interest to note the high proportion of the area of the State held under a low total number of large Pastoral Lease tenures. The Condamine–Maranoa basin is more closely settled, however, and has few Pastoral Lease holdings. The predominance of leases of limited size, especially Grazing Selections, reflects the nature of the region as one of favoured primary production in terms of situation as well as environment.