A REVIEW OF RESEARCH FINDINGS CONCERNED WITH PASTORAL DEVELOPMENT ON THE WALLUM OF SOUTH-EASTERN QUEENSLAND

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ABSTRACT

The information presently available on the ecology of the Wallum region, plant nutrient requirements, pasture species and mixtures, animal production and economic assessment is assembled and reviewed. It is shown that pastoral development is clearly one of the productive uses to which this formerly useless region can be put.

INTRODUCTION

'*Wallum . . . . . is comparatively useless for cultivation.*' (Herbert, 1951).

'*The region presents perhaps the last large scale opportunity in Australia to plan development of a previously useless area . . .*' (McCarthy *et al.*, 1970).

The change in attitude towards the possibilities for the region (see Figure 1) over the last twenty years is illustrated by the two quotations above. Most of the C.S.I.R.O. pasture research has been based at the Beerwah Pasture Research Station (southern Wallum with nodular podzolic, meadow podzolic and low humic and humic gleyed soils) and near Howard and Childers (northern Wallum with gleyed podzolic soils), that of the Queensland Department of Primary Industries at the Coolum Research Station with wet heath and Wallum sand soils and the work of the Queensland Department of Forestry has been centred on its Forest Research Station, Beerwah. The Beerwah and Coolum stations thus contribute different and complementary environments.

Research relevant to the pastoral development of the coastal lowlands of south Queensland (the 'Wallum' in its broadest sense) has been published in a number of journals since 1938 and the significance of many of the papers is not apparent from their titles. The purpose of this review is to bring together and summarise the main results. In addition, where it helps to add to the story, some unpublished work is included. It is probable that the main competition for land use will be between forests and pastures, and it is also likely that a closer integration of these two land uses will occur, e.g. the grazing of pastured firebreaks in forests and the use of farm wood lots. For these reasons some consideration of nutrition work in forestry is included but not work on field or horticultural crops since expansion of these on any large scale is not very likely.

The Queensland Department of Forestry holds 336,000 hectares of Wallum country (McGuire, 1968) while of the 283,000 ha currently available for pasture development 93,000 ha are already held by developers (Peart, 1971).

THE WALLUM ENVIRONMENT

Wallum in the narrow sense refers to sandy marshes less than 8 m above sea level where the sands are derived from sandhills of Pleistocene age (Whitehouse, 1967). On these areas are found low dry sandy ridges of fine oceanic sand which are dominated by *Banksia aemula*, the "wallum" of the former natives of the near north coast of S.E. Queensland. This "true wallum" occupies only a small percentage (10-15%) of the area but the name has been transferred to the whole regional ecosystem as being short and distinctive.

This paper deals only with the lowlands from the northern edge of Brisbane to Baffle Creek, 50 km north of Bundaberg. The Wallum occupies a narrow strip between the shoreline and the foothills of the coastal ranges and varies in width

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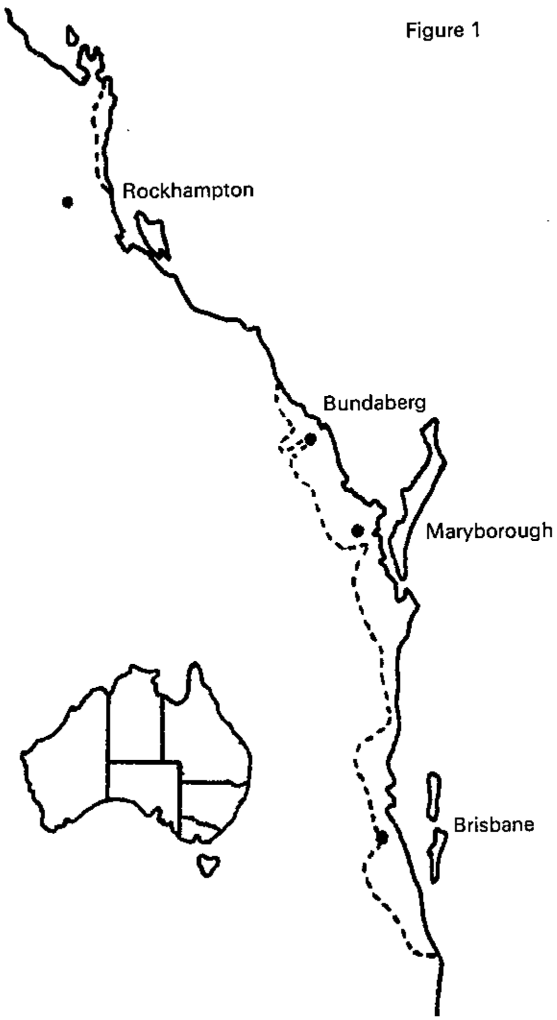

FIGURE 1
The distribution of Wallum lands (shaded) in south-eastern Queensland.

from about 3 to 50 km. The country is undulating to low rolling, in parts hilly, with flood plains bordering streams and some deltas. There is little true coastal plain. The bulk of the area is below 100 m and much of it below the 30 m level.

The region is diverse in topography, soils (especially their water relations) and vegetation, and for experimental work to have any range of applicability it must rest on a sound ecological basis. Such a basis was provided by Coaldrake (1961) who described the region, its geology, climate, soils and vegetation in a monumental paper. Because of the smallness of the pattern of the country, which is on a scale of hectares rather than square kilometers, Coaldrake recognised 12 soil classes, 25 classes of vegetation and 8 topographical classes and on this basis divided the region into 43 land units, 14 land systems and 20 landscapes to present the patterns and variation of the country. This imposing number of units does not mean that the results of experiments on any well chosen site have very limited applicability, but that minor variations of practice can be applied with some confidence. Basically the control of soil type and vegetation is topographic.

A broad outline of the climate, soils and vegetation of the region will be given as a general background for the results of experiments. The region is conveniently divided into two parts, the southern Wallum extending to Big Tuan Creek about 15 km south of Maryborough (which is approximately the northern limit of the 1270 mm (50 in.) isohyet and includes landscapes 1 to 9) and the northern Wallum from this point to Baffle Creek—(including landscapes 11 to 20) (landscape no. 10 is Fraser Island). Of the land available, approximately 85% consists of rolling country with Eucalypt ridges alternating with paper bark depressions, about 10% is wet heath and associated small rises, and about 5% is Wallum in its narrowest sense of flats dominated by *Banksia aemula*.

Climate

"The coastal lowlands have a mild subtropical climate with a marked dominance of summer rainfall and a small but significant winter rainfall. Thunderstorms and cyclones contribute substantially to total annual rainfall which is extremely variable. Temperatures are generally mild but frosts occur in most areas. High run-off resulting from high intensities lowers the effectiveness of the rainfall, but rain can promote rapid growth when it coincides with the high energy levels of the early summer months. The conventional 'spring' months are normally a period of acute water stress." (Coaldrake, 1961).

The northern Wallum differs from the southern in having a lower total rainfall (1070-1270 mm against 1270-1900 mm), (Coaldrake and Bryan, 1957), an earlier rainfall maximum (January as against February or March) and a smaller incidence in spring and early summer because of a lack of breeding grounds for summer storms. Mean daily maximum temperatures are a few degrees higher, soils are shallower and have a dominance of fine sand and silt which reduces infiltration. All these factors tend to greater aridity in the north. In parts of the north the content of soluble salts in the soil is high enough to affect seriously the establishment and survival of sown pasture species (Evans, 1967b).

Soils

There is now considerable knowledge of the soils, their patterns, profile characteristics, genesis and chemical and physical attributes. Pioneer work on some of the soils of the region—Bryan and Hines (1931), Tommerup (1938), Young (1940, 1948), King (1949), Hubble (1954), Thompson (1958), and Talbot and Rossiter (1959)—was reviewed by Coaldrake (1961). As a result Coaldrake (1961) was able to summarise the position as follows:—

"The common soil pattern is one of deep podzolics on rises, progressing downslope through gleyed podzolics to gley and humic gley soils on low-lying areas of impeded drainage. In poorly drained areas with a mantle of Quaternary sand, ground-water podzols with a strongly developed hardpan are common. The deep sands of the sandhills and flanking areas show little profile development except in the areas of vine forest where podzols occur. Acid bog and fen peats are common in areas receiving continual drainage from the sandhills, while there are scattered areas of acid fen peat and peaty-gley soils away from the sandhills. On the flat areas of the Elliott sandstone solodic soils are common, these being the most arid sites on the coastal lowlands.

Except for some alluvial soils, nutrient status is universally low, and physical differences, derived chiefly from topographic control of perched water-tables, seem to be the main soil factors governing plant distribution. Nodular accumulation of iron and manganese is common. Surface litter and organic matter are minimal in most of the mineral soils, this being due chiefly to rapid destruction of litter by fire."

Vegetation

Most of the plants found on the Wallum have a wider distribution than just the Wallum itself, although some species with much more local and restricted distribution occur. A few individual species may be regarded as indicators of special habitats e.g. *Melaleuca nodosa* for salty areas, *Banksia robusta* is restricted to sites where the water-table is at or close to the surface for long periods; but in general different habitats are characterised by distinct communities of plants.

The principal types of vegetation are various forms of eucalypt forest and woodland found on the podzolic, gley and solodic soils. Heath with a prominent ground layer of sedges is widely distributed on wetter areas. *Melaleuca quinquinervia* (paper bark) is very widespread and occurs in a great variety of habitats in fairly open formations and also as a dense forest on the low lying alluvia of many of the streams.

From the point of view of agricultural development the vegetation, after much selective logging, has little value as a source of timber, and apart from some grassy forest areas where kangaroo grass (*Themeda australis*) and cockatoo grass (*Alloteropsis semi-alata*) occur has little or no value for grazing. In fact for almost any form of development clearing is obligatory and constitutes one of the major costs.

SOIL NUTRIENT STATUS AND FERTILIZER REQUIREMENTS

Historical review

Before 1950 when C.S.I.R.O. began its work in this field there was only limited knowledge of the nutrient status of the soils. Young (1940, 1948) had established the exceptionally low phosphate content of soils in the Beerwah area and obtained responses in *Pinus* spp. to both phosphorus and copper. In soils of the Beerburrum-Beerwah area Vallance (1938) noted the extremely low values for nitrogen, phosphorus and bases, the low content of organic carbon and the wide carbon:nitrogen ratios because of a relatively large amount of undecomposed woody material and charcoal. Mitchell and Cannon (1953) recognised the need for N, P and K for successful pineapple growth in these soils and also recommended the addition of copper and zinc to control "crookneck".

Most of the soils have multiple deficiencies. On a low humic gley soil at Beerwah and a humic gley soil at Glasshouse Mountains, Andrew and Bryan (1955) established marked deficiencies for pasture plants of phosphorus, nitrogen, calcium, potassium and copper, and smaller responses to zinc, molybdenum, magnesium and boron. Experiments on a nodular podzolic soil at Beerwah demonstrated gross deficiencies in phosphorus and nitrogen; severely limiting supplies of calcium, copper, sulphur and potassium; a less acute need for molybdenum and zinc and a doubt about boron (Andrew and Bryan, 1958). Subsequent work by the same authors (unpublished) showed that the apparent symptoms of boron deficiency in white clover were caused by a virus, and thus boron is not needed.

In the different soil environment of Coolum, Talbot and Rossiter (1959) and Stieglitz, McDonald and Wentholt (1963) showed that a range of soils, including wet heath and Wallum sands, was grossly deficient in nitrogen, phosphorus, calcium, potassium, zinc, copper and molybdenum. The same deficiencies were shown by Evans (1967a) to occur in the soils of the northern Wallum.

Nitrogen

Sources of nitrogen for Queensland pastures were discussed by Henzell (1968). For most Wallum pastures the nitrogen will have to come from legumes, and much of this paper deals with legumes. The other possibility is the use of fertilizer nitrogen and this is discussed under animal production. In view of its cost such nitrogen is likely to be used on only part of a property, either for fattening some of the cattle quickly to take advantage of good prices or for obtaining a flush of feed just prior to times of stress. Henzell (1970) has reviewed the possible use of nitrogenous fertilizer in sub-tropical Queensland.

Phosphorus

In a detailed study of rates by forms of P in low humic gley soils at Beerwah, Weerawickrema (1953) found that to establish two grasses and a legume satisfactorily there was a need for 625-750 kg/ha superphosphate equivalent, in order to obtain about 50 ppm available P in the top 10 cm of soil. He further showed that a considerable proportion of the phosphates added to these soils move into the subsoil and that the largest concentration of roots of all three species was in the top 10 cm; on this account he recommended the use of some rock phosphate in the mixture to extend availability of P near the surface. The widespread nature of phosphorus deficiency has been further shown by Coaldrake and Haydock (1958) for soils between Gympie and Maryborough, for the northern Wallum by Evans (1967a) and for a wide range of Wallum soils by Andrew (unpublished data).

The addition of phosphorus results in increased yields of dry matter (Andrew and Bryan, 1955, 1958; Bryan and Evans, 1973); in a higher proportion of legumes and higher concentrations of P in both grasses and legumes and a higher concentration of N in legumes (Bryan and Evans, 1973). All these favourable changes are reflected in higher liveweight gains in grazing cattle (Evans and Bryan, 1973).

Most of the experimental work on phosphorus has used single superphosphate as the commercial carrier of P and little work has been done on alternatives. The use of triple superphosphate is unlikely in the southern Wallum as the cost per unit of P is at the time of writing about 30% higher than that in single superphsophate. In addition, many soils are marginally deficient in sulphur (Andrew and Bryan, 1955, 1958 and unpublished data) and require the addition of some form of sulphur if single superphosphate is not used. In the case of rock phosphate, there is a marked difference among species in their ability to extract P from it. *Stylosanthes guyanensis*, *Indigofera spicata* and *Lotononis bainesii* are reasonably efficient users. *Desmodium* spp. and *Phaseolus* spp. are much less efficient (Bryan and Andrew 1971) and white clover is poor (Andrew, unpublished data). The use of rock phosphate is likely to be very limited and would depend very much on the composition of the pasture desired. The practicability of initially using some rock phosphate with single superphosphate, as suggested by Weerawickrema (1953), has not been investigated.

Calcium

The primary purpose of the recommendation for inclusion of 625 kg/ha of lime ($CaCO_3$) in the initial fertilizer mixture (Andrew and Bryan 1955, 1958) is to provide calcium for plant nutrition for a broad spectrum of species, especially white clover and Silverleaf desmodium. On the wet heath at Coolum (Stieglitz, McDonald and Wentholt 1963) the recommendation is for twice this amount. There is a danger in overliming on these lightly buffered soils of raising the pH and affecting the availability of some trace elements, particularly copper and zinc.

It is not known if calcium other than that in the superphosphate is needed for pure grass swards fertilized with nitrogen. The point is being investigated at Beerwah. However, Chippendale (unpublished data) has found a serious depression of pH (below 4) in the top 1 cm of soil under pangola grass pastures at Coolum after heavy dressings of ammonium nitrate.

Potassium

The choice of a carrier of potassium is probably less important although some depression in yield from using potassium chloride at high rates has been recorded by Hall (1971) with Siratro and by Andrew and Robins (1969a & b) with *Desmodium* spp. At the rates of application recommended and in use (125 kg KCl/ha) the choice of potassium sulphate, in which the potassium costs 50 % more per unit than in the chloride, is probably not warranted. Young plants are most susceptible to damage from chloride (Jones, 1972) and a practical solution would be to withhold most of the potassium at sowing and add it later.

Copper

Copper additions have been found to be required for normal growth of most pasture species, although some tropical species such as *Desmodium uncinatum* can manage without added copper (Andrew and Bryan, 1955; Andrew and Thorne, 1962). Low liver copper storages in cattle have been recorded by Chester, Marriott and Harvey (1957) near Caloundra and by Gartner, Young and Pepper (1968) at Coolum. In each case administration of copper, either to the pasture or the animal, increased liver copper levels but had no effect on liveweight gain. This indicates that hepatic copper levels are not always a reliable guide to the copper status of the animal as a whole. The pasture discussed by Chester *et al.* (1957) consisted largely of weeds (especially mat grass, *Axonopus affinis*) which are unable to maintain a good copper percentage for long, whereas sown species such as paspalum and white clover generally have higher mean levels of copper and maintain them better.

Magnesium

Stieglitz *et al.* (1963) used dolomite extensively at Coolum but in the first experiments of Andrew and Bryan (1955) there was a doubt about the need to add magnesium. Later work has nowhere shown a significant response to magnesium and indeed it is the only cation to increase with soil depth (Hubble, 1954).

Cobalt

Cobalt is present in very low concentration in the soils and rather low in pasture plants grown on them (Bryan, Thorne and Andrew, 1960), but despite this there has been no evidence of cobalt deficiency in grazing animals and no animal response to cobalt therapy (Bryan, Thorne and Andrew 1960, Bryan and Evans, 1971b). Nevertheless the possibility of cobalt deficiency arising in some situations in the future should be kept in mind.

General recommendation for pastures

The outcome of all these studies is a fertilizer recommendation for establishing mixed pastures of 625 kg superphosphate (556 lb/ac), 625 kg calcium carbonate, 125 kg potassium chloride, 8 kg copper sulphate, 8 kg zinc sulphate and 280 g sodium molybdate a hectare. All soils in the region have approximately the same deficiencies (except some of the alluvia) and require essentially the same fertilizer for establishment. Minor variations are to be expected, e.g. the humic soils may require more copper, and no doubt some economies will be possible on certain soils. There is probably no need for calcium carbonate and molybdenum for pure grass pastures with bag nitrogen, but work on this is only now in progress.

The annual fertilizer requirement to maintain productive pastures was originally set at 250 kg superphosphate and 125 kg potassium chloride a hectare (Bryan, 1968 a & b; Bryan and Evans, 1971b). More recent work at Beerwah (Evans and Bryan, 1973) has shown that 63 kg potassium chloride is sufficient, but there are strong indications (Bryan and Evans, 1971a) that 250 kg superphosphate may be too little. Further work is being conducted at Beerwah to define maintenance application rates of this fertiliser.

While there is a clear need to maintain a supply of major nutrients, there has been no response so far to the addition of extra calcium or of trace elements (Bryan and Evans, 1971b). Possibly contamination of superphosphate as manufactured up to the present has provided enough copper and zinc and the superphosphate itself enough calcium. Further evidence of adequacy comes from the work of Bryan and

Evans (1973) where satisfactory levels of trace elements were found in pastures eight years after the original applications.

Plant Nutrition (Forestry)

Studies on pine trees on the Wallum by the Queensland Department of Forestry have further confirmed the deficiency of phosphorus and nitrogen in these soils. Young (1940) was the first to demonstrate the need for phosphorus in showing that lack of P was the prime cause of fused needle disease in *Pinus elliottii*. With *Pinus taeda* on a lateritic soil Richards (1961) found a marked response to added P, a response greatly enhanced by adding nitrogen. However, if P was deficient, adding N could depress growth. The addition of calcium carbonate at the rate of 2,000 kg per hectare induced iron deficiency in young seedlings.

The positive interaction of P and N was confirmed in a later paper (Richards and Bevege, 1967b) which also showed that no benefit was derived from continuing the application of N after the first growing season. Continuing N supply was, however, essential for the successful growth on these soils of native conifers such as kauri pine (*Agathis robusta*). Such a nitrogen supply could be achieved by the use of perennial legumes as an understory, by fertilizer N or by underplanting kauri under stands of exotic subtropical *Pinus* spp. that were not less than 5 or 6 years old (Richards, 1962). The effect of well nodulated adapted perennial pasture legumes was later examined in greater detail (Richards and Bevege 1967a). Legumes depressed the yield of exotic pines (three species) but stimulated the growth of the native kauri and hoop (*Araucaria cunninghamii*) pines, resulting in a two-to-three-fold increase in mean height at age 5 years. Richards and Bevege (1968) also found that kauri pine responded strongly to N moderately to P and slightly to K and a trace element mixture containing copper, zinc, boron and molybdenum. The trace element treatment improved the K status of the trees.

As a result of these studies it has been standard practice to add about 300 kg/ha of rock phosphate in the second or third year after planting (Pegg, 1967). Richards (1961) found that 250 kg/ha of rock phosphate was almost as effective as 500 kg/ha of superphosphate after 20 years. The general aim with slash pine (*Pinus elliottii* var. *elliottii*) is to bring the total P content in the top 10 cm soil to at least 50 ppm.

To sum up, pine tree plantations on the coast need additions of P and N for establishment and health. The need for other elements is not yet clear, especially if commercial superphosphate, which contains calcium and is commonly contaminated with copper and zinc, is used as the carrier of P.

IMPROVEMENT IN SOIL FERTILITY

One of the aims of pastoral development is to effect an improvement in the fertility of the poor sandy soils. A marked improvement takes place under productive, well grazed and properly fertilized pastures. This was shown by Bryan and Evans (1971b) under a pasture grazed by sheep, in which organic carbon, nitrogen, sulphur, total P, available P, total potassium and total calcium increased 2 to 10 fold in the top 10 cm of soil. Improvement also clearly occurs under pastures grazed by cattle, although it takes longer and is possibly a little less (Bryan and Evans, 1973). Working on this same experiment, Vallis (1972) measured a mean annual gain of 70 to 90 kg N/ha/year (about 4% per year) in the top 10 cm but could not find any effect of treatment on rate of gain of soil nitrogen.

There is no indication that annual fertilizing with superphosphate and potassium can be reduced or withheld, even after 11 years of grazing (Bryan and Evans, 1971b) and no luxury consumption of nutrient elements has yet been found. As stated earlier, there has been no response to additions of calcium, copper and zinc after establishment, and no visual or animal evidence of trace element deficiencies in pastures from 8 to 16 years old.

PASTURE SPECIES

Little of the native vegetation (Coaldrake, 1961) is of value to grazing animals and the only way to develop a pastoral industry is to clear the land and establish sown pastures. Pastures must be based largely on summer growing species, since it is in summer that most of the rainfall and energy is received. Large numbers of grasses and legumes have been tested at Beerwah and Coolum although little of this species testing work has been published.

The species that are now recommended have come through a range of testing conditions, including droughts, excessively wet spells, grazing mismanagement and fire. Because of the siliceous sandy soils with their high aluminium content and high water tables and waterlogging in the wet season, many pasture species fail on the Wallum, especially on the wetter sites. The extreme soil conditions that prevail make it essential that testing be done in this environment and extrapolation from adjacent mineral soils is likely to be meaningless. Much of the general agronomic information which has become available on the better known species has been collated by Humphreys (1969).

Grasses

The most successful grass tribe in the Wallum is Paniceae and within this the genus *Paspalum* is most likely to thrive in the southern part while *Panicum* and its close allies do better in the northern part. The notable exceptions are pangola (*Digitaria decumbens*) and *Setaria anceps* which have been successful in both regions.

In the northern Wallum the most productive grasses in cutting trials have been *Panicum coloratum* CPI 16796 and CPI 14375, *Setaria anceps* cv. Nandi, *Chloris gayana* cv. Samford (rhodes grass), *Paspalum plicatulum* CPI 21378 and cv. Hartley, pangola and *Paspalum commersonii* cv. Paltridge (Scrobic) (Evans, 1967). Some of these, notably rhodes, pangola and Nandi setaria, have subsequently done well under grazing (Evans, 1968b, 1969, 1971). *P. plicatulum* CPI 21378 is popular with developers in this part of the region (Adams, pers. comm.).

In the southern Wallum major testing programs at Beerwah have been concerned with the genera *Paspalum, Digitaria* and *Cynodon*. Other grasses tested were in the genera *Brachiaria, Cenchrus, Chloris, Eragrostis, Melinis, Panicum, Pennisetum, Phalaris* and *Setaria*. The outstanding grass for this southern region is pangola, as has been shown by Stieglitz, McDonald and Wentholt (1963), Evans (1969, 1971a), Bryan (1970), and Peart (1971). However the superiority of pangola is now in doubt with the advent of a severe rust caused by *Puccinia oahuensis* (Evans, 1972) which has had devastating effects on plant production in the last two very wet summers. Other useful grasses are *Paspalum dilatatum* (paspalum) (Stieglitz *et al.*, 1963); Bryan (1968a, 1970), *P. plicatulum* (Bryan, 1968a; Bryan and Shaw, 1964) *P. commersonii*, (Bryan, 1968a) and *P. notatum* (Bryan, 1968b; Bryan and Evans, 1971b).

While grasses may be considered to be less important than legumes in mixed pastures (Evans, 1968), animal production from pastures based on different grasses may differ significantly. Thus production from *P. plicatulum* cv. Rodd's Bay pastures was clearly less than from other grasses at Beerwah (Bryan, 1968a) although in the northern Wallum it is one of the better species. Similarly production from Nandi setaria has been considerably less than from pangola when both received high levels of nitrogen fertilizer (Evans, 1971).

There are also differences in persistence. Rhodes grass, although it establishes well on the drier soils, diminishes under both light and heavy grazing (Bryan, 1968b, 1970; Bryan and Evans, 1971b, 1973). On the other hand *P. notatum* under continual close grazing tends to become dominant (Bryan, 1968b, Bryan and Evans, 1971b). *Pennisetum clandestinum* (kikuyu), though persistent, is unproductive unless the nitrogen supply is high (Bryan and Evans, 1971b). Scrobic does well for a few years until attacked by a woolly aphis (Bryan, 1968a), when it practically disappears. Pangola is highly persistent (Bryan and Evans, 1971a) unless attacked by rust. Paspalum is persistent in moister situations (Bryan, 1970); *S. anceps* also appears to be persistent in similar conditions but it is not yet completely proven.

No annual grass is of any great value in the region. There has been a little testing of *Bromus unioloides* (prairie grass) but little or no regeneration. Some use has been made of oats for winter grazing, either sod seeded or sown in new ground, but the area has been small; the practice is of doubtful economic value. Cultivars with resistance to leaf and crown rust are required.

Herbaceous legumes

In the northern Wallum, the highest yielding and most persistent legume is *Macroptilium atropurpureum* cv. Siratro (Evans, 1967a; Peart, 1971). In more recent work of Evans (1968b, 1969), Siratro in limited tests has given good animal production in combination with rhodes grass and Nandi setaria. Other legumes that appear to be adapted and reasonably productive are *Desmodium intortum* cv. Greenleaf, *Dolichos axillaris* cv. Archer, *Lotononis bainesii* cv. Miles and *Trifolium semipilosum,* kenya white clover. Lotononis has the additional advantage of some resistance to moderate salt levels, viz. 0.2 to 1.0% total soluble salts where the major salt is magnesium chloride (Evans 1967b). Kenya white clover, which is tap rooted and can grow well in summer, is a likely substitute for white clover which thrives in the south but fails in the north because of the drier winters and springs. More intensive testing of species is needed in the north.

In the southern Wallum, a much wider range of material has been tested at Coolum than that listed in Stieglitz, McDonald and Wentholt (1963) but the work has not been published. Lotononis, white clover and *Desmodium* spp. have been the best. At Beerwah, major programs have been carried out with the genera *Desmodium*, *Indigofera* and *Trifolium* and less extensive testing has been in the genera *Cajanus*, *Calopogonium*, *Cassia*, *Centrosema*, *Crotalaria*, *Dolichos*, *Glycine*, *Lespedeza*, *Leucaena*, *Lotononis*, *Lotus*, *Macroptilium*, *Medicago*, *Sesbania*, *Stylosanthes*, *Teramnus* and *Vigna*. Little of this has been published.

The outstanding species, seed of all of which is now commercially available, have been (in alphabetical order)—*Desmodium intortum* (Bryan, 1966, 1969, 1970; Bryan and Evans, 1971a & b, 1973); *D. uncinatum* cv. Silverleaf (Bryan, 1966, 1968, 1969); *Lotononis bainesii* (Bryan, 1961; Bryan and Evans, 1971a, 1973; Peart, 1971; Stieglitz, McDonald and Wentholt, 1963); *Macroptilium lathyroides* (Bryan, 1970; Bryan and Evans, 1973) and *Trifolium repens* (Bryan, 1968a & b, 1970; Bryan and Evans, 1971a & b, 1973; Stieglitz, McDonald and Wentholt, 1963; Peart, 1971).

Lotononis and white clover are persistent under fairly close grazing (Bryan, 1968a, 1970; Bryan and Evans, 1971b, 1973), where competition for light is reduced. On the other hand the trailing broad leafed legumes such as Siratro and the Desmodiums are more persistent under lighter grazing (Bryan and Evans, 1973). There is a need for more detailed studies of behaviour under different grazing systems and also a need for more species capable of withstanding hard grazing both in general and during occasional droughts.

Two annual legumes have a place in pasture development in providing early grazing on new pastures where the perennials are slow to provide bulk. These are *Macroptilium lathyroides* (phasey bean) and *Dolichos lab lab* cv. Rongai, which normally provide excellent grazing within three months of sowing. Although neither species regenerates well under grazing in most coastal lowland pastures their inclusion in a seeds mixture is well worthwhile.

It is of interest that many of the legumes that thrive on the high aluminium soils of the Wallum, notably phasey bean, silverleaf Desmodium, lotononis and kenya and white clover, are tolerant of high concentrations of aluminium, while many of those that fail, e.g. *Glycine wightii* and *Medicago spp.*, are intolerant (Andrew, pers. comm.).

Shrub legumes

Only limited work has been done on these. *Leucaena leucocephala* makes slow seedling and first year growth on the Wallum and established plants are liable to stagheadedness if waterlogged. The species is not recommended. *Codariocalyx (Desmodium) gyroides* comes away faster, is unaffected by high water tables, does not appear to have a high requirement for calcium or magnesium and is only slightly deciduous in winter (Bryan, 1966). If browse plants are considered this species warrants further trial although such plants probably have limited use in this region with its reasonable rainfall. Most other shrubby species of *Desmodium* are much more deciduous, some completely so.

LEGUME NODULATION AND NITROGEN FIXATION

The virgin soils of the Wallum are generally supplied with strains of Rhizobium that can effectively nodulate promiscuous legumes requiring "cowpea type" bacteria. (Vincent, unpublished data; McKnight, 1949; Bowen, 1956; Norris, unpublished data). They lack entirely rhizobial strains that inoculate clovers and medics (Bryan and Andrew, 1955) and also are very deficient in strains for the more specific tropical legumes such as *Desmodium uncinatum* (Norris, 1971a), *Dolichos lab lab* (Norris, 1971b), *Glycine javanica* (Bowen, 1956 and Norris, 1971) and of course such highly specific plants as *Lotononis* spp. (Norris, 1958). It is therefore recommended that all legume seed be inoculated before sowing. A list of suitable strains of Rhizobium was given by Date (1969) and the latest information is in the hands of the seed trade which retails approved peat cultures.

In most sowings there is no advantage in pelleting inoculated seed (Norris, 1970, 1971a), especially if the seed is sown within a day or two of being inoculated. Exceptions are *Desmodium uncinatum*, where Norris (1971a) showed a lime pellet to confer an advantage, although if the pelleted seed were kept for a month the pellet was highly deleterious to the Rhizobium (Norris, 1972); and white clover which has a higher calcium requirement than the tropical legumes (Andrew and Norris, 1961). On the other hand, lime pelleting was disadvantageous to *D. intortum* and Norris (1967, 1971a & b) has shown that with most tropical legumes rock phosphate pellets are far better than lime ones. The effect on *D. uncinatum* is probably related to the relative inefficiency of the host in obtaining calcium from the soil (Andrew and Norris, 1961).

If seed is to be mixed with superphosphate, which is toxic to bacteria, a pellet is a necessary protection (Norris, 1967).

Bowen and Kennedy (1959) drew attention to the high temperatures of over 40°C recorded in moist bare Wallum sands in mid summer and found that a range of tropical legume strains of Rhizobium died within ten hours when incubated at 40°C in such soils. This poses a threat to inoculation, but this work predated the use of peat cultures and pelleting, techniques which normally ensure higher populations of bacteria on the seed and better resistance to stress. Moreover, so long as sufficient moisture is available in the seed zone, in practice few problems of establishment and inoculation have been encountered.

Bowen (1959) also studied the effect of cutting on regrowth of centro (*Centrosema pubescens*) at Coolum and concluded that the course of plant growth determined nodule initiation and longevity and not *vice versa*. Cutting led to marked losses of root tissue and nodules, but regrowth resulted in new infection.

Nitrogen contribution by a legume

The contribution made to a Wallum soil by a subtropical legume was measured by Henzell, Fergus and Martin (1966) who found that a stand of *Desmodium uncinatum* added about 110 kg N/ha/yr to the soil, depending on the amount of superphosphate applied. On the basis of 2240-8960 kg/ha dry matter of tops, the annual production of N in tops, assuming a concentration of 2.5%, would be

56-224 kg. Bowen (1959) found that a 15 month old stand of centro had 60.8 kg N in tops and 16.3 kg N in roots. These figures compare favourably with those for temperate legumes.

FEEDING VALUE

Many of the species tested for the Wallum were new to agriculture at the time of their introduction. Details of their life history, agronomy, chemical composition and value for and performance under grazing animals had to be worked out. One aspect of this was the screening work of Bindon and Lamond (1966) who found that none of the 28 pasture legumes they tested for deleterious substances was likely to be toxic except *Indigofera spicata* and *Leucaena leucocephala*. It was shown later by Hamilton and Ruth (1968) that one of the plants, *Dolichos lab lab*, may cause bloat in cattle.

The nutritional value of some pasture plants used in the Wallum has been recorded in a number of papers by Milford and Minson, although the data have no more pertinence to Wallum conditions than to others. For mature stand-over material in winter, Milford (1960) found differences in digestible crude protein and dry matter intake among 17 grasses. After frosting *P. plicatulum* CPI 11826 was still good feed but scrobic and rhodes declined markedly. At the young leafy stage all were good, especially *P. plicatulum* and scrobic.

Three papers dealt with pangola grass. Minson and Milford (1966) showed that intake of digestible energy was four times as great for young material as for old and that there was a gradual decline with age. When pangola was given a late dressing of N (Minson, 1967) the crude protein almost doubled and voluntary intake increased by a mean of 43%. If mature pangola was supplemented by lucerne or white clover hay, the dry matter digestibility of the diet increased in proportion to the percentage of legume, and intake increased by the amount of legume in the diet (Minson and Milford, 1967). In a study of seven legumes harvested in autumn and winter, Milford (1967) found that lotononis, which was unaffected by frost, was better in dry matter digestibility than the other five tropical species that were so affected. Of the others, Silverleaf desmodium was least changed by frost. Dry matter digestibility was generally low, ranging from 47 to 69% in the better species.

There may be a place for fodder conservation, especially considering modern techniques of silage making, when intensive systems of management are finally worked out. In this case the work of Catchpoole (1970a & b) is relevant. He showed that in the preparation of silages the preservation of lotononis was excellent, setaria and Greenleaf desmodium produced reasonably well preserved silages, but Siratro was poor unless 8% molasses was added, when it preserved well. The practical aspects of hay and silage making in the Wallum have hardly been touched.

ANIMAL PRODUCTION

The bulk of the pastoral development in the region is based on beef cattle and it was estimated that 20,000 head were being carried in 1970 (Peart, 1971).

From grass-legume pastures

Two facts stand out in consideration of liveweight change of steers on grass-legume mixtures. One is that the pattern of change is fairly constant over the years, with the most rapid gains being made in spring, a slightly slower rate of gain in mid to late summer, slower still in autumn and either no gain or a loss in winter (Bryan, 1968a & b; Bryan and Evans, 1971a). The duration of the period of rapid gain in spring and early summer depends on the seasonal rainfall. The other fact is that the rates in general and the winter lull in particular are associated with the legume content, the higher the content the better the animal performance (Evans, 1968a, Evans and Bryan, 1973).

In the early grazing work at Beerwah, when there was no information on appropriate stocking rates or grazing systems, animal production was relatively low. Thus in the years 1959-61 (Bryan, 1968a & b) liveweight gain (LWG) was 267 kg/ha a year, while in the years 1963-1965 in the same trials the LWG rose to 310 kg/ha as stocking rate was increased to match greater pasture production. With better pastures this was raised to 330-360 kg/ha (Bryan and Evans, 1973) and with extra annual fertilizer and still higher stocking rates to 507 kg/ha (Bryan and Evans, 1971a).

A large grazing trial carried out at Beerwah over a six year period (Bryan and Evans, 1973) showed a striking effect of soil type on the botanical composition of the pasture—an effect that was manifest quite early in the life of the pasture and persisted in the face of other marked treatment effects. Two important findings in this experiment were that the soils could be grouped into very wet ones (humic gleys) and others, and that the species best adapted to each group could be defined. The wet soils had much more sedge, rush, paspalum and more white clover, while rhodes grass, Desmodium spp., lotononis and mat grass (*Axonopus affinis*) were much more prominent on the drier soils. In this trial a light stocking rate (1.23 beasts/ha) was generally favourable to grasses (especially scrobic and pangola), and *Desmodium* spp., while the heavy stocking rate (2.47 beasts/ha) was more favourable to paspalum, white clover and lotononis. The higher level of superphosphate (250 kg/ha annually) encouraged rhodes, pangola, *Desmodium* spp. and white clover, while paspalum and lotononis achieved greater prominence at a lower level of superphosphate (125 kg/ha/year). This lower level also carried higher amounts of all important weeds. This was reflected in animal liveweight gain, which was on average 64 kg/ha/year less on the low P treatments (Evans and Bryan, 1973). The best animal gains per hectare were 348 kg at 2.47 beasts/ha and 328 kg at 1.65 beasts/ha at the higher P level. There was no advantage in increasing the annual K application over 63 kg/ha KCl.

On the low rolling country a production of 336 kg/ha LWG could be regarded as reasonable over a fairly wide range of conditions with well fertilized mixed pastures.

On the wet heath country at Coolum, a pasture of pangola grass and lotononis carrying 25 steers on 16.2 ha in 1964 produced a LWG of 333 kg/ha (Anon., 1965). In the following year, with 30 head, LWG/ha remained the same (unpubl. data). The animals on this trial had low hepatic copper reserves, but although copper therapy increased these levels there was no significant response in LWG (Gartner, Young and Pepper, 1968).

In later work at Coolum the legume content in a pangola-white clover-lotononis pasture declined sharply, and after producing an average LWG of 170 kg/ha over the first two years, production dropped to half this amount in the third year, despite substantial annual inputs of P and K (Young and Chippendale, 1970). *Desmodium uncinatum* and white clover also declined in a mixture with Nandi setaria. Both these failures were attributed to periodic inundation and an inability to maintain balanced plant nutrition. Information on grazing procedures is not recorded.

In contrast to the declines recorded at Coolum the general experience at Beerwah has been a steady increase in LWG per unit area over the first few years of grazing, (during which stocking rate was safely increased), after which a more or less steady state was maintained (Bryan, 1968a & b). However, in later work at Beerwah (Bryan and Evans, 1973; Evans and Bryan, 1973) there was also a gradual decline in legume content and this was accompanied by a decline in LWG.

In the northern Wallum on nodular podzolic soils at N. Isis, Evans (1968b, 1969a) in favourable seasons has obtained about 480 kg/ha with pastures of siratro and either rhodes grass or Nandi setaria. Long term means would be lower because production in poor seasons is very low.

Few sheep are carried on the Wallum and little is known of their performance. The only record is a very limited one by Bryan and Evans (1971b) who on an area of 0.32 ha carried an average of 25.8 Romney Marsh wethers a hectare for eight years. Animal health was satisfactory and the mean annual wool clip was 3.86 kg a head. However, the economics of sheep raising were considered to be poor by McCarthy *et al.* (1970).

From grass pastures with nitrogen fertilizer

At Coolum (Anon., 1971) a pangola pasture fertilized with 336 and 560 kg N a hectare was continuously stocked at 4.9, 7.4 and 9.9 beasts a hectare (2, 3 & 4 beasts/ac) In a particularly unfavourable year (June 1970 to May 1971) 9.9 beasts/ha gave very low gains, with heavy weight losses in winter. Best gains were from 336 kg N, being 558 kg/ha at 7.4 beasts and 485 kg/ha at 4.9 beasts. A similar pasture (pangola) at Beerwah over the same period given 476 kg N/ha produced 610 kg/ha at a stocking rate of 4.3 beasts/ha and 456 kg/ha at 6.2 beasts/ha (Evans, unpublished data). The results are thus fairly comparable, although from very different environments.

Several experiments with nitrogen fertilized pangola grass have been carried out at Beerwah. In one trial (Bryan and Evans, 1971a) a pangola grass-legume pasture was compared with grass receiving 168 or 448 kg N/ha/year. The LWG's were approximately 500, 700 and 1100 kg/ha respectively. In another experiment using 448 kg N/ha, Evans (1969b) obtained a LWG of 1280 kg/ha. There was no real advantage from increasing the level to 896 kg N/ha. Looking further into how to apply the nitrogen Evans (1971a) found that splitting the 448 kg N/ha into three applications gave an annual mean LWG over three years of 1170 kg/ha, while 6 applications produced 1440 kg/ha. One of the significant features of this result (Evans, pers. comm.) was that using proportionately more N in autumn and winter had a markedly favourable effect on animal production, even though this tended to oppose the growth curve of pangola established by Bryan and Sharpe (1965).

In a comparison of Nandi setaria and pangola grass at different stocking rates with different amounts of N, (Evans, 1971a, 1972) the most outstanding result has been the superiority in LWG of pangola over setaria, a difference which was most marked at the higher stocking rates. The best LWG from pangola in this experiment has been about 800 kg/ha at 476 kg N/ha.

Although the use of fertilizer N on grass has given considerable increases in LWG over grass-legume mixtures, the use of such grass pastures as the sole source of feed is doubtful as an economic proposition (Michell, Bryan and Evans, 1972). Possibly the role of nitrogen fertilized pastures will be to supplement a main use of grass-legume pastures at times when these are low in quality or amount. A possibility yet to be explored is the limited use of N on mixed pastures themselves. It should be possible to make strategic applications to such pastures without reducing the legume content.

THE USE OF PIONEER CASH CROPS FOR EARLY RETURNS

Because of the time interval between clearing of virgin land and receipt of substantial income from cattle, the use of pioneer cash crops to offset development costs could be considered. The possibilities are very limited since so few crops of commercial value can be grown successfully on virgin land. The most likely ones seem to be pasture seed production (Adams, 1967) or pulse crops. Several developers (e.g. Summers, 1967) have successfully produced seed of a range of adapted pasture plants, notably lotononis, *Paspalum plicatulum*, *Macroptilium atropurpureum* cv. Siratro and *Setaria sphacelata*. As Redrup (1966) has pointed out, the problems of seed production and marketing are great and only reasonable momentary returns can be expected. Seed production should be regarded as a separate enterprise from pasture development; using pure stands, as seed crops do not generally develop into well balanced pastures without considerable amendment.

Bryan and Sharpe (1965) showed that the soybean varieties Avoyelles and Hernon gave satisfactory yields of beans in 2 or 3 years out of 4, Avoyelles being somewhat more disease resistant. Soybeans, however, would have to be restricted to the better drained soils. The same workers later (unpublished data) obtained reasonable yields of seed from cowpeas (*Vigna sinensis*) but the flowering and fruiting period was too long and there was too much shattering.

In view of the fact that some cattle (at about one third of the final stocking rate) can be put on a new pasture within three months of sowing and be sold nine months later, it is doubtful if cash crops now warrant serious consideration.

ECONOMIC ASSESSMENT

No research has been done on costs or techniques of clearing or on the cost of and need for drainage. Drainage may have a place in preparation for clearing, but not thereafter except on wet heaths. A good deal of practical experience in clearing has been gained in the region.

The first economic study was that of Moore (1967) who considered a cattle fattening enterprise on 1620 ha based on purchased stores and funded by a syndicate of five each contributing $20,000 initially and thereafter $4,000 a year for nine years. Assuming a turn-off of 2.47 beasts/ha/year, he calculated a net return to each investor of about 12½% on the total cost of development. This included income tax concessions but not interest on total capital invested.

In a study assuming 650 ha of pasture under single ownership, McGuire (1968) estimated that if steers were purchased and fattened over two periods of 150 days a year (omitting two months in winter), the internal rate of return (IRR) ranged from 3% to 10% depending on beef price assumptions. On the same basis the IRR if cattle were bred and fattened was less profitable, ranging from 1% to 4%. Tax concessions were not considered.

McCarthy *et al.* (1970) compared a sheep enterprise, three beef enterprises and two forestry alternatives from the public point of view, i.e. the development of all available land and no tax concessions. They found that a 40 year pulp-timber rotation was most profitable (IRR 8-9% and benefit-cost ratio (V/C) about 2), closely followed by a beef breeding and yearling marketing operation where replacements for the breeding herd were bought in (IRR 7.6% and V/C 1.1). Beef fattening of purchased steers (IRR 5.9, V/C 1.0) was superior to a 20 year pulp rotation (IRR 5.5, V/C 0.9) while the maintenance of breeding herd with yearling marketing was least profitable (IRR 4.6, V/C 0.9).

The most recent study by Michell, Bryan and Evans (1972) considered the profitability of a pangola grass-legume pasture compared with pangola grass at two levels of N fertilization based on the experimental data of Bryan and Evans (1971a). Fattening purchased steers on a property size of 607 ha, the IRR for grass-legume was 2.8%, for 168 kg N/ha it was 4.5%, and for 448 kg N it was 2.6%. Reducing the potassium chloride input to 125 kg/ha/year improved the IRR'S to 5.4, 6.3 and 4.2% respectively. By applying taxation concessions to an investment of non-farm taxable income, it was shown that some cases using the legume or low N systems with large taxable incomes and a long time horizon were better than a 9% debenture investment.

In considering these economic studies, which generally indicate only modest profitability for pastoral development on the Wallum, it might be as well to keep in mind the finding of Waring (1967) that the average return to capital for Australian farms about that time was 3.5 to 4.5%. Agriculture does not often compare favourably with 9% debentures—provided the debenture company remains solvent!

CONCLUSIONS

The extent of pastoral development in the Wallum is very much in the hands of the State Government as to how it decides to allocate for use its 130,000 ha of vacant crown lands and its 190,000 ha of State Forests considered unsuitable for planting (Peart, 1971). At present this land is frozen. At a conservative estimate this land could carry between 400,000 and 500,000 head of cattle when developed.

1. Although the natural environment apart from its useful rainfall was initially considered to be a difficult one for pasture plants, productive and fairly persistent pastures can be grown once the vegetation has been removed and the necessary nutrients added.

2. The soils are deficient in nitrogen, phosphorus, potassium, calcium, sulphur, copper, zinc and molybdenum and inputs of fertilizer have to be high. The requirement for pasture establishment on most soils is 625 kg superphosphate, 625 kg calcium carbonate, 125 kg potassium chloride, 8 kg copper sulphate, 8 kg zinc sulphate and 280 g sodium molybdate a hectare. For maintenance, an annual application of at least 250 kg superphosphate and 63 kg potassium chloride is recommended. This maintenance input is required for a long time, perhaps indefinitely.

3. Suitable species are available for all but the wettest areas. For the northern Wallum these are Siratro, lotononis, Green leaf desmodium, phasey bean and possibly kenya white clover, pangola grass, *P. plicatulum*, *Panicum coloratum*, rhodes and *Setaria* spp.; for the southern Wallum the legumes lotononis, Greenleaf and Silverleaf desmodium, phasey bean and white clover, and the grasses pangola, paspalum, Setaria spp., rhodes and scrobic have done well. However, there are still major problems to be resolved. In most mixed pastures there has been a decline in the legume content with time and in view of the positive relationship between legume content and LWG this aspect requires more research effort. Pangola, the best grass to date, is now being strongly affected by disease and its reliability comes into question. There is an urgent need for a substitute.

4. Land is preserved and improved under exotic pine forests and grazed pastures whereas it is unlikely that equal improvement can be achieved under cropping regimes.

5. Liveweight gains in fattening cattle of 336 kg/ha should be attainable on well established grass/legume pastures. On grasses dressed with N much higher gains can be made, but the use of N is of doubtful economic value.

6. The stage has been reached where further studies of pasture management and feed systems are needed so that the leads from past work can be integrated for the benefit of developers.

7. The problem of the flattest and wettest soils (only about 6,000 ha) remains intractable.

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