Soil fertility and animal productivity in the Nebo–Broadsound district of central Queensland

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Abstract

This paper examines the relationship between soil fertility and estimated animal performance in the Nebo–Broadsound district in central Queensland. It describes a scheme to classify the grazing productivity of land types.

Soil research in the Middlemount area has shown that total nitrogen (%) and available phosphorus (ppm) levels in the surface soil explain much of the variation in grazing productivity seen within the district. Inherent levels of both soil nutrients reflect the interaction of climate, geology, topography, vegetation and fire history over time.

Soil levels of 0.08% for total nitrogen and 10 ppm for available phosphorus were the minimum critical levels measured on country used for fattening in the Nebo–Broadsound district. Land types with fertility levels below these cut offs are more suited to growing or breeding enterprises.

Introduction

Consider a situation where a grazier owns 2 properties: a brigalow block with a mix of fertile brigalow clay and duplex soils developed to buffel grass; and located nearby in the same district, a block that is a mixture of red tableland and poplar box country with native pastures on soils of low fertility. The grazier buys store cattle with a view to producing finished (600kg) animals on both places. As such, management and climate are effectively constant throughout the operation.

The brigalow block is highly productive and produces export quality cattle with little or no extra inputs. The eucalypt block, on the other hand, has a significantly lower carrying capacity and slower growth rates and requires continual inputs such as extended dry season supplementation simply to maintain stock condition in most years. Even in exceptional seasons, animals on the eucalypt block grow more slowly, look 'rangy' and are difficult to finish. By comparison, breeding herds on similar eucalypt country on neighbouring properties perform very well.

The point of this example is simply to emphasise the role the inherent land resource plays in a production system where the practicality and economics of changing the resource base are prohibitive.

In grazing systems, where management is optimal and seasonal conditions are not limiting, pasture productivity is dependent on the supply of water either from rainfall or stored moisture and nutrients from the soil.

Grazing performance, however, is largely controlled by the supply of energy, protein and soil nutrients available through the pasture.

Concept of grazing productivity

Definitions

Grazing productivity is defined as the ability of a land type to produce grassfed cattle at a young age for premium export markets (*i.e.*, 600 kg finished animal with 12–18mm of rump fat at 2½ years of age), without inputs other than pasture development.

A land type in this scheme is defined as an area with relatively uniform geology, landform, soil and vegetation. Land types are not location-

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specific but are repeated within a district wherever the same combination of these factors occurs.

Factors controlling grazing productivity

Soil research near Middlemount in the Nebo–Broadsound district [J. Burgess in preparation (a)], has established benchmark soil fertility levels for all essential plant nutrients, across a range of land types. Of the data collected, total nitrogen (%) (Kjeldahl N) and available phosphorus (ppm) (bicarbonate extractable) in the top 0–0.1m have shown the most promise in explaining the variations in grazing productivity seen across the district.

The levels of total nitrogen (%) and available phosphorus (ppm) in soils provide a useful framework for developing a productivity-based land type classification. When land types, grouped according to fertility status (*i.e.*, from high to low), are compared with groups based on animal performance, (*i.e.*, from fattening to seasonal breeding), remarkable similarities become apparent. Without liveweight data, however, for a range of different land types over a number of seasons, it is impossible to statistically validate these comparisons. Irrespective, nitrogen and phosphorus fertility, at least from a practical point of view, appear strongly correlated with animal productivity.

The importance of soil nitrogen and soil phosphorus in the grazing system

In any pasture situation, adequate and balanced levels of all 14 essential soil nutrients (N, P, K, S, Ca, Mg, Fe, Mn, Zn, Cu, B, Mo, Co and Cl) are necessary for successful plant growth. However, nitrogen (N) and phosphorus (P) are the soil nutrients that most commonly limit plant growth and animal productivity in the grazing system.

Deficiencies of both nutrients in grazing animals are widely recognised across much of Queensland, particularly in central and northern areas. They are generally most deficient on older landscapes where soils are highly weathered and leached, with low cation exchange capacities and low organic matter contents. Under these conditions, nutrient retention is very poor and is restricted to the organic nutrient store within the top few centimetres of the soil.

Shields and Anderson (1989) and Ahern *et al.* (1994) have shown that, while soil deficiencies of calcium, magnesium and potassium occur in Queensland, symptoms in animals are rarely seen. Since the availability of these nutrients is controlled by similar factors to those of nitrogen and phosphorus, it is likely deficiencies of these lesser nutrients are almost always overshadowed by the first limiting major nutrients.

Levels of sulphur in the surface soil are closely linked with the organic fraction and follow similar trends in build-up and availability to that of nitrogen.

Processes controlling the nitrogen and phosphorus fertility of soils

The natural build-up of nitrogen and phosphorus fertility in different land types is a complex process. It involves the interaction of:

- geology and nature of the parent material;
- landscape age and weathering intensity;
- the processes of soil formation;
- climate;
- leaching history;
- erosional history;
- size and form of the biomass;
- biomass efficiency (in trapping and cycling nutrients);
- fire history; and
- time.

While the processes controlling the build-up of fertility in the surface soil under natural conditions are effectively the same for all land types, there are differences in:

- the initial supply of nutrients;
- the intensity of biological cycling;
- losses to the atmosphere; and
- losses through leaching and erosion;

that ultimately determine the fertility levels currently seen in the landscape.

The origins and supply of nitrogen and phosphorus are very different. Almost all nitrogen comes originally from the atmosphere, through additions in rainfall or fixation by legumes and micro-organisms. In contrast, phosphorus is supplied from the weathering of rocks. In most soils, phosphorus levels are determined directly by the parent material. Where soils are developed on alluvium or other transported sediments, the phosphorus content generally reflects levels in the sediment source.

As nutrients become available in the soil for the first time, they are absorbed by plants and trapped and stored in the biomass. Litter accumulates on the soil surface and is broken down by micro-organisms. Nutrients that were tied up in plant matter are released back to the soil and the cycle continues. There is a relative increase in the levels of organic matter and total nutrients in the surface soil with this process.

The biomass store is the driving force behind the build-up and maintenance of soil fertility. The absolute quantity and growth form of the biomass as well as the intensity of biological cycling and fire history all contribute to the size of the nutrient store. Where either the quantity of the biomass is low, or uptake efficiency is poor, available nutrients will be lost from the system through leaching and erosion. A low fertility equilibrium will result.

Conversely, where an ecosystem is characterised by a large biomass that is extremely efficient, a high fertility equilibrium results. The soil fertility differences commonly seen between eucalypt country and softwood scrub or brigalow country provide evidence of this effect.

The mechanisms by which nitrogen and phosphorus are lost from the landscape under natural conditions include:

- atmospheric losses (mainly nitrogen);
- leaching losses;
- erosional losses; and
- chemical fixation (mainly phosphorus).

Cumulative losses through leaching and erosion over geologic time are major factors in the development of fertility levels apparent today. Atmospheric losses mainly involve nitrogen, although significant losses of both nitrogen and phosphorus can result from frequent burning. Fixation losses are restricted to phosphorus and result from the formation of insoluble compounds in the soil that are permanently unavailable to plants.

Grazing productivity scheme

Definition

Simple class limits for total nitrogen (%) and available phosphorus (ppm) in the surface soil can be defined that categorise the productivity of a land type. This allows country to be classed according to whether it is capable of producing young, finished, export cattle or whether it is more suited to growing or breeding enterprises. The grazing productivity scheme described here uses a system in which Class 1 is the most productive land and Class 5 is the least productive. The soil fertility criteria used to define each productivity class, together with approximate stocking rates and estimated weight gains are presented in Table 1.

It is important to recognise that any scheme that attempts to rank land types from best to worst can only be district-specific. The criteria used in this scheme are based on fertility data measured in the Nebo–Broadsound district and therefore do not necessarily apply elsewhere. This is a function of the unique combination of climate, geology, landscape, soils and vegetation that are present in any district. The problems that occur when using

Table 1. Soil fertility criteria, grazing productivity classes and approximate stocking rate and weight gains for the Nebo–Broadsound district (J. Burgess in preparation (b); R. Dodt and G. Lambert, personal communication).

Avail. soil P (ppm)	Total soil N (%)	Soil fertility rating	Grazing productivity classes[1]	Grazing enterprise	Stocking rate (ha/beast)	Annual weight gain (kg/hd)
≤5	<0.03	Very low	5. Very low (seasonal grazing)	Breeding (seasonal grazing)	>12	<100
6–9	0.03–0.05	Low	4. Low	Breeding	6–12	100–140
10–15	0.05–0.08	Moderate	3. Moderate	Growing (occasional fattening)	4–7	140–170
16–40	0.08–0.15	High	2(b). High (seasonal grazing due to flooding)	Fattening (seasonal grazing)	3–5 (Apr–Oct)	NA
			2(a). High	Fattening	3–5	170–200
>40	>0.15	Very high	1(b). Very high	Fattening	2–3	>200
10–40	0.05–>0.15	Moderate to very high	1(a). Cropping	Fattening	NA	NA

[1] Class 1(a) includes a range of forage, crop stubble, leucaena and grassfed options; Class 1(b) to Class 5 are grassfed only.

fertility criteria from another area can be seen when total nitrogen levels from the Nebo–Broadsound and Biloela districts are compared [J. Burgess in preparation (a); P. Muller in preparation (a)]. Total nitrogen levels are consistently higher at Biloela across a range of land types. As a result, critical cut offs for total nitrogen categories (from very low to very high) have been set much higher for the Biloela district [J. Burgess in preparation (b); P. Muller in preparation (b)]. Use of criteria from the Biloela district for ranking land types in the Nebo–Broadsound district would result in inconsistencies.

Examples from the Nebo–Broadsound District

The following discussion briefly outlines the main land types in the Nebo–Broadsound district and provides some practical examples of the relationship between inherent fertility and grazing productivity [J. Burgess in preparation (c)]. Class 1 is defined as the most productive grazing country in the Nebo–Broadsound district. It includes successful long-term cropping soils (Class 1a) as well as softwood scrub pasture country (Class 1b). Class 1 was split into 2 subclasses to allow the inclusion of dryland cropping land types in the scheme. Land types in Class 1a vary in their ability to fatten cattle under pasture, but have great versatility and the potential for high productivity (*e.g.* leucaena, forages and crop stubble) under cropping systems. Successful dryland cropping soils have the following characteristics:

- cracking clays with an effective rooting depth of at least 0.75m;
- self mulching surface;
- well structured subsoil;
- neutral to alkaline pH throughout the root zone;
- available phosphorus levels >10ppm; and
- total nitrogen levels >0.08%.

Land types in Class 1a include non-gilgaied brigalow clays that are not saline or strongly sodic within the top 0.75m, as well as deeper open downs country and brigalow flood plains not subject to high velocity, erosive flooding. The brigalow clays have high levels of nitrogen and phosphorus, while the downs country has levels that are usually only moderate. In all cases, nutrient supplies are at least adequate for plant and animal productivity.

Class 1b, by comparison, represents the most productive grazing country in the district. Land types in this class consistently finish cattle for premium export markets, entirely on pasture. It includes only softwood scrub land types and is the one group where very high levels of both nitrogen and phosphorus are normally present.

Class 2a includes all brigalow lands between Dingo and Collinsville that do not flood. There is significant variation in the brigalow land types, which include:

- country with mixed brigalow and eucalypt strips;
- brigalow-eucalypt country where brigalow occupies the understorey, *e.g.* brigalow-blackbutt or brigalow-yapunyah;
- "whipstick" brigalow scrubs;
- "melonholed" brigalow and/or blackwood scrubs; and
- dense, brigalow scrubs with a significant component of shrubby softwood species or belah.

All are considered capable of producing cattle that meet export specifications. The levels of nitrogen and phosphorus generally increase as the eucalypt component declines and the scrubs get thicker. Levels of both nutrients are only moderate to high in the lighter brigalow-eucalypt land types but increase to consistently high levels in the thicker scrubs.

Class 2b was split from Class 2a to subdivide flooded country capable of fattening cattle from the remainder of the fattening country (*i.e.*, the rest of the brigalow land types that do not flood). Class 2b includes all country that regularly floods on low lying, alluvial plains along the major rivers. Creek flats and high alluvial plains that do not regularly flood are not included. Class 2b land types include:

- open coolibah flood plains;
- blue gum–coolibah–bloodwood river flats;
- seasonal swamps; and
- brigalow flood plains.

Phosphorus levels are high to very high on flooded land types, which are recognised by graziers as excellent fattening country. Differences in nitrogen fertility occur, however. The eucalypt land types have only moderate levels, while the brigalow flood plains have levels similar to those for other brigalow land types. The high phosphorus status associated with the eucalypt country, however, places these land types in Class 2. Prudent grazing management normally requires this country to be destocked each wet season due to flood risk. As a result, only seasonal grazing during the dry season is commonly practised, thereby under-utilising summer growth and limiting pasture productivity to standover winter feed. This situation lowers the potential grazing productivity of flooded land types and has required a separate category within the fattening class.

Class 3 equates with country on which younger cattle perform well, but are difficult to finish. Animal growth rates are slower and cattle achieve export specifications only in very good seasons. It includes a range of eucalypt open woodlands with better quality native pastures such as black speargrass and bluegrasses. The main land types are:

- narrow-leaved or silver-leaved ironbark on andesites or shales;
- shrubby poplar box on unconsolidated sediments;
- poplar box creek flats (that rarely flood);
- alluvial sand ridge country (that rarely floods);
- blue gum creek flats in the coastal ranges; and
- mountain coolibah and downs country on unconsolidated sediments, basalt or shale.

Fertility levels are mostly moderate. Levels of phosphorus range from low to moderate (6–15 ppm), although higher levels (16–40 ppm) often occur on creek flats and alluvial sand ridge country. Phosphorus levels on blue gum flats in the coastal ranges are consistently lower than on other creek flats (<15 ppm), because of lower fertility in the surrounding ranges. Nitrogen levels are moderate on all land types except alluvial sand ridge country and sandy creek flats where levels are low to very low. The high phosphorus status associated with the sandy alluvial land types places them in Class 3, however.

Class 4 includes most of the land types commonly thought of as 'reasonable' breeding country. Again a range of land types occur including:

- yapunyah country;
- open narrow-leaved ironbark and poplar box country not associated with creek flats, ranges or tablelands (*i.e.*, everything in between); and
- open narrow-leaved or silver-leaved ironbark 'red soil' country without scarps (for example around Bombandy and north-west of Moranbah).

Fertility levels are generally low. Phosphorus levels range from low to very low (3–9 ppm). Land types that have sandy topsoil (*e.g.* poplar box country), or are highly weathered and leached (*e.g.* 'red soil' country), or are developed on rocks low in phosphorus (*e.g.* the coastal ranges) have the lowest levels. Where the topsoil is heavier on some poplar box and narrow-leaved ironbark land types, the effect of leaching is less and levels are mostly low (6–9 ppm). Nitrogen levels are low on all land types. Yapunyah is the exception, having moderate to high phosphorus levels and moderate nitrogen levels. However, limitations associated with acidity and salinity often restrict productivity on this land type, placing it in Class 4.

Class 5 represents country that is used only for breeding on a seasonal basis. It is normally grazed over the summer growing season, often with supplements, and is destocked during the dry season. It includes most of the country associated with tablelands and ranges:

- lancewood, bendee or rosewood country;
- bull oak country;
- narrow-leaved ironbark in the steeper coastal ranges;
- narrow-leaved ironbark on steep hills and sandstone ranges; and
- red tableland country with scarps.

The fertility status of these lands is very poor. Phosphorus levels are very low throughout (*i.e.*, always <5ppm). Similarly, nitrogen levels are low to very low with the exception of lancewood, bendee and rosewood land types, which have levels similar to brigalow. The reasons for this probably relate to biomass quantity, biomass efficiency and fire history. Extreme acidity and phosphorus deficiencies, however, mean the benefits of this higher nitrogen are rarely ever seen.

In summary, it is clear that the grazing productivity of a land type is controlled by the inherent nitrogen and phosphorus status of the soil. Differences in fertility between land types provide the best explanation for the changes in estimated animal performance (from fattening through to breeding) that occur within the Nebo–Broadsound district.

Nitrogen and phosphorus fertility and animal productivity

The relationship between soil fertility and class of cattle

In central Queensland, where the majority of properties turn off steers or bullocks to meet carcase specifications for export markets, it is generally accepted that poorer land types (*i.e.*, low fertility) are best utilised by breeders, while the better soils (*i.e.*, high fertility) are used to finish cattle.

The kilograms of beef turned off a property in any given year can be estimated from the stocking rate and the average annual weight gain. It can be argued that both of these variables are determined to a large extent by soil fertility. Table 2 illustrates the significant effect soil fertility can have on the level of production that is achieved from different types of country.

Table 2. Estimated stocking rates, annual weight gains and the resulting kilograms of beef that can be produced off country with different levels of soil fertility in the Nebo–Broadsound district (J. Burgess in preparation (b); R. Dodt and G. Lambert, personal communication).

Soil fertility rating	Stocking rate (ha/beast)	Estimated weight gain (kg/beast/yr)	Beef produced (kg/ha/yr)
Very low	12	80	7
Low	8	120	15
Moderate	5	160	32
High	3.5	180	51
Very high	2.5	220	88

To obtain premium prices for export cattle, graziers must aim to produce a 600kg animal at 30 months of age with 12–18 mm of rump fat. Assuming the animal is weaned at 6 months weighing 180 kg, to reach 600kg by 24 months post-weaning, the animal must grow at 210kg/year. This equates with an average daily weight gain of 0.58 kg from weaning to slaughter. In practice, grass-fed steers achieve such growth rates only on land types with a high fertility status or better.

Most growing or fattening enterprises attempt to achieve 'optimum production' with sale animals to maximise the level of income returned. In comparison, breeders are expected to perform only at an 'adequate' level of production (*i.e.*, produce one calf per year). Although this is still a challenge, management strategies (strategic supplementation, seasonal calving) can be implemented to achieve a calf every 12 months on soils of low fertility.

There are also differences in the nutrient requirements and nutrient utilisation patterns of cows and steers (Figure 1).

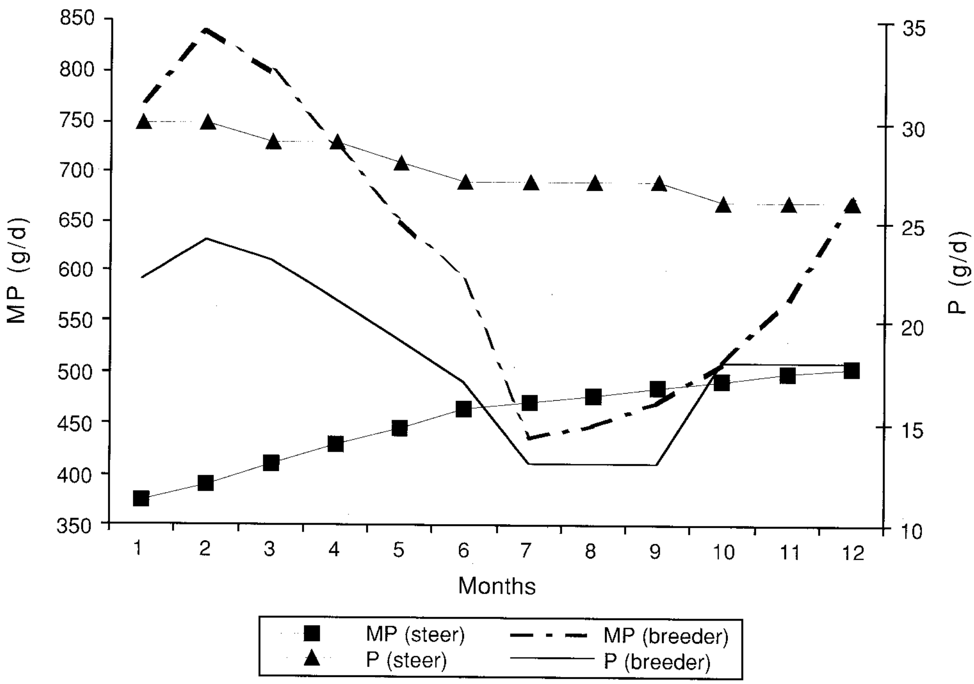

Figure 1. Levels of metabolisable protein (MP) and phosphorus (P) required by a mature cow (calving month 1) and by a steer growing from 250kg to 450kg (c.0.5 kg/d) (NRC 1996).

Metabolisable protein can be used to indicate the change in nitrogen requirements over time, although the actual level of nitrogen required can not be quantified from this graph. It does illustrate, however, that breeders have a cyclical demand for both nitrogen and phosphorus while steers have a constantly increasing requirement for both nutrients.

Since breeders have a cyclical demand for nutrients, they can utilise stored energy and nutrient reserves during lactation and then restore those reserves as they dry off. If the seasonal changes in a cow's nutrient requirements are matched to the seasonal changes in nutrients available from the pasture, there will be limited loss of production. In comparison, such changes to the plane of nutrition of a fattening animal will have significant effects on growth rate, weight gain, turn-off age and ultimately income.

The interaction between soil fertility and seasonal variation in nitrogen and phosphorus supply to cattle

Phosphorus deficiencies are accentuated in the growing season because phosphorus becomes the primary limiting factor to animal productivity. During this period, pasture quality is optimal and there are high levels of available energy and nitrogen, in the form of crude protein, in pasture (crude protein = nitrogen × 6.25). As a result, growth rates increase and the animal requires more phosphorus in the diet.

Conversely, over the dry season, nitrogen becomes the primary limiting factor as the level of crude protein in the pasture decreases. While phosphorus levels are also lower than in the growing season, it is the lack of nitrogen and energy in the diet that most limits growth and production in the animal. Consequently, nitrogen needs to be supplemented over the dry season while phosphorus is required over the wet season.

With appropriate supplementation, breeders can efficiently utilise infertile country. In comparison, steers on the same soil types would not reach target weights in under 30 months. Optimum growth in steers is achieved only for approximately two months of the year on low fertility soils. Over the dry season, weight loss occurs. Steers grazing fertile brigalow country, however, could achieve growth rates greater than 1.0 kg/d over the wet season and would still grow (but at a slower rate) over the dry season.

Conclusions

1. Comparison of the levels of soil fertility, particularly nitrogen and phosphorus, for different land types in the Nebo–Broadsound district appears well correlated with estimated grazing performance (*i.e.*, from fattening through to breeding).
2. Nitrogen and phosphorus are the nutrients required in the largest quantities by plants. They are also critical for both plant and animal growth and metabolism, and are deficient in a number of central Queensland soils. In addition, the availability of other organic and inorganic nutrients in the soil generally follows similar trends to the availability of nitrogen and phosphorus.
3. The nitrogen and phosphorus fertility of a land type reflects the history of soil and landscape development. The interactions between climate, geology, topography, vegetation and fire history over time ultimately determine inherent fertility.
4. Soil levels of 0.08% for total nitrogen and 10 ppm for available phosphorus represent the minimum critical levels for fattening country in the Nebo–Broadsound district. Fertility levels below these cut offs are normally associated with growing or breeding country.
5. Only land types with high nitrogen and phosphorus fertility are capable of consistently finishing cattle at a young age suitable for premium export markets. Breeders have a cyclical demand for nutrients that can be matched to seasonal changes in pasture quality. This allows them to utilise stored nutrients if necessary and then restore these reserves when conditions improve. Effectively breeders can lose weight for certain periods and still produce a calf each year. In comparison, finishing steers at under 3 years of age requires a high and preferably constant plane of nutrition. Any loss or reduction in animal productivity in that time equates with lost income.

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