# Soils refresher to veterinarians

***P E H Gregg***


## Abstract

A sound knowledge of soil properties and processes allows opportunities to improve the efficiency of land management practices on pastoral farms. Two important features of New Zealand soils under pastoral farming are the wide range of soils existing and the changes taking place in soil properties as the soil develops. These features are of significance in relation to the productivity and sustainability of pastoral farms. Animals impact on the soil resource in many ways. They can initiate erosion and are the main mechanism of nutrient cycling which has both negative and beneficial effects. Several misconceptions exist about the role of soils in pastoral farming and these are briefly discussed.


## Introduction

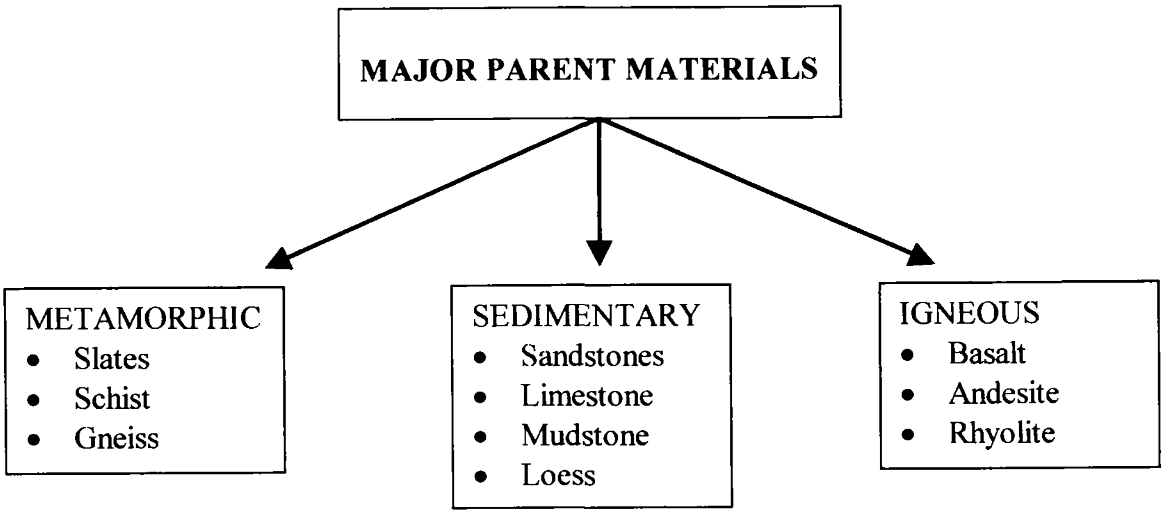
The soil resource on a farm property has a significant influence, either directly or indirectly, on animal production. Many soil properties and processes influence the quantity, quality and utilisation of pasture by animals. The soil resource also impacts on animal health and welfare. On the one hand it is a potential reservoir of infection from a range of diseases whose life cycles involve a period of residence in the soil, on the other hand its drainage status particularly over winter months, plays a role in influencing soil conditions which may effect animal welfare. Anyone involved in pastoral farming requires some basic knowledge about the soil resource in order to improve the efficiency of land management practices.

## Some features of New Zealand soils under pastoral farming

### *Wide Range Of Soils*

For a country the size of New Zealand, there are more soils per unit area than most other countries involved in pasture production. The reason for this is that the variability in each of the five soil forming factors which through their integrated effects create a soil at any one site. The five factors involved in soil formation are TIME, CLIMATE, PARENT MATERIAL, LIVING ORGANISMS and TOPOGRAPHY or RELIEF. Within each of these soil forming factors, in New Zealand, a wide range in characteristics exists. For instance, parent material can be separated into several broad types that exist throughout NZ (Figure 1). Pastoral farming in NZ would be confined to soils mainly derived from sedimentary and igneous rocks each with a further subdivision of parent material types. As soon as one of the soil forming factors changes significantly in a region then a different soil is created.

***Figure 1:*** *Major parent materials*




Even at a very broad scale (1: 1000000), NZ has a wide range of contrasting soils whose properties will influence pasture productivity (Molloy 1998). At this large scale, 13 broad soil orders are recognised in the South Island and an additional 2 in the North Island where 15 soil orders exist. The differences between these orders are analogous to one being able to recognise the differences between various vegetation groups such as forest grassland and shrubland. The main soil orders of importance in pastoral production are Allophanic, Pumice, Brown, Pallic and Recent. Deer farms will be located on all these soil orders.

Allophanic soils are mainly in Taranaki and Waikato districts and parts of southern Taupo and develop in volcanic ash. Their main characteristic is that they contain allophane minerals which are jelly like in appearance under an electron microscope They coat sand and silt grains and maintain a porous low density soil which has a greasy feel when rubbed between fingers. The allophane has a high affinity for P (phosphorus) which means that for a high level of pastoral production, maintenance rates of fertiliser need to be at a high level (40-60 kg P/ ha/yr). The high P retention, however, reduces S (sulphur) leaching from these soils. Physical properties are considered very suitable for root growth but chemically they have a low natural fertility with low K (potassium) reserves and K fertiliser is needed once pastures are developed.

Pumice soils are derived from one of the greatest volcanic eruptions ever known from the crater now occupied by Lake Taupo. These soils are sandy or gravelly soils dominated by pumice. Drainage of excess water is rapid The pumice is fresh or only moderately weathered and has low reserves of major nutrients such as P, S, and K. For pastures, several trace elements are in low supply such as Cu (copper),B (boron) and stock generally require Se (selenium) and Co (cobalt).

Brown soils occur where summer drought is uncommon and are recognised by their brown or yellow brown subsoil below a dark grey topsoil. They exist throughout both the North and South Islands. Physically they are stable with good rooting zone. Natural chemical fertility is low to medium and biologically they have active populations of soil organisms and respond well to P and S fertilisers..

Pallic soils occur in seasonally dry eastern parts of the North and South Islands and in the Manawatu. Their main parent material is loess-a wind blown silt sized yellow material. Physically the soils have slow permeability because of a natural pan at a depth which limits the rooting zone of pasture plants. They are very susceptible to erosion if vegetation is disturbed. Phosphorus fertiliser requirements are moderate but good responses to S and Mo (molybdenum) are gained but biological activity is low. Se is required by animals in some areas.

Recent soils occur throughout NZ on young land surfaces such as alluvial plains, unstable steep slopes and slopes mantled by young volcanic ash. Most soils are less than 1000 years old. Physically they are spatially variable and tend to be stratified with contrasting textural materials. Chemically they are fertile as minerals are relatively unweathered.

Within each of these broad soil orders a further three hierarchical subdivisions exist. A general soil map of New Zealand is of little use when it comes to determining specific soils on a farm but it does give some idea of the main soils to be expected in a geographic region. At farm scale, several different soils are common. This variable soil pattern will obviously lead to differences in pasture growth and utilisation within the farm.

### *Changes In Soil Properties Over Time*

Many people consider that soils are static entities but that is incorrect. One has only to look at what happened after the Ruapehu eruptions in 1995 and 1996 to realise that these events impinged on soils and in some areas close to the mountain new soils developed on fresh ash but more significantly the spread of ash altered the chemical fertility in many areas where ash falls were greater than 2cm (Cronin et al 1997). Sulphur was a major input but in some areas significant amounts of Se were added to the soil resource.

Other changes are more subtle but important and it is often not realised that as a pasture system develops over time changes are taking place within the soil. Some changes of significance in New Zealand pastoral soils are in organic matter composition, acidification and heavy metal accumulation.

With respect to organic matter, the results from an early study (Walker et al 1959) tracing the effects of pasture development on a Pumice soil are used. Superphosphate was applied annually over a 25 year period. Important things to note in Table 1 are

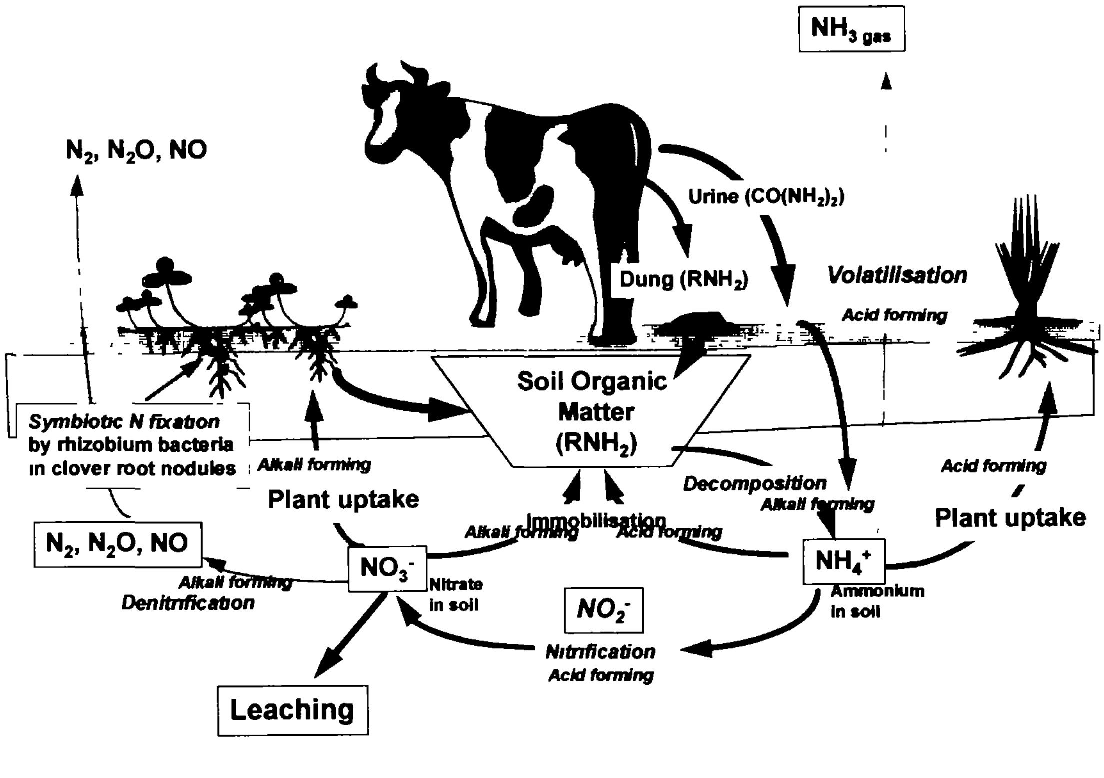
- Nitrogen (N) has accumulated and this would be mainly as organic N, but there has been little accumulation of carbon (C) which comprises 50% of organic matter. This means that there has been a large change in the type of organic matter from one of a wide C:N ratio to a narrow C:N ratio. This low ratio would indicate an active release of N in the soil system.
- Phosphorus (P), like N, shows that a large increase has occurred but mainly in the upper soil layer which one would expect as P is relatively immobile in soils. The increase occurs in both organic and inorganic P, but more so in inorganic P (the difference between total P and organic P). Under our current environmental constraints this accumulation of P near the soil surface has a downside (Gregg et al. 1994). If soil erosion occurs on developed pastures it is likely that P will be transported into waterways with implications for water quality.

**Table 1:** **Increases in C, N, S and P in improved grassland soils following 25 years of annual superphosphate application.**

| Soils | Depth (cm) | Air-dry soil (kg ha-1) | Carbon (kg ha-1) | Nitrogen (kg ha-1) | Sulphur (kg ha-1) | Organic P (kg ha-1) | Total P (kg ha-1) |
|---|---|---|---|---|---|---|---|
| Virgin | 0-10 | 428 000 | 43 000 | 1 320 | 157 | 179 | 202 |
| | 10-20 | 419 000 | 16 000 | 717 | 134 | 134 | 157 |
| | TOTAL | 847 000 | 60 000 | 2 038 | 291 | 313 | 358 |
| 25 yrs | 0-10 | 631 000 | 40 000 | 3 718 | 448 | 370 | 650 |
| | 10-20 | 606 000 | 23 000 | 1 277 | 235 | 157 | 224 |
| | TOTAL | 1 236 000 | 63 000 | 4 995 | 683 | 526 | 874 |
| Increase in 25 yrs | (0-20) | | 3 100 | 2 957 | 392 | 213 | 515 |
| Average Annual Increase | | | 124 | 118 | 16 | 9 | 21 |

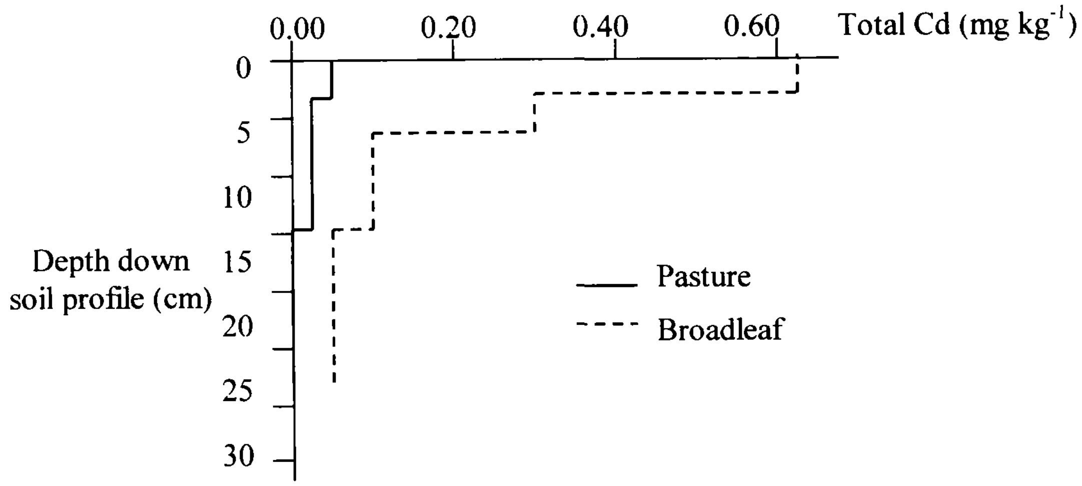
The oxidation and reduction of carbon and other elements during plant and microbial driven transformations in their respective cycles can generate either protons or consume protons causing water to form hydroxl ions. The pathways of acidification and alkalisation are shown in Figure 2 for N. In closed nutrient cycles, no net acidity occurs. However, it is more common to have open systems under farming and acidification occurs if the form of an element leaving a soil/plant/animal system is more negatively charged than the form of the nutrient entering. Thus where leaching is common and nitrate is leached (Figure 2) then acidification occurs and in general, pasture systems acidify soils. This trend can of course be corrected with lime applications, but in hill country situations little lime can be economically applied and net acidification will continue. However, the rate of decrease in pH of NZ soils seems less than that in other countries such as Australia where some pastoral systems are now so acidic that legumes cannot thrive and the traditional legume/grass pastoral systems are no longer sustainable.

***Figure 2:*** *Acid generation and consumption in a grazed pasture nitrogen cycle*



Most of the changes that occur in pasture development in NZ are considered beneficial but in recent years some concern has been expressed that the levels of Cd (cadmium) in animal offal (kidneys, livers) exported from New Zealand is of significance. There is no doubt that cadmium levels in our soils have increased since pastoral development. A recent PhD study by J. Zanders at Massey University measured the accumulation of Cd in a range of soils. Figure 3 demonstrates the extent of accumulation in a Brown soil from the Waikato area. An area in native bush was compared with a pasture fertilised with superphosphate for about 65 years. In the absence of any other obvious source of Cd, the accumulation reflects the input from fertiliser where it is well known that cadmium is a constituent of the rock phosphate used to manufacture superphosphate. These Cd levels in the soil are not alarming but if Cd continues to be added to soils accumulation seems inevitable and from a trading viewpoint this would seem undesirable.

***Figure 3:*** *Brown soils (taken from J Zanders Ph D Thesis, Massey University)*




## Impact of animals on soils

Animals have several impacts on soils. Two impacts of importance are in relation to soil erosion and nutrient cycling.

### *Soil Erosion*

Many factors influence the extent and type of soil erosion. The relative role of domestic and wild animals as initiators of erosion in NZ is somewhat controversial but it is generally agreed that rabbits and possums through their grazing habits are far from blameless. The role of deer in causing soil erosion is not so clear cut. Early reports of deer damage in some NZ forests linked them to soil erosion and presumably created the situation for identifying them as noxious animals.

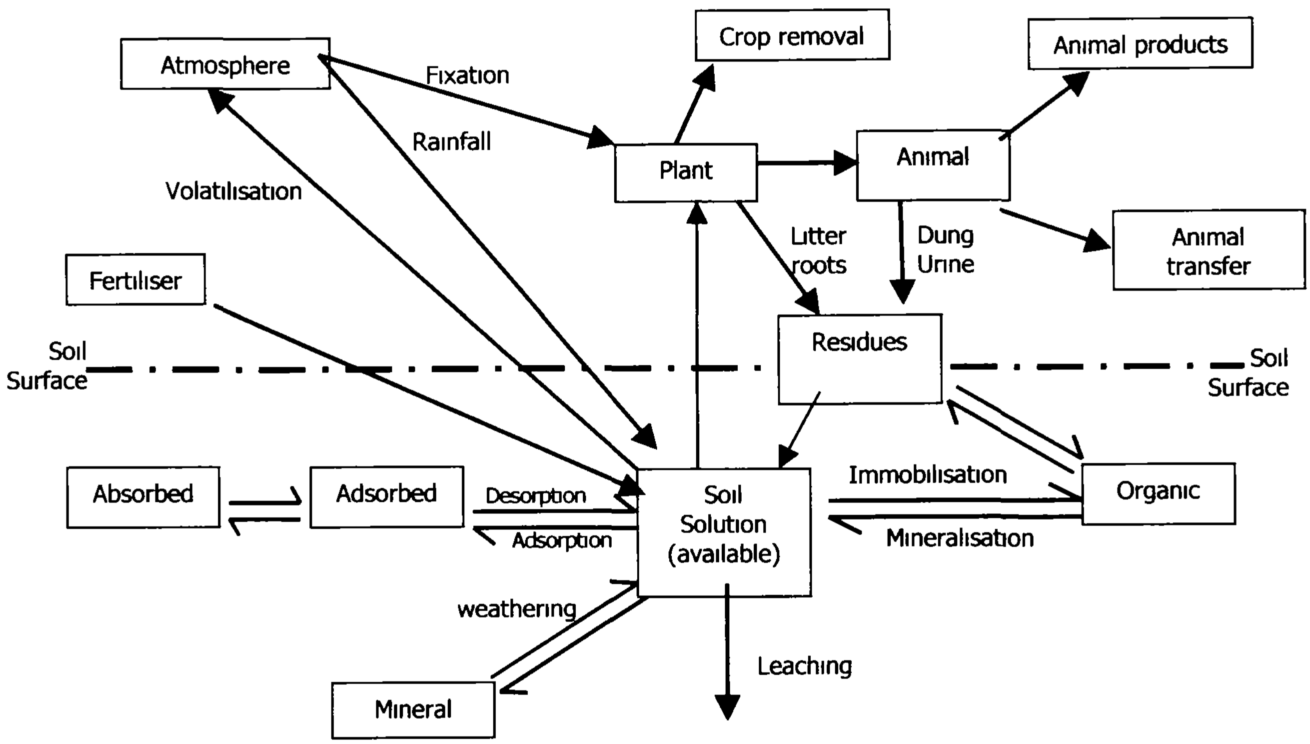
Domestication of deer carried with them the suspicion that, compared to sheep and beef, they were more likely to create erosion on farmland. The evidence to confirm this suspicion is lacking but there is no doubt that on some farms deer are involved in initiating erosion through their habits of fence pacing, communal camping and wallowing, all of which predispose to the baring of vegetative cover and allowing water and wind erosion to develop. Whether sheep and beef farms on similar landforms and soils have similar amounts of erosion is not proven. It seems that rather than prove whether deer are any worse than sheep and beef in initiating and creating erosion, it would be more productive to determine how to reduce these effects through management and control measures.

The effects of erosion on the productivity of farming systems is difficult to evaluate in monetary terms but it needs to be appreciated that a soil takes a long time to form and in terms of our time scale it is considered as a non-renewable resource. Therefore control of erosion on any type of farm is of importance

### *Nutrient Cycling*

In a pasture system, grazing animals further impact on the soil through their important role in the cycling of nutrients. The effects of deer should not differ from that of sheep and beef. In Figure 4, the main pathways of nutrient cycling are shown. The soil resource obviously plays a major role in controlling this movement through the retention, storage and release of nutrients both from inorganic sources and organic sources. The animal is important in recycling nutrients but because of the nature and pattern of excreta return, the soil experiences uneven concentrations and large spatial variations in soil nutrient status occur. Additionally through urine return the animal creates losses from the soil resource via leaching. This loss is particularly important for nitrate and sulphate, two important nutrients for plant and animal growth. You will note also that the animal creates a net loss of nutrients from the grazing area. This means that the longer the period that intensive grazing continues on a soil then the likelihood of an increasing number of nutrient deficiencies increases if the fertiliser policy is not replacing these losses. A good example of this is Mg (magnesium). Many soils, especially those from volcanic material, have low inherent levels of Mg and yet losses are not being replaced. Inevitably, Mg deficiency will result in the pastures growing on these soils.

***Figure 4:*** *Generalised nutrient cycling for a farm ecosystem*



For the major nutrients, knowledge of the extent of losses is comprehensive on dairy farms but less precise for sheep and beef farms. On hill country farms the opportunity for stock to camp on hill tops and other flat areas creates transfer of nutrients from the main grazing areas. Transfer losses per hectare on well stocked hill farms are much greater than on dairy farms (Williams and Haynes 1991).

## Misconceptions

Over the years one hears and reads many strange things about soils and their properties. For instance take the term "fertile" soils. It is often thought that for a soil to be fertile then the nutrient status must be high. That is only part of the story. In simple terms, a soils' fertility is a function of its chemical, biological and physical fertility and if all are not optimal soil fertility will not be high. It is of little use having a soil with a high P and K status if the drainage status is poor. Consider soils as a growing medium rather than a nutrient bank.

Many of New Zealand's soils have formed under low rainfall conditions, less than 600 mm, but this does not imply that they are free draining. as some people assume. The drainage properties of a soil are controlled by many other factors. Often soils under low rainfall are subject to rising water tables and these could hardly be described as free draining.

Some people say that only the topsoil is of importance in pastoral systems. A soil consists of a topsoil and subsoil and both need to be considered when evaluating the soil as growing medium. The properties of the subsoil exert a controlling influence on the ability of the soil to grow plants. The water holding ability of a soil depends on three things - the amount of organic matter, the soil textures of both the topsoil and subsoil and the depth of plant roots. The subsoil is very influential in influencing root depth and may have a texture that holds substantial amounts of water for pasture use.

A frequent problem experienced with some people is their concept and interpretation of soil maps. It is often considered that the mapped areas of different soils are all uniform. That is most unlikely even if one is using a detailed map (1:15000) which would identify specific soils on a farm. All a map can provide is a guide to the likely soil pattern and their accuracy is like any other type of map - very dependent on the scale. One should always inspect a site of interest by digging holes and relating observations to the expected modal description of the soils on the map.

Under farm practice, drainage of a poor draining soil will not automatically convert it to a free draining soil. Drainage methods used to remove surplus water from a soil are designed to remove water at a certain rate. The more intensive the drainage design the faster the rate of removal. In conventional tile and mole systems, the design aims to discharge about 25 mm in 24 hours. Obviously if more rain than this is received the soil will remain quite wet for a long period. If drainage pathways to moles are impeded by pugging then it will take a lot longer to drain surplus water from the soil.

## Sources of information

With all the changes that have been going on in the science sector it is now no longer easy to readily access soil maps. Additionally, any further mapping will now be done by private enterprise. Fortunately most of NZ has been mapped at a broad scale(1:63,000), but this scale is not accurate enough to delineate soils on most individual farms and further differentiation would be required.

Soil maps can be viewed or accessed at Landcare Research offices, some Regional Councils and Universities (Massey, Lincoln, Waikato).

Books defining soils and properties for New Zealand conditions are-Molloy (1998), McLaren and Cameron (1997), Cornforth (1998)

Extramural Soil Science courses are also available at Massey University.

## Conclusion

The soil resource of a farming system is the most important physical asset. The only way to start learning or refreshing yourselves about soils on pastoral land is to dig a few holes and observe the main features such as topsoil depth, texture, drainage status, stoniness, rooting depth and the presence of any compacted layers. Reflect on what these characteristics collectively infer in terms of producing pasture over the year and how the grazing animals will be able to utilize the pasture grown.

### References

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