Soil - the "battery" of your business

By DAVID HANLON

The basis of our farm business is the soil and increasingly all growers are focusing their attention on this vital resource. Just what state it is in and how we go about checking that requires a better understanding of soil science. At university, soil science was one of the most boring topics I had, and this was mostly due to the lecturer we had. He simply did not have the knack of putting any life into his subject and we, young and energetic, could not be bothered to put up with his style. He never got the number of high distinctions that many of our other lecturers could…and it had nothing to do with the degree of difficulty of the course. Looking back on those days, there is a strange parable – a subject that now interests me so much was much denigrated by not having the right people in charge. Unfortunately, in agriculture to-date, we have had an attitude of not being bothered to really understand our soils, relying on others to give us a "fix" for what we believe will produce the best crops.

But things are changing rapidly I am pleased to say.

And this was brought home to me recently while I was conducting our Bio-BusinessFarming™ School. At the end of each day, I ask each person what is the most important thing for them. For the day on soils and crop nutrition, it was overwhelmingly "the battery". The majority of attendees said that the concept of soil as a battery helped greatly in their understanding of what was happening.   Now, these people came from a range of farming backgrounds and quite a number had, like me, studied agriculture at university, yet had not had the relationships occurring within their soils explained so clearly.

Dr Phil Wheeler introduced me to the analogy and, like most analogies, what it does, is take the principles and put them in simple terms that we can understand.

Before we start

The first thing we need to understand, is that a battery is providing **energy** (or power) to our car. Without the battery, we have to crank or jump start our car. Just how well our car is running, determines how well maintained our battery is. For example, if the alternator fails, we end up with a flat battery. If we have a leaky circuit, then we come back after letting a car sit for a week and the battery is dead flat. A very good (and expensive!) car I had a few years ago, used to "eat" batteries. Leave it a week, and it would be dead. No auto-electrician ever found the problem and no battery in that car ever lasted more than two years.

So lets build a battery

Starting with the basics, a battery consists of two terminals, the positive and the negative, a series of plates, some water and acid.   Using our analogy, we say the negative terminal represents the **clay** plates whilst the positive terminal represents the **humus.** This is also our ground or **earth**. Humus comprises the dead and dead organic matter particles in our soils. The acid (or more correctly, the **electrolyte**) in the case of our soil, can be a range of things, from the urea or nitrate (NO_3) we apply through to other salts we have allowed to build up over time.

Also floating around in the soil solution are a range of **cations** and **anions**. These are the elements (or compounds of the elements) that are necessary to feed our crop. Cations are simply the positive charged elements whilst the anions are the negatively charge elements (see Table 1). The anions are more easily remembered by thinking of them as the "ates": nitrates, sulphates, etc.

Just as a magnet will attract nails and other metal objects, so do the plates within our "battery" attract charges. The higher the charge the tightly held are the charges to these plates.

Table 1:Examples of common cations and anions

Cations (positively charged)			Anions (negatively charged)		
Element	**Symbol**	**Charge**	**Element**	**Symbol**	**Charge**
Calcium	Ca	2	Nitrogen (nitrate form)	NO_3	1
Magnesium	Mg	2	Phosphorous (phosphate form)	P_2O_5	3
Sodium	Na	1	Sulphur (sulphate form)	SO_4	2
Hydrogen	H	1	Chlorine	Cl	1
Manganese	Mn	2			

Mineral balancing

The key to successful plant energy management is a foundation of mineral balance, with not only adequate nutrient levels but also the desired ***proportions*** of calcium, magnesium, potassium, etc. The volumes of research conducted by soil scientist Dr William Albrecht in the 1950s have provided the principles upon which the practices of modern biological farming are founded.

In order to evaluate and manage soil mineral fertility, we need to measure it and have comparative values. There are a number of measures we use and these include: Cation Exchange Capacity, base saturation percentage, pH and ratios of minerals to each other.

What size battery?

Just as a small car has a very small battery and a D8 bulldozer has a very big battery, so the size of our soil battery varies. The "size" of a soil battery is given by the **Cation Exchange Capacity (CEC)**. This measure is found on virtually all soil tests but what is it exactly?

The CEC provides a measure of the soils capacity to hold nutrients, or if you like the rating/voltage of the battery, and is governed by the amount of clay and humus within your soil. The greater the CEC the greater the soils buffer, or resistance to change.

CEC is conventionally regarded as the sum of the exchangeable cations: calcium, magnesium, potassium and sodium being some of the more common ones that can be absorbed or held on the surface of the clay particles in the soil. It is measured in milli-equivalents per 100g (meq/100g). In other words, the measure is an **energy** rating of your soil. The CEC is a function of the amount of clay, the type of clay and the percentage of organic matter that is in the soil.

Some common soil ranges are shown in Table 2 although it should be noted that different soil labs will give variations on these ranges.

Table 2:Cation exchange capacity of typical soils

Soil type	CEC range
Sand	<5
Sandy loam	5-10
Clay loam	10-20
Clay	20-30
Heavy clay	>30

Electrolytes – essential for conductivity

Your battery cannot operate with water alone: it needs something else in the solution that will conduct the current which is acid. In the soil, we need the same, an electrolyte for effective conductivity of the nutrients in solution to the plant. Salts are conductors (most fertilisers are salts) as well as salinity. We need the right proportions of salts. If we have too little, we get a **brownout** whilst if there is too higher salt content, we get **burnout**.

Base saturation – the shape of your battery

The concentration of cations within a soil means very little unless it is used in relation to the capacity of the soil to hold them. For example a soil samples showing a there are 1,000 ppm (5 meq/100g) of calcium may be excessive in a sand whilst extremely low in a heavy clay soil.

Base saturation then is the amount of cations that can be held within a particular soil and is expressed as a percentage of the total cation exchange capacity of that soil. In Table 3 we have a heavy soil (CEC = 37.17). From this the individual proportions of these cations have been calculated from their extraction values in the soil test. Since each clay particle only has so much space to hold elements there is competition for the spaces. If there is a lot of sodium in the soils (a sodic duplex soil for example) then these sodium ions will compete with the other cations for a position resulting in less of the more desirable ions being available in the soil since they have probably been leached out.

Table 3: Base saturation calculation

Cation	Symbol	Unit	Value	Base saturation %
Calcium	Ca^{++}	$cmol^+/Kg$	24.93	67%
Magnesium	Mg^{++}	$cmol^+/Kg$	8.76	24%
Potassium	K^+	$cmol^+/Kg$	1.34	4%
Sodium	Na^+	$cmol^+/Kg$	2.14	6%
Hydrogen	H^+	$cmol^+/Kg$	0.00	0%
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Cation Exchange Capacity		$cmol^+/Kg$	37.17	

Note: 1 cmol+/Kg = 1 meq/100g

Irrespective of how many ppm or kg/ha of a cation there may be in the soil, the **proportion** of cations to each other is critical to soil properties of structure, drainage, permeability, biological make-up and nutrient exchange with plants.

Base saturation values are ineffective if, in acid soils, the proportion of non-nutrient Hydrogen is excluded from the calculations since this gives an inflated proportion of a smaller potential volume.

A low **calcium to magnesium ratio** is often referred to as a cause of drainage and structure problems, this actually refers to the ratio of calcium base saturation to magnesium base saturation in the soil, where a *minimum* 3:1 is desire and up to 6:1 preferred in most soils.

For *optimal* soil structure, pH, humus formation and nutrient flow into plants there is a desired mix of cation proportions, ie base saturation levels.

Table 4: Desired base saturation levels

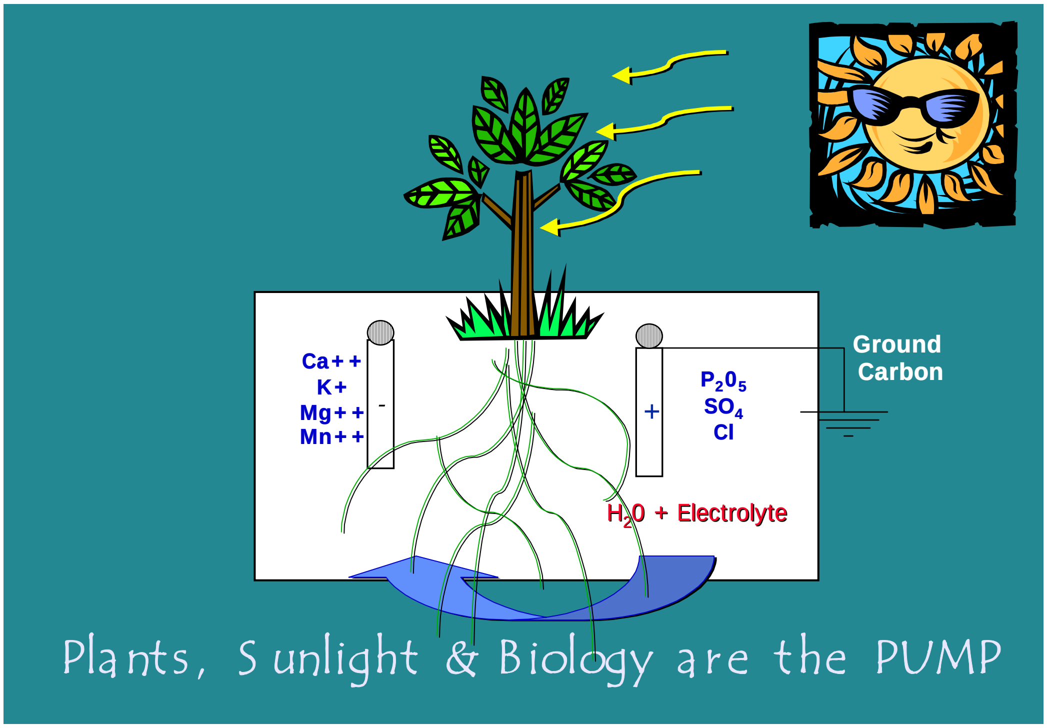
Calcium	60-70%	Greater end of the range desired in heavier soils to provide flocculation
Magnesium	12-18%	Greater levels desired in lighter soils
Potassium	3-7%	Higher end desired for tree/vine crops
Sodium	1-5%	Dispersion (sodicity) is a function of sodium percentage and electrical conductivity (salt) of soil solution
Aluminum	1-3%	Non-nutrient. High levels cause toxicity effects to roots
Hydrogen	10-15%	Low levels of acidity aid in mineral cycling and nutrient availability

What is keeping the battery charged?

Just as our car has an alternator to keep the battery charged, we need to see what the alternator is within our soils. Think for a moment. What happens to the soil when it is put in an oven and dried out? It becomes lifeless (or flat, to continue our battery analogy). To get this soil going again (that is, to have a crop successfully grow) we need to jump start it. And we do this with our electrolyte; and in most cases, this is with a good dose of nitrogen in some form.

So, the alternator in the soil is the combination of plants, sunlight and biology keep the system charged.

Figure 1: The complete system



More ratio analysis

Finally there are a number of other ratio's that explain why soil test results don't necessarily seem to match plant performance. The ratio's and their values are illustrated in Figure 2

Figure 2: Key nutrient ratio's

- Calcium : Magnesium %
  - 3:1 in light sandy soils
  - 5:1 in heavier textured loam/clays
- Available Phosphorous : Zinc
  - Approx 10:1 (ppm)
- Magnesium : Potassium
  - Equal ppm of each
  - Mg% > K% base saturation
- Potassium : Sodium
  - K% > Na% always desirable
- Iron : Manganese
  - Greater than 1:1
- Phosphate : Potassium (ppm)
  - Greater than 0.5:1

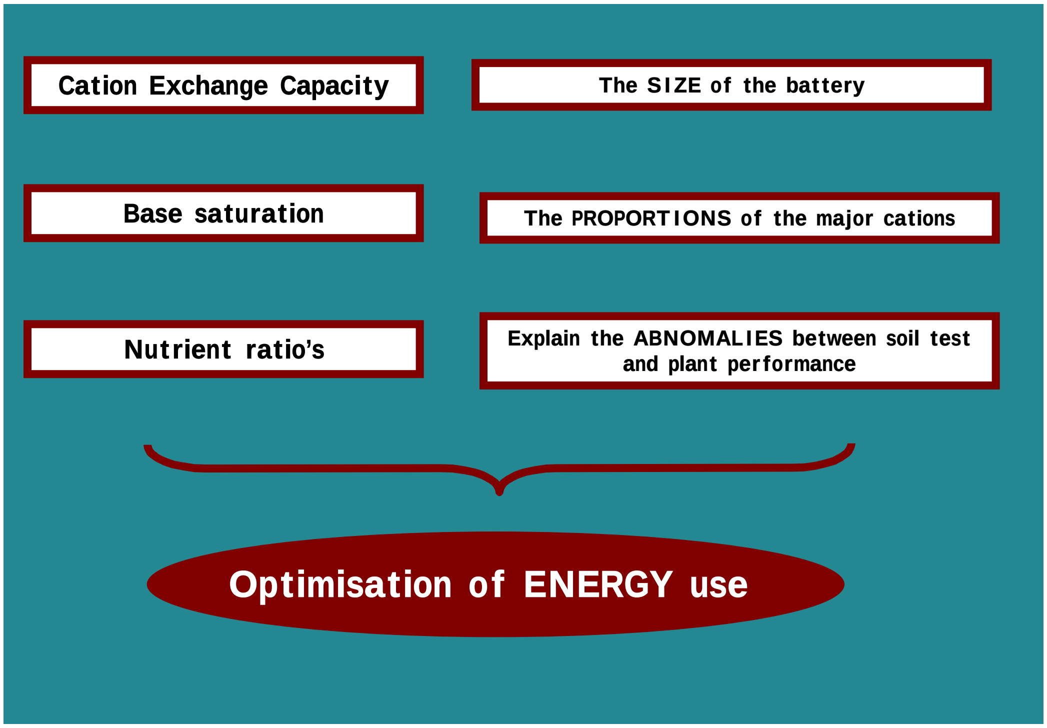
Nutrient availability

In summary nutrient availability is a function of a number of things. It is more than just the total NPK content as shown on a soil test. It is a function of:

1) soil pH
2) soil biological activity and composition
3) soil moisture
4) time of the season
5) overall nutrient balance

By checking for all parts, you are likely to improve the uptake of nutrients by a crop through less **energy** wastage within the system. The key steps are outlined in Figure 3.

Figure 3: Key three steps to energy optimisation



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