MODULE 3

Case study 3

Assessing fertility of four non-improved pasture soils in the Riverina

Resilient Soils

Building Resilient Soils for the Riverina

The chemical, physical and biological properties of diverse soil types located across NSW vary considerably, as does their productivity for crops, pastures, and rangelands. Here, we assess the fertility of four distinct soil types supporting non-improved pastures, based on soil test results.

Soil sampling

Soils were previously identified as a) red chromosol, b) red kandosol, c) grey vertosol, and d) brown rudosol according to the Australian Soil Classification. Soils were collected from field sites that supported unimproved pasture growth or fallow. Chromosol and kandosol soils were collected from pastures at Charles Sturt University (CSU) Wagga campus (35°02'00.5"S 147°21'40.6"E), while rudosol soil was collected in Marrar NSW from a pasture located near a riverbank and vertosol soil was collected from an irrigated cropping area located in Leeton NSW.

Approximately 1kg of each soil type was processed after collection from 0 to 10 cm depth by composite sampling of 20 samples from each site. Samples were oven dried at 40°C for 48hr and sieved through a 2mm soil sieve. For soil testing, three replicates of 100g of each composite sample were sent to a NATA accredited Environmental Analysis Laboratory in NSW for testing. The results are shown in the following table.

Parameter	Chromosol	Kandosol	Rudosol	Vertosol	Expected values for clay-loam soils	Critical values for pastures on clay-loam soils
Nitrate Nitrogen (mg/kg)	4.35	2.26	0.49	12.74	13	110-50
Ammonium Nitrogen (mg/kg)	6.64	7.45	5.80	12.05	18	10-50
Phosphorus (mg/kg)	7.22	12.79	11.26	87.03	50	39
Potassium (mg/kg)	199	405	127	508	190	161
Sulphur (mg/kg)	4.64	6.94	4.17	22.29	8.0	8
pH (water)	6.91	6.80	7.00	7.66	6.5	
pH (CaCl2)	6.10	6.10	6.10	7.00	N/A	
Electrical Conductivity (dS/m)	0.04	0.04	0.03	0.11	0.15	<0.15
Estimated Organic Matter (%)	1.33	1.40	0.62	1.61	>4.5	
Exchangeable Calcium (cmol+/kg)	2.6	4.3	2.07	19.49	10.8	
Exchangeable Magnesium (cmol+/kg)	0.53	1.49	0.49	8.42		
Exchangeable Potassium (cmol+/kg)	0.51	1.04	0.32	1.30	1.7	
Exchangeable Sodium (cmol+/kg)	0.08	0.08	0.08	0.24	0.50	
Exchangeable Aluminium (cmol+/kg)	<0.01	<0.01	<0.01	<0.01	0.26	
Exchangeable Hydrogen (cmol+/kg)	<0.01	<0.01	<0.01	<0.01	0.5	
Effective Cation Exchange Capacity (ECEC) (cmol+/kg)	3.71	6.87	2.97	29.46	0.5	5-25
Calcium (%)	70.31	62.13	69.61	66.16	14.3	60 – 75
Magnesium (%)	14.27	21.73	16.48	28.56	75.7	10-20
Calcium/Magnesium Ratio	4.9	2.9	4.2	2.3	11.9	
Potassium (%)	13.6	15.09	10.94	4.43	6.4	3-8
Sodium - ESP (%)	1.63	0.94	2.83	0.82	3.5	<1
Aluminium (%)	0.20	0.11	0.13	0.03	1.8	<1
Hydrogen (mg/kg)	<1	<1	<1	<1	7.1	5-10
Chloride estimate (equiv. mg/kg)	27.09	27.95	9.99	68.48	5	
Zinc (mg/kg)	0.60	0.65	<0.5	0.82	N/A	
Manganese (mg/kg)	37.22	27.27	24.17	11.02	5.0	
Iron (mg/kg)	29.47	38.05	14.57	39.67	22	
Copper (mg/kg)	0.45	1.01	0.31	2.00	22	
Boron (mg/kg)	0.51	0.82	0.33	1.22	2.0	
Silicon (mg/kg)	42.45	74.65	36.98	46.31	1.7	
Total Carbon (%)	0.76	0.80	0.35	0.92	45	
Total Nitrogen (%)	0.11	0.11	0.07	0.14	>2.6	
Carbon/Nitrogen Ratio	6.86	7.24	4.68	6.54	>0.25	
Basic Texture	clay loam	clay loam	clay loam	clay loam	10-12	

Recommendations to improve soil fertility based on interpretation of soil test results

Understanding of soil textural properties guides interpretation of associated soil parameters, and is important for identification of nutrient deficiencies, by comparing test results with suggested fertility levels for each soil group based on texture. Interestingly, following soil analysis, the texture of all four soils was reported by the laboratory as clay loam, and generally desirable for pasture production. However, it is important to note that the rudosol generally has a lighter texture with more sand, while this vertosol was heavier with more clay.

Plant available forms of nitrogen, i.e., nitrate and ammonium nitrogen, were highest in vertosol and lowest in rudosol. Chromosol, kandosol, and rudosol samples had nitrates and ammonium concentrations which were considerably lower than expected levels for reference clay-loam soil and critical levels for pastures. Therefore, adding nitrogen fertiliser and taking measures to reduce nitrate and ammonia leaching will be essential to gradually improve soil fertility. Mixed pastures with legumes inoculated with nitrogen-fixing rhizobia microbes will help to gradually build soil nitrogen reserves. High ammonium relative to nitrate, such as with the kandosol and rudosol soils here, can suggest reducing conditions in a soil, such as waterlogging.

Plant available phosphorous is measured as exchangeable phosphate values which are more accurate on slightly acid to alkaline soils. Vertosols showed nearly eight times more available phosphorus than the other three soils, which in turn were below the indicative value for a clay loam soil, and also well below the critical value for pastures. Therefore, phosphorus fertiliser application is essential to increase pasture production on kandosol, chromosol and rudosol. Soil available phosphorous is also limited by the amount of clay encountered in the soil. Vertosols having more clay contribute to a greater amount of plant available phosphorus.

Plant available potassium in chromosol, kandosol and vertosol are well above the expected level for clay-loam soils as well as the critical value for optimum pasture production. Sandier soils such as the rudosol have a lower potassium holding capacity than clayey soils such as kandosol and vertosol, and potassium may leach before the plants can use it. Therefore, applying potassium fertiliser is also essential to improve pastures growing on rudosols. Chromosol may benefit from potassium fertilizer application as well. A soil with higher clay content such as the vertosol could fix or provide more exchangeable potassium. However, this depends on the proportion of clay and organic colloids in the soil as well as pH. Magnesium and sodium can also affect the availability of potassium. Application of organic matter to rudosol and chromosol soils could also gradually increase the potassium holding capacity.

Soil sulphur measured as extractable sulphates accurately shows the soil sulphate supplying capacity as it considers sulphur that will become available from the breakdown of organic matter. This is particularly relevant for dairy pastures, which often have thick root mats and therefore a significant potential to supply sulphur via organic matter breakdown. Here, rudosol which has a relatively low amount of soil organic matter as well as chromosol and kandosol which have comparatively higher amount of soil organic matter, appear to contain considerably lower amounts of plant available sulphur than the critical level for pastures. Increasing the accumulation of soil organic matter through the incorporation of stubbles, pasture residues, animal manure or by reduced tillage would increase the organic sulphur pool in rudosols. Soil microorganisms are primarily responsible for the mineralisation of organic sulphur, thus, soil biological activity and environmental factors such as temperature and soil moisture that influence microbial population numbers and growth rates will determine the rate available sulphur to plants. Therefore, facilitating healthy soil microbial communities by maintaining good carbon: nitrogen ratio through composting and incorporating animal manure would be helpful for kandosol and chromosol soils.

The general desired pH level in soils is in the neutral range as estimated either in water or CaCl2 as pH (water) 6.0 - 8.5 or pH (CaCl2) 5.0 - 7.5. The pH values of all four soil samples fall in the desired range, so liming to correct acidic soil pH is not required.

Effective Cation Exchange Capacity (ECEC) results are related to the texture of the soil, and the fractions of clay and organic colloids. The desired range for pastures is 5-25 cmol/kg. Where ECEC is less than 5, such as in the case of rudosol and chromosol, soil fertility could be improved by incorporating organic matter. When there is a high amount of clay in soil, it holds more cations on clay colloids, as shown by higher ECEC value for clayey vertosol. Vertosol ECEC is ten times that of rudosol, which is sandier.

The exchangeable cation measurements as a percentage of ECEC assist in identification of nutrient imbalances caused by soil salinity, sodicity, and structural problems such as dispersion, and can also indicate potential animal health issues in pastures grown under nutrient imbalance, such as grass tetany. The desired proportion of magnesium is 10-20 % of ECEC, whereas desirable calcium is 60-75% of ECEC. Magnesium >20% may cause potassium or calcium deficiencies which are sometimes related to poorly structured surface soils. All four soil types in this study contain calcium levels within the desired limits, however kandosol and vertosol have higher magnesium levels than desired.

Well-structured soils have a calcium: magnesium ratio greater than 2. A ratio < 1 indicates a high clay content soil and possibly a clay sub-soil. The cation imbalance may be due to soil compaction and poor water infiltration in clay-like soils. The Ca/Mg ratio of the four soils in this study ranges between 2.3 to 5, indicating these soils might develop structural issues such as soil dispersion, hard setting on surface (crusting) and hard setting in profile (sub soil clay pan), which can hinder drainage, root growth of perennial pastures and contribute to soil erosion, particularly with the vertosol. The structure of a soil with a Ca/Mg ratio of 1–5 may benefit from additional calcium by liming.

The desired range of potassium in soil is 3-8 % of ECEC. Rudosol, chromosol and kandosol contain >10% potassium which may result in magnesium deficiency leading to dispersion, in combination with higher sodium levels. The value of potassium in relationship to magnesium plus calcium should be less than 0.07. A result of 0.07 or higher indicates a greater danger of grass tetany; a result less than 0.07 indicates minimal danger of grass tetany. A magnesium-to-potassium ratio of less than 1.5 indicates an increased chance of grass tetany, although many other factors influence the occurrence of grass tetany.

Electrical conductivity (EC) indicates soil salinity. An EC value greater than 0.15 dS/m for clay-loam soil may indicate a salinity issue. Generally, an EC (1:5) water extract <0.15 does not affect pasture growth. Estimated EC corrected for soil texture is a more accurate measurement of salinity. ECe for these clay loam soils, 0.15 × 8.6 = 1.2, can be considered as low salinity (<2 ECe).

The desired Exchangeable Sodium Percentage (ESP) is <1 of eCEC. Chromosol and rudosls show ESP levels higher than that. Rudosol also has an ESP is higher than the indicative ESP of 1.8 for clay-loam soils. When ESP is > 5%, it can result in salinity issues due to chloride presence. It is also speculated that chloride can compete with nitrate uptake in plants. In areas where rainfall is relatively high and internal soil drainage is good, it may leach from the soil profile, thus when interpreting chloride levels, one should consider soil texture. However, the estimated chloride levels of all four soils are well below the critical chloride levels for salinity in a clay loam soil that is >180 mg/kg.

Extractable aluminium closely follows the soil pH and becomes a problem when the pH (water) is less than 5.5. Where extractable aluminium is >2 as is the case with vertosol, sensitive pastures will be affected by aluminum toxicity.

Plant available micronutrients such as iron, manganese, copper, and zinc should be compared to indicative levels to assess whether levels are particularly low or high.

Zinc levels in all four soils appears to be well below the indicative levels. Manganese levels are well above except for the vertosol, and iron level are well above the indicative level except for rudosol. It should be noted that iron and manganese availability is significantly influenced by soil pH. Copper levels are lower than desired in all soils except for vertosol, while silicon is slightly lower in rudosol. Boron is also below the desired levels in all four soils. Leaf testing is ideal for confirming potential issues with micronutrient concentrations.

Organic matter amount in soil is an important indication of soil health and impacts the ECEC by providing organic colloids and promoting soil biodiversity.

The soils tested in this study have considerably less organic matter than the indicative value of 4.5% for a clay-loam soil.

Organic matter (%) = Total organic carbon (%) x 1.72

Soil type	Chromosol	Kandosol	Rudosol	Vertosol
TOC %	0.76	0.80	0.35	0.92
OM %	1.3	1.38	0.6	1.58

Desired TOC range is 2-5 % for pastures in moderate to high rainfall zones in the Riverina. Increasing TOC levels will result in increased soil CEC and nutrient holding capacity leading to increased production capacity. However, higher organic carbon levels are also observed under long term pasture or in waterlogged soils where TOC build up occurs due to reduced biological activity. Therefore, TOC should be viewed relative to total nitrogen.

Total nitrogen values indicate the total amount of nitrogen in the soil, much of which is tied up in organic matter and is not readily available to plants. The nitrogen in organic matter pools is mineralised to form nitrate and ammonia over the course of the growing season, thereby becoming available to plants. TON in the four soils in this study is 0.05 – 0.15, which is considered as low. However, all four have C/N ratio values below the indicative value for a typical clay-loam soil which is 10-12. The C/N ratio is an important indicator for soil microbial activity particularly for nitrogen fixing bacteria. A higher C/N ratio would indicate depletion in organic nitrogen which can be improved over time by adding organic matter from cattle and other livestock dung.

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