FEEDCHAR® DAIRY SOIL TEST RESULTS VS NON-FEEDCHAR® DAIRY SOIL TEST RESULTS

INDEPENDENT REPORT FOR AGSPAND PTY LTD, TASMANIA

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This report shows the differences in a range of soil parameters in a non-Feedchar® paddock/dairy farm with tests taken in 2015, compared with tests taken at another nearby dairy across a range of paddocks before Feedchar was fed to cows in 2019, then after Feedchar was fed in 2021.

FEEDCHAR® is a registered trademark and certified allowed input in Australia, made and sold by Agspand Pty Ltd. Feedchar® is a feed-grade hardwood charcoal-biochar and mineral clay combination that has a high stabilised carbon content (90%) and surface area (250 sqm/g).

Feedchar® is mixed with concentrates by a stockfeed company and fed at 50 mL per day to 200 dairy cows, with 12 tonnes of Feedchar fed over 2 years from 2019 to 2021.

The wet weight of the 200 dairy cows' manure is 4 tonnes a day (20 kg manure each daily). That is 2628 tonnes of bioactive dung spread across 90 hectares over 2 years.

With this spread-rate of bioactive dung there were great results in the soil, and we would expect this to pass on to plant tissue and animal health. Overall, the figures below show that the biochar did have a positive effect on all parameters measured. In paddock 16 some levels decreased and it would be interesting to understand paddock applications of fertilisers, or other applications, to better understand the biochemical processes.

The fertiliser application the last 12 months was mostly urea and one application of DAP at 10 kg/ ha plus some kelp and fish and felic acid/ humates, about 2000 L across the farm. It would be interesting to understand differences per paddocks.

Anecdotally the farmer who fed Feedchar with dairy cows has noticed he is irrigating less than his neighbours during drier months.

The figures below compare and discuss measurements of pH, soil-organic carbon (SOC), sulphur, phosphorus, electrical conductivity, chloride, nitrate nitrogen, ammonium nitrogen, potassium, cation exchange capacity, calcium, magnesium and sodium.

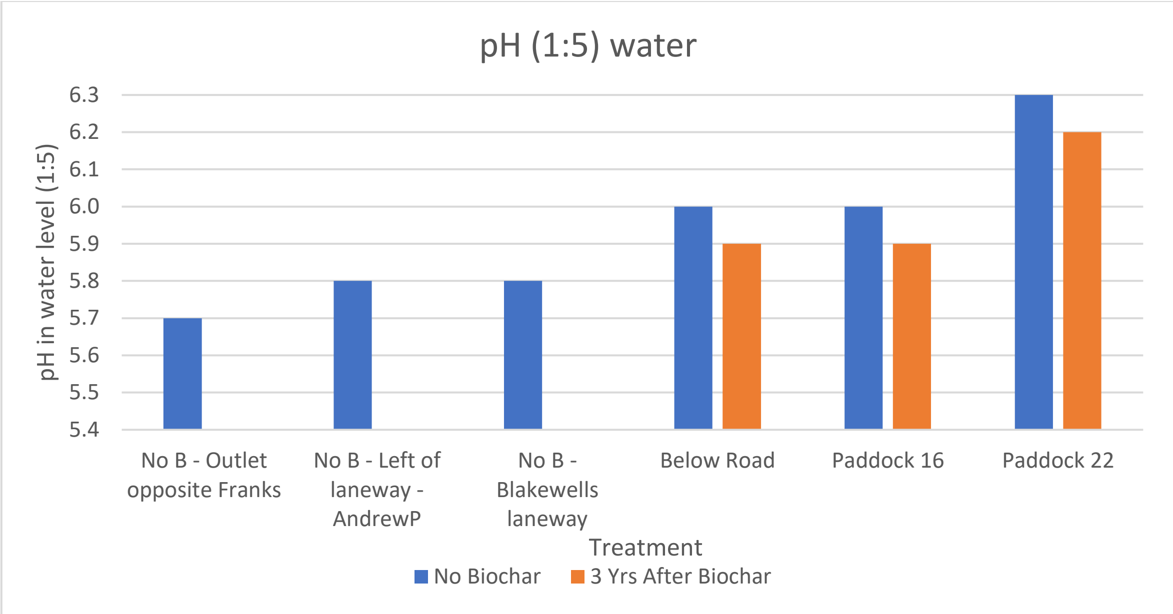

FIGURE 1: PH (1:5) WATER IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED, AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED.

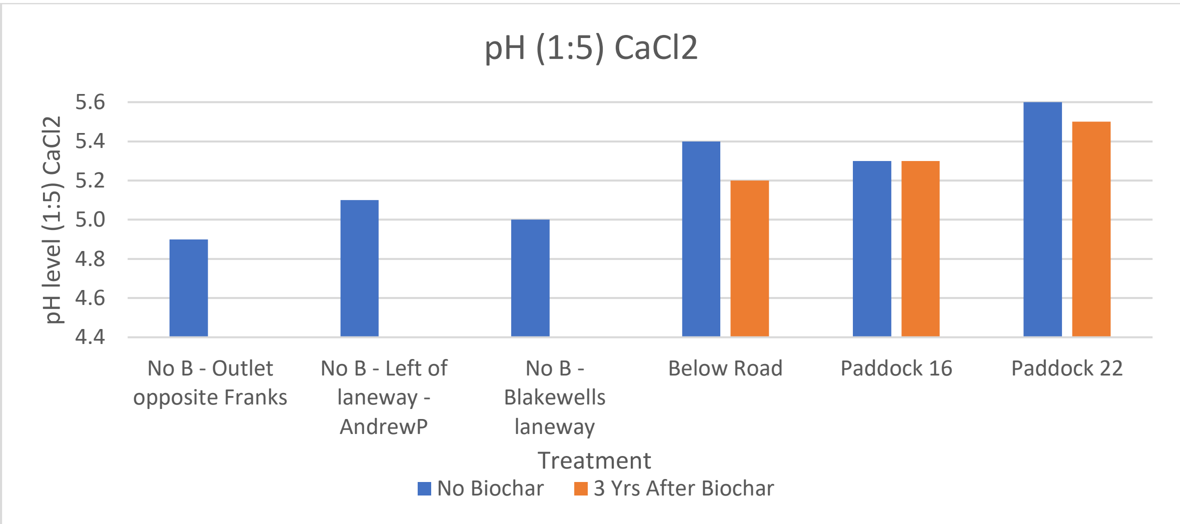

FIGURE 2: PH (1:5) CACL2 IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED, AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

The pH trends in water (fig 1) and CaCl2 (fig 2) are similar. The CaCl numbers more accurately reflects what the plant experiences in the soil. The pH in the nearby farm measured in 2015 was more acidic than the pH on the biochar farm. The pH measured in 2021 reduced compared with the pH measured in 2019 and was consistently lower measured in all 3 paddocks. By increasing pH, porosity, and water availability, biochar can create favourable conditions for root development and microbial functions.

Time of year or measurements may have played some role; however, consistency of the pH in water and in calcium across the 3 sites is encouraging.

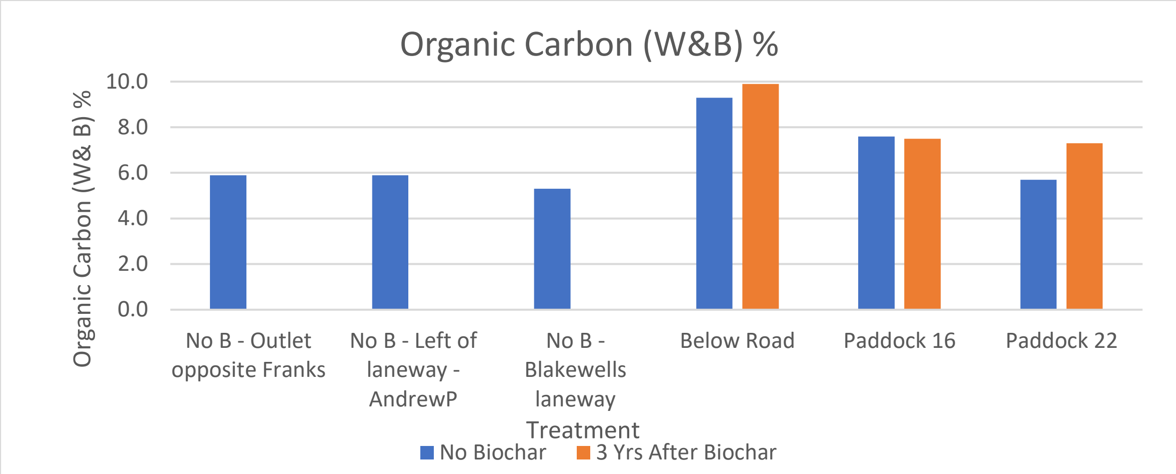

FIGURE 3: ORGANIC CARBON (W & B) % IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND, THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

The organic carbon measured in the nearby farm had a lower base than the farm with biochar. The organic carbon on 2 of the 3 paddocks with biochar increased by 0.6% on the below road paddock and 1.6% in paddock 22, while it decreased by a marginal amount 0.1% in paddock 16. There was a high carbon base on all paddocks, with impressively high levels on the biochar paddocks. Often it is asked how far we can push up the carbon when it is already high, but this shows that even on a paddock at 9.3% there is room to grow the carbon.

There is evidence to show that for every 1% increase soil carbon we increase water-holding capacity by 10 tonne/ha (minimum), pending soil type. This in turn will improve crop or pasture yield. Meta-analyses have shown increases in plant-available water content of 33%–45% in coarse-textured soils, and 9%–14% in clay soils (Edeh et al., 2020; Omondi et al., 2016; Razzaghi et al., 2020), with greatest response adding biochar at 30–70 Mg ha−1 (Joseph et al 2021).

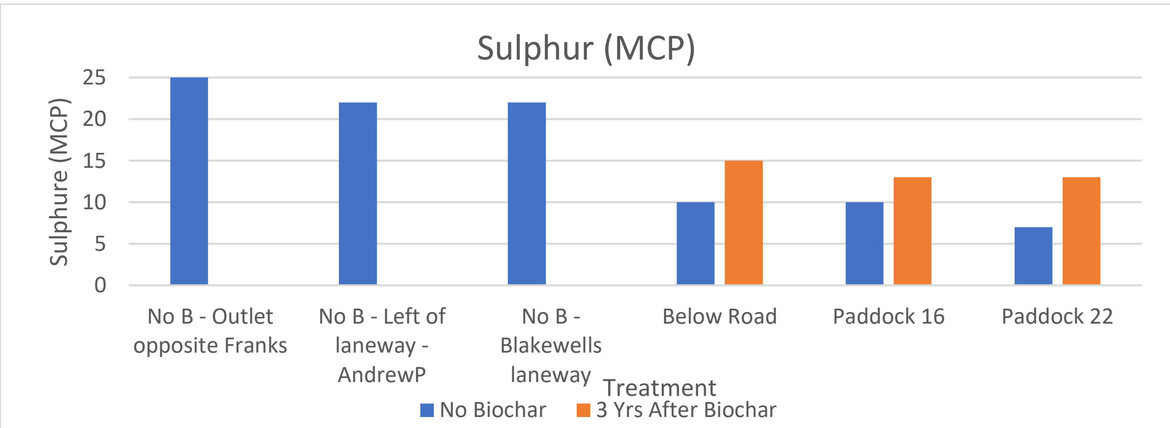

FIGURE 4: SULPHUR (MCP) IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Sulphur is an anion. In the soil solution, it is very leachable. Sulphur levels on a soil test indicate how much precipitation an area receives, or at least how much water is running through the soil profile. If sulphur is low, that means it is getting leached out. In those types of soils, most of the sulphur is supplied through organic matter. 90% of sulphur in soil is found in organic matter and, as biology mineralises the organic matter, it releases sulphur for plants. While plants take up about as much sulphur as phosphate, much more of it leaches every year than phosphorus. The results above show that the sulphur levels were higher on the nearby farm (not sure what optimum levels when measured by MCP are). The biochar farm's levels are encouraging and increased as a result of the biochar. The biochar may be preventing leaching of sulphur due to its porous nature. It is also an anion and would be positively attracted to the anions also in biochar, keeping it activated and available to the plant.

Sulphur and nitrogen are critical in amino acids and proteins in plants. They are partners in almost every protein in a plant. The fertiliser application the last 12 months was mostly urea and one application of DAP at 150 kg/ha plus kelp and fish and felic acid/humates, about 2000L across the farm.

Sulphur-to-nitrogen ratios have been found for many crops. Often when nitrogen is too high, it makes plants much more susceptible to sulphur deficiencies.

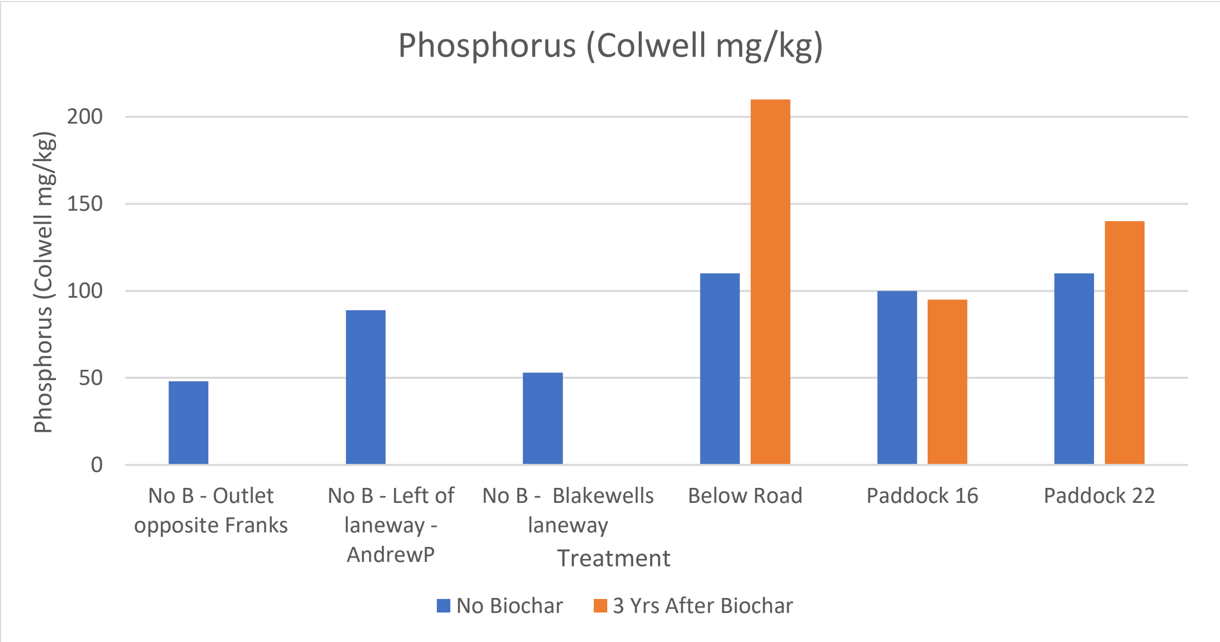

FIGURE 5: PHOSPHORUS (COLWELL) MG/KG IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

The phosphorous levels were above adequate (35–40 mg/kg) in all paddocks. The biochar appeared to have increased the P in the below road and paddock 22; however, in paddock 16 there was not much change in P levels, though P is adequate. Meta-analyses found that, on average, biochar increases P availability by a factor of 4.6 (Joseph et al 2021). No additional P would be needed on the biochar-applied soils at present.

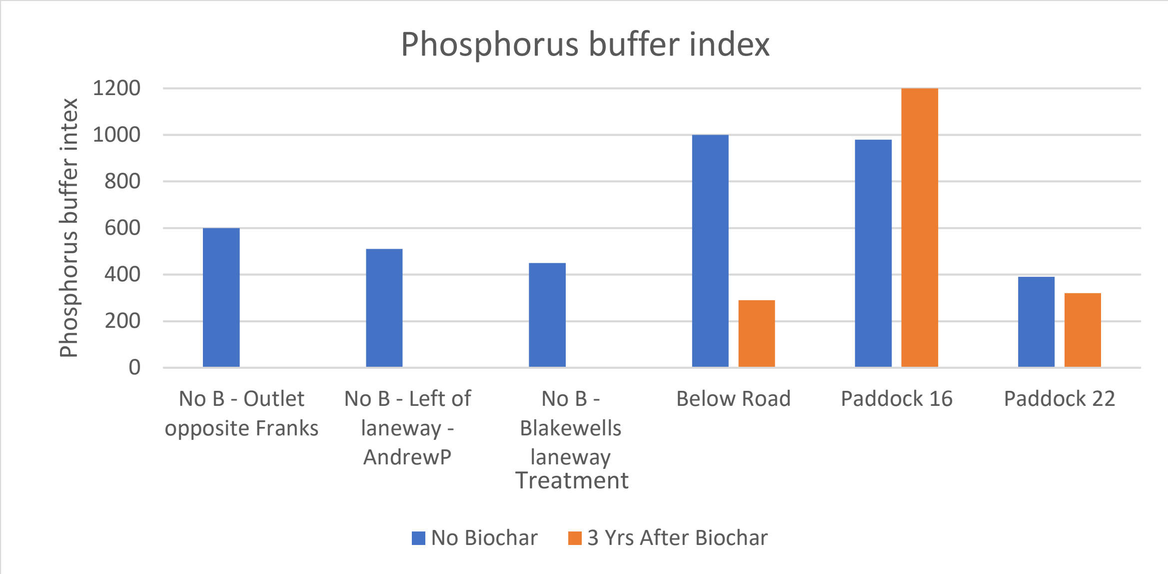

FIGURE 6: PHOSPHORUS BUFFER INDEX IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

When phosphorus is applied to soils as a fertiliser, it reacts with soil components and becomes less available for plant uptake. This reactivity between applied phosphorus and the soil is called "phosphorus buffering capacity" and is measured by the Phosphorus Buffering Index (PBI) soil test. Consequently, a soil with a high PBI value will require more phosphorus fertiliser than a soil with a low PBI. The PBI level decreased on 2 of the 3 biochar paddocks, but increased on paddock 16. This paddock likely needs the addition of P.

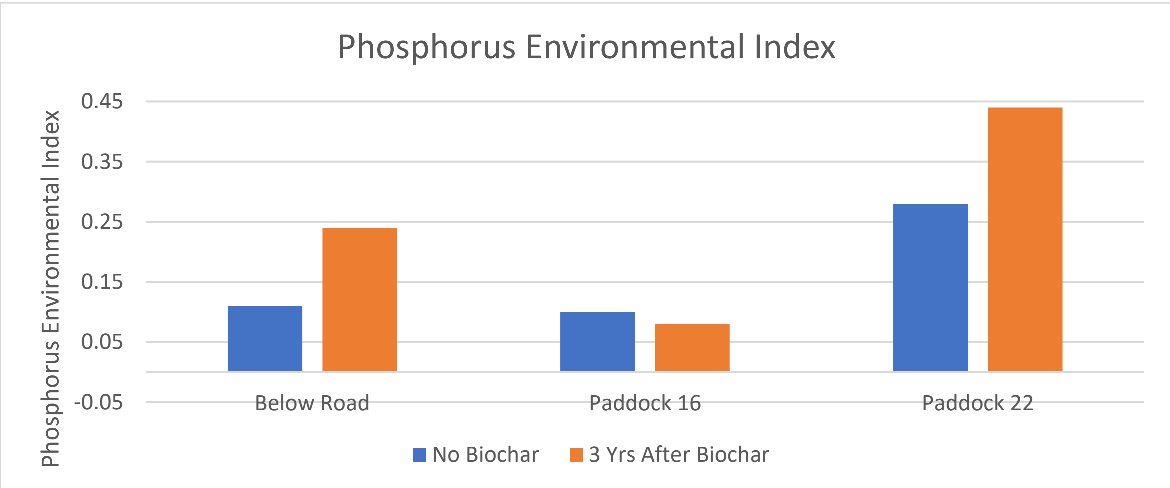

FIGURE 7: PHOSPHORUS ENVIRONMENTAL INDEX WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

The phosphorous environmental index or PEI is used to address the risk of surface-water environmental concerns resulting from phosphorus. In many cases, best management practices can be used to increase this index. PEI has been increased by adding biochar through feed on the below road and paddock 22. It has decreased slightly on paddock 16. Care will need to be taken on this paddock going forward.

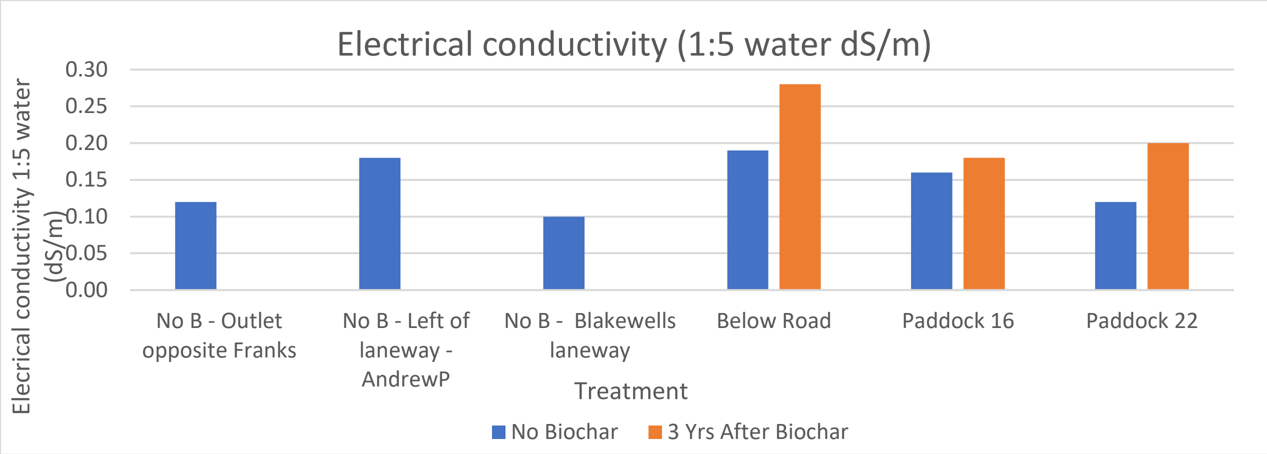

FIGURE 8: ELECTRICAL CONDUCTIVITY (1:5 WATER DS/M) IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Soil electrical conductivity (EC) measures the ability of soil water to carry electrical current. Electrical conductivity is an electrolytic process that takes place principally through water-filled pores. Cations (Ca2+, Mg2+, K+, Na+, and NH4+) and anions (SO4 2-, Cl-, NO3-, and HCO3-) from salts dissolved in soil-water carry electrical charges and conduct the electrical current. Consequently, the concentration of ions determines the EC of soils.

In agriculture, EC has been used principally as a measure of soil salinity (table 1). However, in non-saline soils, EC can be an estimate of other soil properties, such as soil moisture and soil depth. EC is expressed in Deci Siemens per metre (dS/m). Soil EC does not directly affect plant growth but has been used as an indirect indicator of the amount of nutrients available for plant uptake and salinity levels. EC has been used as a surrogate measure of salt concentration, organic matter, cation-exchange capacity, soil texture, soil thickness, nutrients (e.g. nitrate), water-holding capacity, and drainage conditions. In site-specific management and high-intensity soil surveys, EC is used to partition units of management, differentiate soil types, and predict soil fertility and crop yields. For example, farmers can use EC maps to apply different management strategies (e.g. N fertilisers) to sections of a field that have different types of soil. In some management units, high EC has been associated with high levels of nitrate and other selected soil nutrients (P, K, Ca, Mg, Mn, Zn, and Cu). Most microorganisms are sensitive to salt (high EC).

The blue bars in figure 8 above suggest the EC was at desirable levels and has increased in the orange bars. Rainfall can increase the EC. A question would be the timing of these tests. However, the EC is perhaps at more acceptable levels pending what is grown. Some studies suggest the higher EC will increase yield until it becomes too saline. The current or increased EC levels should better facilitate uptake of nutrients.

Table 1: EC and Soil Salinity (next page)

EC (dS/m)	Salinity Class
0 < 2	Non-saline
2 < 4	Very slightly saline
4 < 8	Slightly saline
8 < 16	Moderately saline
≥ 16	Strongly saline

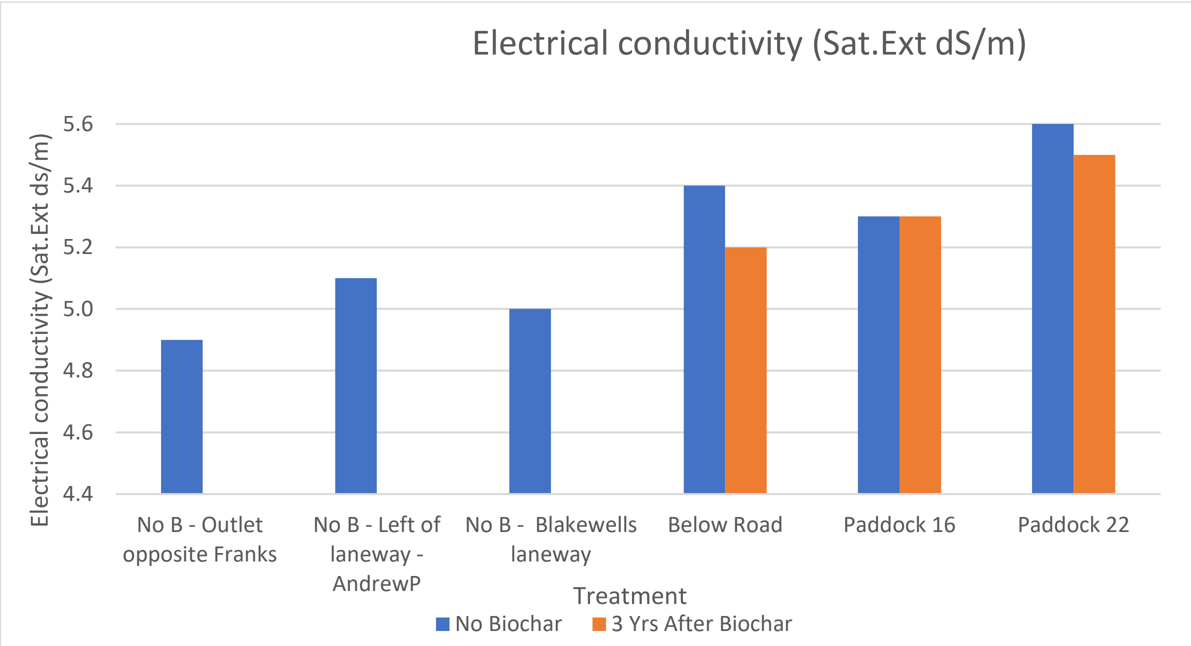

FIGURE 9: ELECTRICAL CONDUCTIVITY (SAT. EXT. DS/M) IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

The EC (sat. ext.) has decreased in paddocks with biochar.

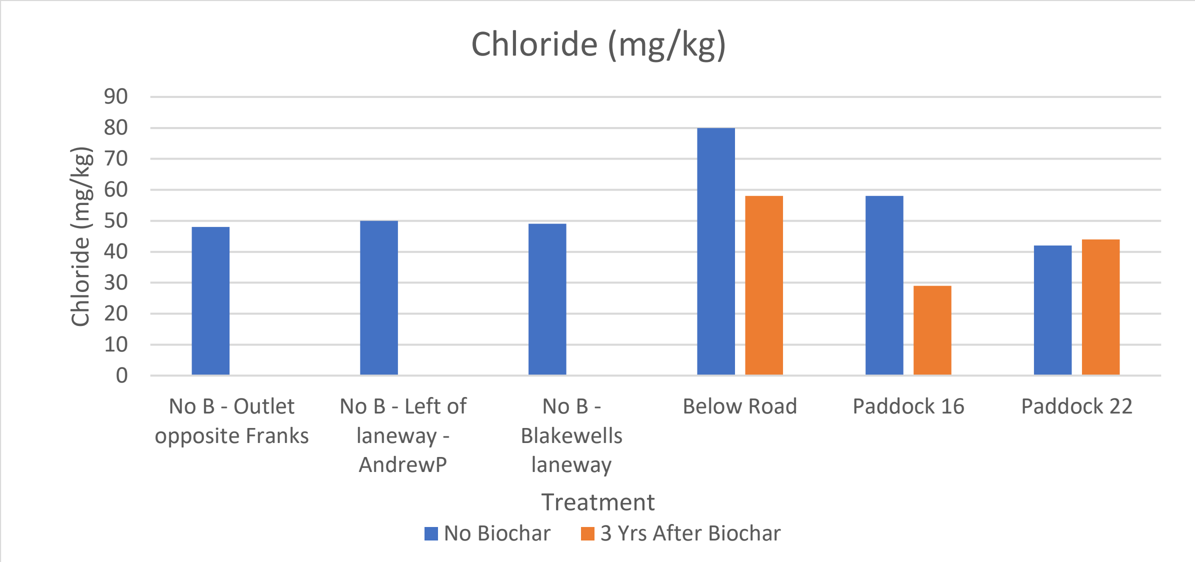

FIGURE 10: CHLORIDE MG/KG IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Chloride (Cl) in subsoils are major constraints to crop production in many soils of Australia because they reduce the ability of roots to extract water. The estimates of the critical levels of subsoil Cl for a 10% reduction in grain yield were above 400 mg/kg. All chloride levels are not toxic in the soil results above (figure 10), though it is encouraging they have reduced under biochar treatments.

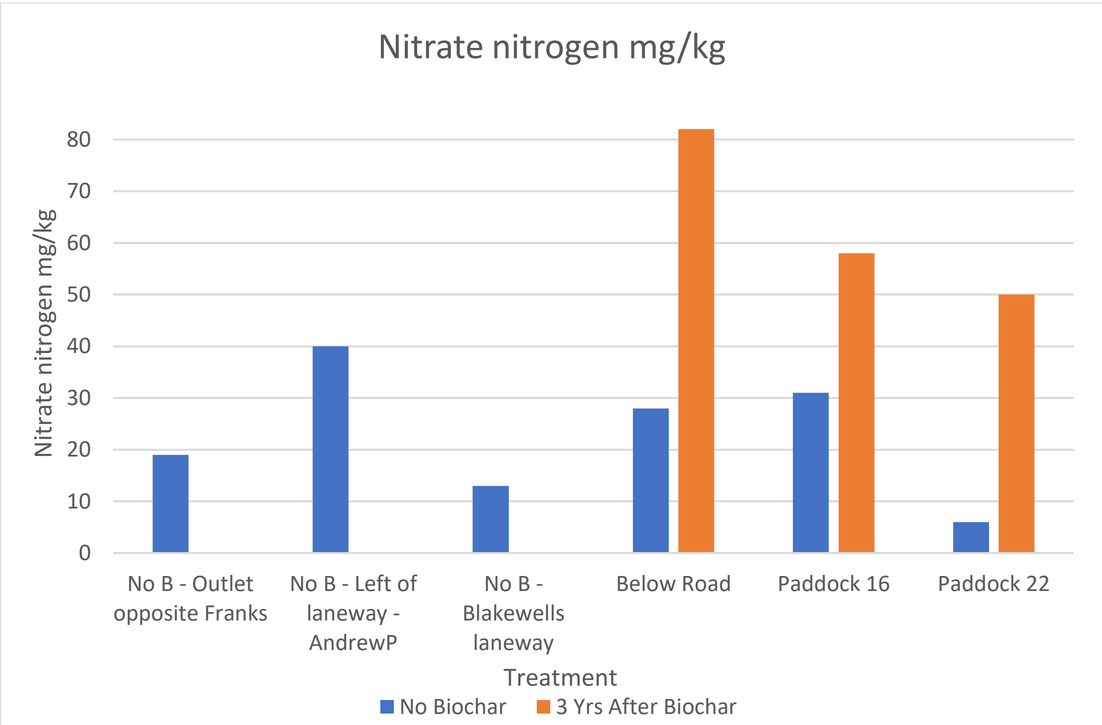

FIGURE 11: NITRATE NITROGEN MG/KG IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Nitrate-N is plant-available N converted from NH_4^+ (ammonium) to NO_3^- (nitrate). The biochar has made more N available to the plant, as shown by the orange bars in figure 11.

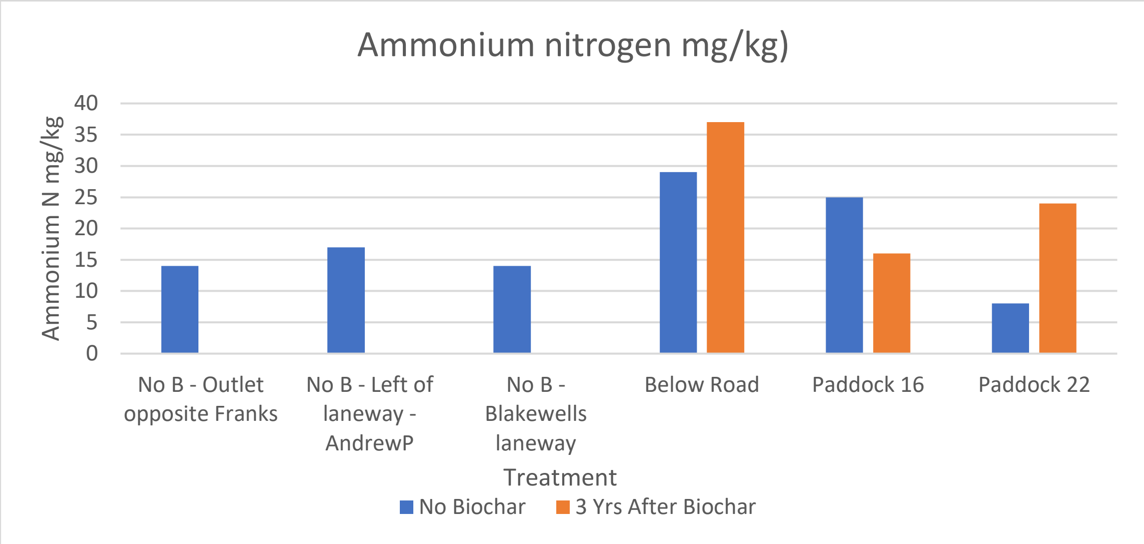

FIGURE 12 AMMONIUM NITRATE MG/KG IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Ammonium-N is plant-available N converted from organic N to NH_4^+. Ammonium N has increased under biochar application in figure 12, apart from paddock 16. Ammonium N is more resistant to loss through leaching and denitrification than nitrate N, but nitrate N is often more readily absorbed by plants. Ideally, there should be a moderate amount of conversion to optimise the benefits of both forms of N.

It would be beneficial to calculate the **Organic N (%)**, which is calculated by subtracting the Ammonium N and Nitrate N from Total N. We can then understand if N is being fixed by N-fixing bacteria and drawn out of the atmosphere into the soil because of the biochar.

However, one would assume this is what is happening due to the increase in organic carbon. No additional urea or N would be needed at present under the biochar-applied soils.

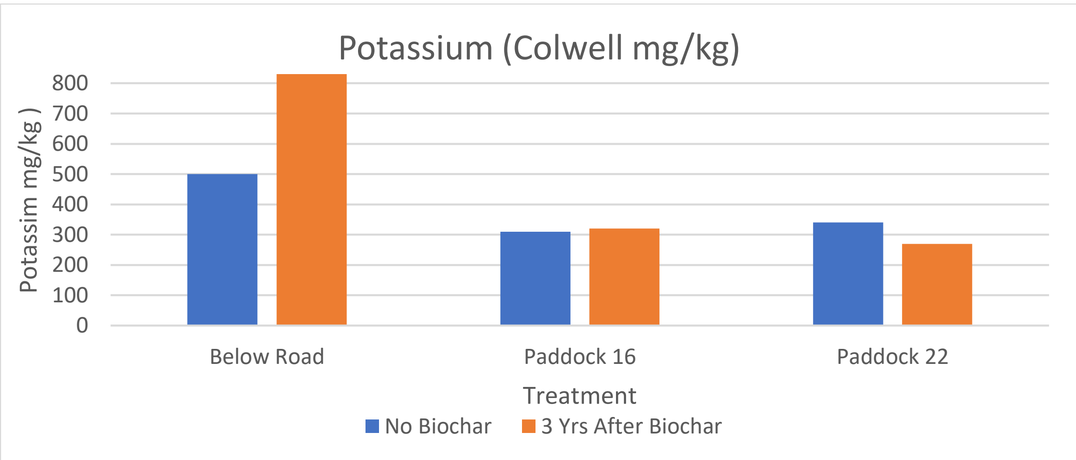

FIGURE 13: POTASSIUM COLWELL MG/KG IN THE SOIL WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Potassium is needed for a wide range of important processes within the plant including: cell wall development, flowering and seed set.

Available potassium is measured by the Colwell K. The appropriate target for available potassium depends on soil type because the holding and supply capacity of potassium in soils can differ. In clay soils, levels of 160 to 250 mg/kg are best. In figure 13 potassium levels are high and, when potassium levels are high, potassium inputs can be reduced from the fertiliser regime until levels fall. Potassium levels have increased in the below road paddock under biochar; however, no additional potassium is needed and not sure if it was added.

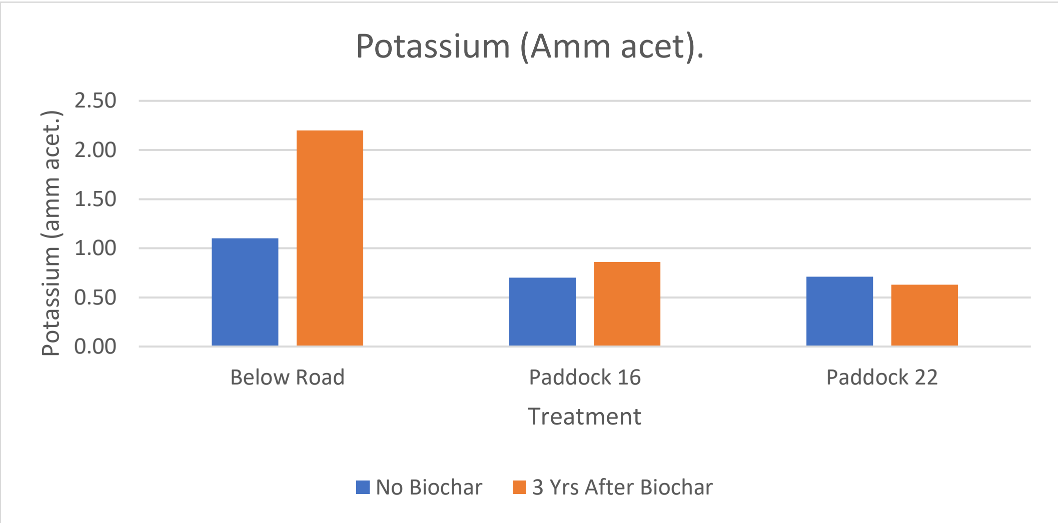

FIGURE 14 : POTASSIUM (AMMONIUM ACETATE) IN THE SOIL WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND FOLLOWED BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Similar trends to above and discussion.

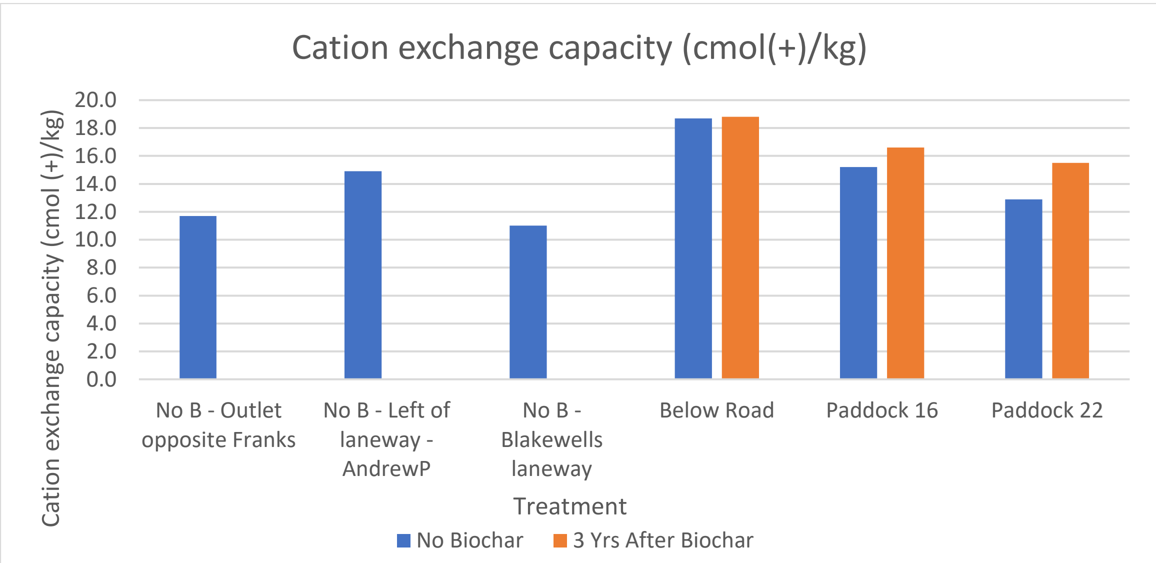

FIGURE 15: CATION EXCHANGE CAPACITY (CMOL(+)/KG IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Cation exchange capacity (CEC) is the total capacity of a soil to hold exchangeable cations, including calcium, magnesium, sodium, potassium and aluminium. It influences soil structure stability, nutrient availability, soil pH and the soil's reaction to fertiliser and ameliorants. The CEC of soils varies according to the clay %, the type of clay, soil pH and amount of organic matter.

The CEC of the soil is largely dependent on the amount and type of clay and organic matter that is present.

The biochar treatments in figure 15 appear to have increased the CEC of the soils, meaning more of the cations mentioned will exchange to the plants. This is often seen when biochar is applied to the soil as biochar also has a high CEC and we would therefore expect this to increase in the soil being positive for plant uptake and plant health.

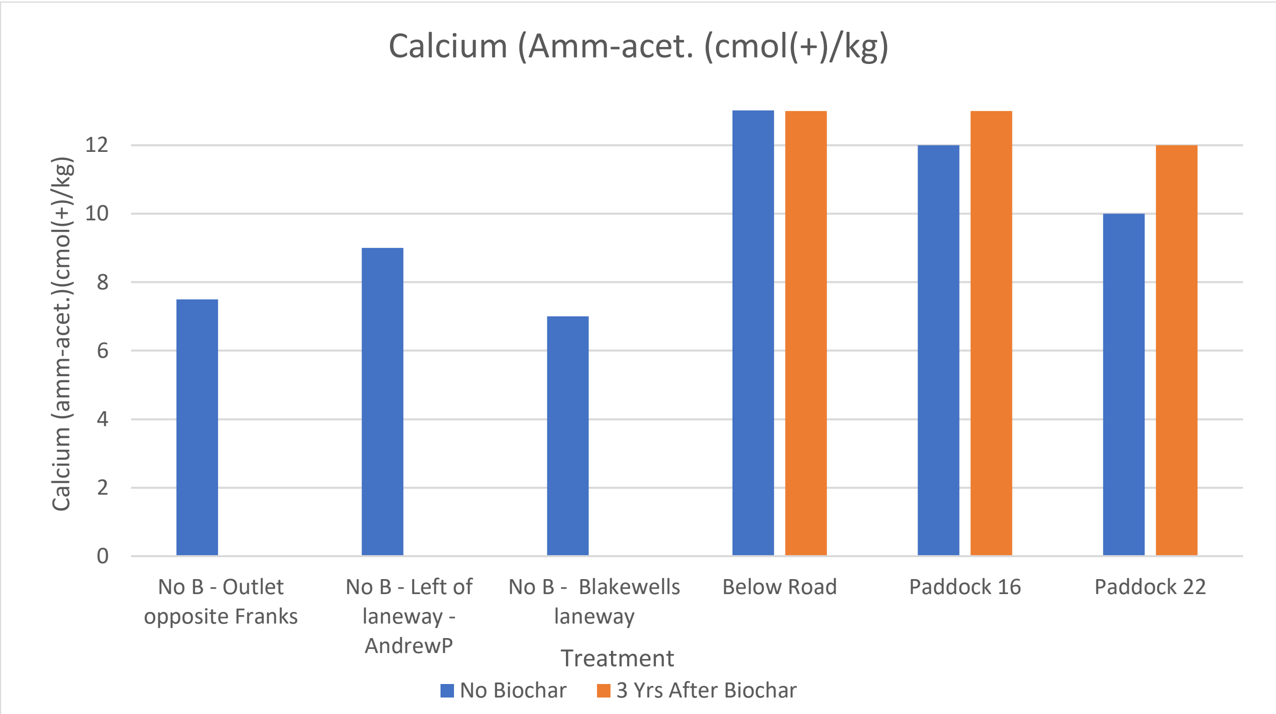

FIGURE 16: CALCIUM (AMMONIUM ACETATE) (CMOL (+)/KG) IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Calcium levels have increased in the soil under biochar (figure 16) and will be more available to the plant due to increased CEC.

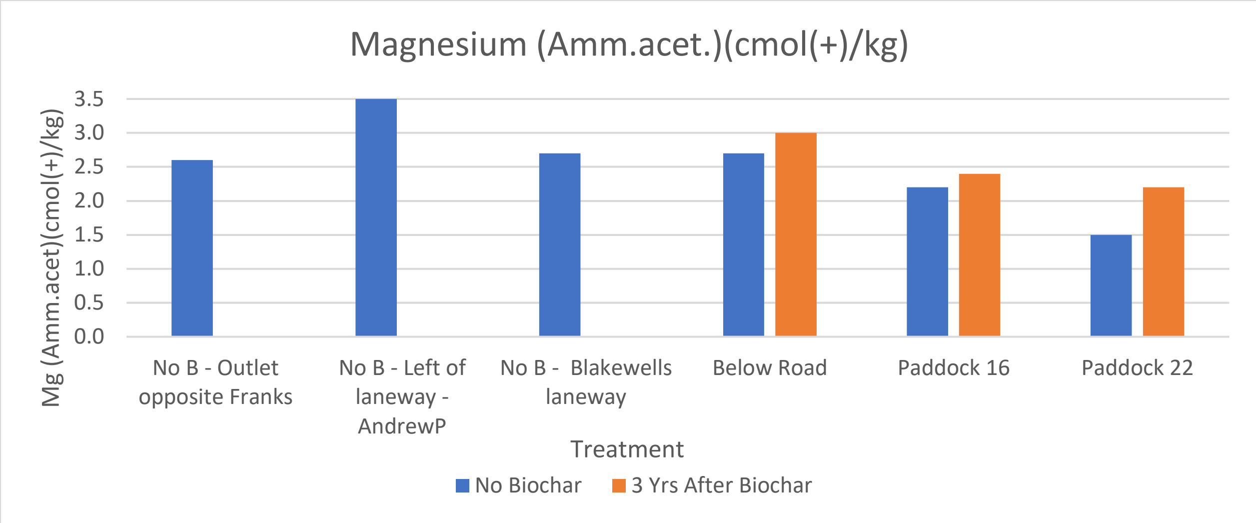

FIGURE 17: MAGNESIUM (AMMONIUM ACETATE) (CMOL(+)/KG IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Magnesium levels (figure 17) have increased under biochar and will be more available to the plant due to increased CEC, as shown in figure 15.

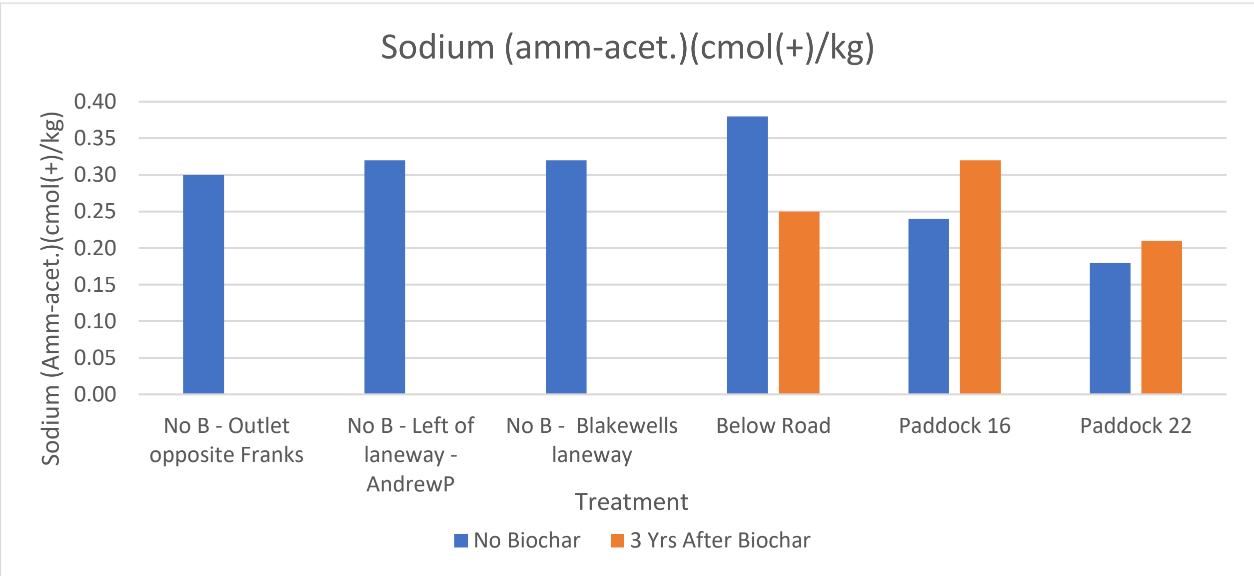

FIGURE 18: SODIUM (AMMONIUM ACETATE) (CMOL(+)/KG) IN THE SOIL FOR NEARBY FARM TAKEN IN 2015 (3 LEFT COLUMNS) COMPARED WITH ANOTHER FARM WHERE DATA WAS TAKEN IN 2019 ON A RANGE OF PADDOCKS BEFORE BIOCHAR WAS FED AND THEN FOLLOWED UP BY SUBSEQUENT TESTS IN 2021 AFTER BIOCHAR WAS FED

Sodium levels have increased in paddock 16 and 22 under biochar and reduced in the below road paddock. However, all levels are adequate and small changes are still adequate.

Overall, using Agspand's FEEDCHAR® (feed-grade biochar-based supplement for animals) appears to have had a positive effect on all parameters measured. In paddock 16 some levels decreased, and it would be interesting to understand paddock applications of fertilisers, or other applications to better understand the biochemical processes.