# CAN Project

## (Capturing Airborne Nutrients)

## Summary Final Reports of the four farm trials.

## Saturday 5th May 2018

Boho CFA Fire Shed – Boho Church Road

*Aeration & Biological Amendments for soil health and low-cost pasture production*


This project was supported by Goulburn Broken CMA's Beyond Soilcare Project through funding from the Australian Government's National Landcare Program

## Acknowledgements:

'Glen Shee' - Peter and Meg Johnson
'Trevista' – Ken and May Heywood
'Hillside Manor' – Marg Davis
'Spion Kopje' – Ethne Green
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K.E.V. Engineering Kevin Long - Bendigo, Robby Hodge Biological Practitioner – Euroa,
La Trobe University and NutriSoil – Wodonga. Victoria.

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## “Glen Shee”

## CAN Project Summary and specific Summary of the 'Glen Shee' - CAN Project farm trial 2017/2018 - Observations/Comments/Findings

Elements of the Objectives for the CAN Project (Capturing Airborne Nutrients) that arose from the 2016 ‘Proof of Concept’ experimentation have been fulfilled within the 2017 ‘Beyond SoilCare’ grant and other objectives only partially fulfilled.

The most striking finding pertaining to the four farming properties was that the treatments (aeration and biological amendments) significantly influenced the plant growth (quantity, quality, varietal-expression and growing period) and this finding was attributed to a specific bacteria *Acotobacter chroococumm* that facilitates ‘nitrogen-binding’ in the root-hair zone of grasses when it is not starved of oxygen. This finding was irrespective of aluminium and pHwater levels indicating an activated localised community of bacterium working in close symbiosis with the plant roots.

The most striking finding specific to ‘Glen Shee’ was the exceptionally heavy quality rye grass grown on the trial plot where aeration and biological amendments had been applied to a soil profile with high aluminium levels and transforming pHwater values. This was in an environment where Available and Total Calcium levels were high.

## A summary of the Objectives

## Objectives:

**Objective One – *To Double the Soil Carbon in one year*.** Aeration and biological amendments produced **a 16% increase in organic carbon** in the first 100mm of soil and **117% from 100-200mm.** This would have been greater if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Two – *To Double the Soil Depth in one year*.** Aeration and biological amendments produced about an **82% increase in soil depth**. This would have been greater if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Three – *To noticeably decrease Soil Acidity in one year.*** The pHwater values in November 2017 range from 5.4 to 5.6 in the 0-100mm depth and 5.2 to 5.4 in the 100-200mm depth. The March 2017 pHwater values ranging from 4.8 to 5.0 in the 0-100mm depth signal previous limited pasture growth and it is heartening to see the current pHwater value in the A&B trial plot currently at 5.6: this is where the maximum pasture production was grown.

The H %. Adjusted Cation Exchange Capacity levels in the 0-100mm and 100-200mm depths have decreased by 10% or more from March 2017 to November 2017 and there has been no lime added during the trial period. This is an indication of the soil becoming less acid and is possibly mainly due a 10% increase in Available Ca and to a lesser extent the aeration and biology treatments. **This outcome supports 'Objective Three a pHwater decrease in Soil Acidity in one year'.**

**Objective Four – *To Double the Pasture Growth in one year.*** Aeration and biological amendments **produced a 116% increase in pasture in one year**. These aeration and biological amendments produced a predominantly rye grass pasture: one preferred by both the cattle and the farmer. The control C had a lesser pasture with a mixture of rye grass and clover. The pasture in A was predominantly rye grass. **This is a significant finding**

## 'Trevista'


## CAN Project Summary and specific Summary of the 'Trevista' - CAN Project farm trial 2017/2018 - Observations/Comments/Findings

Elements of the Objectives for the CAN Project (Capturing Airborne Nutrients) that arose from the 2016 'Proof of Concept' experimentation have been fulfilled within the 2017 'Beyond SoilCare' grant and other objectives only partially fulfilled.

The most striking finding pertaining to the four farming properties was that the treatments (aeration and biological amendments) significantly influenced the plant growth (quantity, quality, varietal-expression and growing period) and this finding was attributed to a specific bacteria *Acotobacter chroococumm* that facilitates 'nitrogen-binding' in the root-hair zone of grasses when it is not starved of oxygen. This finding was irrespective of aluminium and pHwater levels indicating an activated localised community of bacterium working in close symbiosis with the plant roots.

The most striking finding specific to 'Trevista' was the lack of vigorous root and hair-root development below 120mm and the stressed bacteria below this proximity of the soil profile.

## A summary of the Objectives

## Objectives:

**Objective One – *To Double the Soil Carbon in one year*.** Aeration and biological amendments produced **a 42% increase in organic carbon** in the first 100mm of soil. The increase in %C for the control C from March 2017 to November 2017 was 13%. These percentage increases in carbon are much less than double which was the objective. It is expected this 42-13=29% increase will become larger over time as the identified severely stressed bacteria continue to improve their overall microbial presence and approach normalised community diversity and numbers.

**Objective Two – *To Double the Soil Depth in one year*.** Aeration and biological amendments produced about a **15% increase in soil depth**. It is expected increases will become larger over time as the identified severely stressed bacteria continue to improve their overall microbial presence and approach normalised community diversity and numbers.

**Objective Three – *To noticeably decrease Soil Acidity in one year.***

Overall there has been an increase in the pHwater for the three trial plots for the 0-100mm depth in one year. In the depth 100-200mm the pHwater has decreased in A&B, unchanged in C and increased in A. The pHwater is at a level where aluminium presence should not impair root growth.

It is to be noted the Exchangeable Hydrogen Cation Percentages shifted in a correspondingly inverse proportion to the increased pHwater values. **This was an expected, but a confirming, outcome.**

**Objective Four – *To Double the Pasture Growth in one year.*** Aeration and biological amendments produced a 16% increase in pasture in one year. These aeration and biological amendments produced a very different pasture: one preferred by both the cattle and the farmer since the flatweed was replaced by a dominance of rye grass and phalaris and emerged earlier in the growing season. An ongoing increase in pasture quantity and quality is expected over time as the identified severely stressed bacteria continue to improve their overall microbial presence and approach normalised community diversity and numbers. **This is a significant finding.**

## ‘Hillside Manor’

### CAN Project Summary and specific Summary of the ‘Hillside Manor’ - CAN Project farm trial 2017/2018 - Observations/Comments/Findings

Elements of the Objectives for the CAN Project (Capturing Airborne Nutrients) that arose from the 2016 ‘Proof of Concept’ experimentation have been fulfilled within the 2017 ‘Beyond SoilCare’ grant and other objectives only partially fulfilled.

The most striking finding pertaining to the four farming properties was that the treatments (aeration and biological amendments) significantly influenced the plant growth (quantity, quality, varietal-expression and growing period) and this finding was attributed to a specific bacteria *Acotobacter chroococumm* that facilitates ‘nitrogen-binding’ in the root-hair zone of grasses when it is not starved of oxygen. This finding was irrespective of aluminium and pHwater levels indicating an activated localised community of bacterium working in close symbiosis with the plant roots.

The most striking finding specific to ‘Hillside Manor’ was the vigorous root and hair-root development below 120mm that ameliorated plant toxic levels of Extractable Aluminium that had levels consistently greater than 100ppm and soil acidity at pHwater 4.9.

## A summary of the Objectives

## Objectives:

**Objective One – *To Double the Soil Carbon in one year*.** Aeration and biological amendments produced **a 77% increase in organic carbon** in the first 100mm of soil. This would have been greater if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Two – *To Double the Soil Depth in one year*.** Aeration and biological amendments produced about a **50% increase in soil depth**. This would have been greater if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Three – *To noticeably decrease Soil Acidity in one year.*** The pHWater shifted for soil depth 0-100mm **from 5.3 to 6.5** for both A&B and A compared to control C from the period November 2016 to January 2018. It is of importance to note that during this period the control C value shifted **from 5.3 to 6.0**. Of special interest to these outcomes is that the paddock that held the three trial plots was treated with the lime and other amendments in addition to the Aeration (A) and Aeration and Biology (A&B) described in the methodology and still delivered 0.5 pHwater units greater than the control C indicating an additional outcome attributable to the A and A&B treatments. **If this observation can be repeated the above is an outstanding outcome.**

Below 100mm deep the soil pHw was 5.1 in control C at 23/3/2017 as shown in Table 3 and rose to pHw 5.5 in A&B by 22/01/2018. This indicated that the aeration zone had facilitated the amelioration of the aluminium toxicity enabling significant root development below a soil depth of 100mm. **If this observation can be repeated the above is an outstanding outcome.**

It is to be noted the Exchangeable Hydrogen Cation Percentages shifted in a correspondingly inverse proportion to the increased pHwater values. **This was an expected, but confirming, outcome.**

**Objective Four – *To Double the Pasture Growth in one year.*** It is **not known** whether the pasture growth was doubled in one-year since the trial plot areas were not fenced off and were periodically grazed by sheep. It was observed that the treated pastures were preferentially grazed by the sheep at every opportunity: this made the task of estimating the comparative pasture production impossible.

## ‘Spion Kopje’


## CAN Project Summary and specific Summary of the ‘’Spion Kojpe’ - CAN Project farm trial 2017/2018 - Observations/Comments/Findings

Elements of the Objectives for the CAN Project (Capturing Airborne Nutrients) that arose from the 2016 ‘Proof of Concept’ experimentation have been fulfilled within the 2017 ‘Beyond Soilcare’ grant: other objectives partially fulfilled, and others not even partially achieved.

The most striking finding pertaining to the four farming properties was that the treatments (aeration and biological amendments) significantly influenced the plant growth (quantity, quality, variety and seasonal timing) and this finding was attributed to a specific bacteria *Acotobacter chroococumm* that facilitates ‘nitrogen-binding’ in the root-hair zone of grasses when it is not starved of oxygen. This finding was irrespective of aluminium and pHwater levels indicating an activated localised community of bacterium working in close symbiosis with the plant roots.

The most striking finding specific to ‘Spion Kopje’ was the vigorous root and hair-root development along the aeration lines where the sampled data recorded plant toxic levels of Extractable Aluminium consistently greater than 100ppm and soil acidity at pHwater 4.9.

The ‘Spion Kopje’ aeration and biological amendments noticeably accentuated the growth of the monocotyledon (grasses – silver grass). The aeration immediately enhanced the root tip penetration and its development throughout the shattered soil aeration zone while the biological amendments stimulated the plant growth as shown captured in the pasture cages. The existing monocotyledon grasses germinated and reached maturity earlier. The existing pasture in the Control (C) was predominately dicotyledons (flat-weeds) and remained greener into the summer due to its effective tap root. The pasture growth in all three trial plots was inhibited to some degree.  White clover remained present in the three trial plots.

## A summary of the Objectives

## Objectives:

**Objective One – *To Double the Soil Carbon in one year*.** Aeration and biological amendments produced **a 2% decrease in organic carbon** in the first 100mm of soil and **a 5% increase** for the 100-200mm depth. Given the enlarger root mass in the treated A&B and A trial plots a larger percentage of OC% was expected compared to C. The reason could to be attributed to the existence of a thick thatch on the control C soil surface and none on A&B. This OC% would have been greater if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Two – *To Double the Soil Depth in one year*.** Aeration and biological amendments produced about a **500% increase in soil depth**. This was so large an increase because the initial effective soil depth was so small and would have been more general if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Three – *To noticeably decrease Soil Acidity in one year.*** The acidity of the soil remained basically unchanged at pHWater 4.9. The H% Adjusted Cation Exchange Capacity for the three trial plots has remained basically unchanged at around 79% which corresponds to a small increase in soil acidity.

**Objective Four – *To Double the Pasture Growth in one year.*** It is **not known** whether the pasture growth was doubled in one-year since the pasture production was not measured for the three trial plots as the trial areas were not fenced off and were grazed by sheep, kangaroos and deer. On the 21/9/2017 small pasture cages were installed to enable the monitoring of the growth for the two treatments against the control plot. The aeration initiated earlier germination and growth of the existing grasses (predominantly silver grass) to what appeared to be a greater height than for grasses in C. The grasses in A&B and A quickly out-competed the flat-weed grasses in C. It was observed the treated pastures were preferentially grazed by the animals. The treated pastures started earlier and finished earlier. The root depth and root structure in A&B and A was significantly deeper and more robust than that in control C.

# CAN Project

(Capturing Airborne Nutrients)

Final Report of the 'Glen Shee' farm trial.

Saturday 5th May 2018

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**Objective Two –** ***To Double the Soil Depth in one year****.* Aeration and biological amendments produced about an **82% increase in soil depth**. This would have been greater if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Three –** ***To noticeably decrease Soil Acidity in one year.*** The pHwater values in November 2017 range from 5.4 to 5.6 in the 0-100mm depth and 5.2 to 5.4 in the 100-200mm depth. The March 2017 pHwater values ranging from 4.8 to 5.0 in the 0-100mm depth signal previous limited pasture growth and it is heartening to see the current pHwater value in the A&B trial plot currently at 5.6: this is where the maximum pasture production was grown.

The H %. Adjusted Cation Exchange Capacity levels in the 0-100mm and 100-200mm depths have decreased by 10% or more from March 2017 to November 2017 and there has been no lime added during the trial period. This is an indication of the soil becoming less acid and is possibly mainly due a 10% increase in Available Ca and to a lesser extent the aeration and biology treatments. **This outcome supports ‘Objective Three a pHwater decrease in Soil Acidity in one year’.**

**Objective Four – *To Double the Pasture Growth in one year.*** Aeration and biological amendments **produced a 116% increase in pasture in one year**. These aeration and biological amendments produced a predominantly rye grass pasture: one preferred by both the cattle and the farmer. The control C had a lesser pasture with a mixture of rye grass and clover. The pasture in A was predominantly rye grass. **This is a significant finding**

## Sub-Objectives:

**Sub-Objective One - *Roots and Microbial Action*.** In the A&B and A trial plots many of the roots near the surface appeared like 'dreadlocks'. These 'dreadlocks' comprised a central root structure with innumerable hair-roots which gave the impression of 'dreadlocks'. When viewed under the microscope the hair-roots were inhabited with "zillions" of bacteria in comparison to the sparely populated bacteria in adjacent soil particles distant from any roots. It is postulated that many of the observed "zillions" of hair-root bacteria were *Acotobacter chroococcum* which is considered to promote 'nitrogen-binding' in the hair-root zone of grasses when in the presence of adequate oxygen: a bacterium that becomes involved in Capturing Airborne Nutrients (CAN).

**Sub-Objective Two - *Microbial Populations.*** Microbial Diversity and Bacterial Stress are the indicator variables that can be improved. Other indicator-variables for both depths appear to be meeting the Guide values. Aeration and biological amendment did not seem to influence the indicators; however, it is to be remembered the cattle preferentially grazed the treated trial plots (A&B and A) compared to the remainder of the paddock. Also, it should be noted that although 'Microbial Populations, Soil Indicators and Key Groups' of microbes in soils are an essential guide to the makeup of the soil biomass they do not necessarily forebode a productive soil since microbes need to be actively involved in a symbiosis process with plants/Sun which can be readily inhibited by soil compaction and their need for respiration.

**Sub-Objective Three – *Soil Chemistry*** The H %. Adjusted Cation Exchange Capacity levels in the 0-100mm and 100-200mm depths have decreased by 10% or more from March 2017 to November 2017 and there has been no lime added during the trial period. This is an indication of the soil becoming less acid. **This outcome confirms 'Objective Three – pHwater decrease in Soil Acidity in one year'.**

The % Available Ca levels in the 0-100mm and 100-200mm depths have increased by 10% or more from March 2017 to November 2017 and there has been no lime added during the trial period. The available Ca in November 2017 was in greater than of 90% available whereas on March 2017 it was 70 to 85% available. Why? All % Available Mg levels and ratios have increased from March 2017 to November 2017. Could this be attributed to the biological amendments?

The available N has been reduced for both depths over the period March 2017 to November 2017 while the Total N in the 100-200mm depth layer has substantially increased. These values do not account for nitrogen metabolised into the plant tissue and there are significant reserves of N. The question does arise as to whether this is due to the stimulation caused by aeration or inoculation with additional Acotobacter bacteria; the data would suggest perhaps both. It is known that stimulated Acotobactor bacteria does capture more Nitrogen from the atmosphere when more oxygen is readily available to these 'nitrogen-binding' bacteria and so of the critical importance to reduce compaction in the soil profile. **This is a**

**potentially critical explanation of the supply of Nitrogen and justification for aeration and biological amendments as another pathway for capturing nitrogen from the atmosphere.**

The available P values are relatively small. These values have all decreased from March 2017 to November 2017 where some of the P would have been consumed due to the large crop of rye grass. The Total P in the reserves are substantial.

Overall the Extractable Aluminium levels are high and particularly high in the 100-200mm depth levels and it is the availability of Calcium, see table 5, in the soil profile that restrains it from becoming too acid to produce productive pasture growth.

At these increased levels of aluminium, the root growth in the 100-200mm depth would, under usual circumstances, be inhibited when pHwater is around 4.8/4.9 and the aluminium present would have a toxic effect on root growth. However, where there has been aeration the aluminium's presence is not toxic to root development since the aeration has demonstrated accelerated root and root-hair growth in similar challenged environments. **This poses a conundrum: can soils with what is described traditionally as a toxic level of aluminium be ameliorated by the application of soil aeration in acid soils?**

**Sub-Objective Four – *Soil Physics*** – Aeration markedly facilitated deep root penetration (whenever there was substantive rainfall) and a significate reduction in compaction was confirmed through penetrometer cross-sectional readings of the A&B and A trial plots on this and the other three farms.

**Sub-Objective Five – *Comparative costs*** – For 'Glen Shee' the pasture production was continuously measured so it was possible to consider a comparison between conventional pasture production and that due to the aeration/biological amendment methodology. However, if comparable pasture production of the two practices was assumed over a period of nine years the aeration/biological amendment methodology would be about a 1/3rd the cost of conventional production. The estimated comparison costs assumed all the work would be conducted by contractors at contractor's rates.

## Introduction

For many years it has been well known that judicious aeration of the soil and applications of biological amendments could enhance soil fertility, promote plant growth, build soil resilience and over a period reduce the reliance on artificial inputs. The Yeomans and Wallace ploughs attest to the success of soil aeration and the application of many and varied biological amendments have demonstrated their efficacy over the years.

Dr John Russell of La Trobe University applied a modified Wallace Aerator (slippers at 12 inches spacings and run at 280mm deep) in a loamy soil at a property in the Western District south of Ararat in 2004: just the aeration produced an increase in dry matter of over 50% for four consecutive years confirming the earlier achievements of P. A. Yeoman of Richmond NSW and Geoff Wallace of Kiewa Valley Victoria in the development, manufacturing and sales of numerous soil aerators. At this point it is necessary to distinguish a difference between aeration and deep ripping as they are similar activities with significantly different applications and therefore outcomes. Aeration 'slippers' lift and shatter the consolidated soil profile into small discrete pieces whereas deep ripping fractures the soil into large lumps along lines of weakness.

In January 2016 the modified Wallace Aerator was trialled in granite pluton derived soils at 'Hillside Manor' Warrenbayne on the mild northern slopes of the Strathbogie Ranges. This initial trial, which has become to be known as the 'Proof of Concept', delivered some exceptional results by the years end: a near doubling of the carbon content in the aerated soil profile, nearly double the pasture growth and the top soil depth deepened to the depth of the underside of the slipper - was this fortuitous or could it be repeated in a formalised research trial? It is to be remembered that 2016 was an exceptionally wet year and January 2016 turned out to be a wet month (66 mm of local rainfall in January 2016) that initiated a plunging root curtain to the depth of the aeration slipper in just six weeks. Refer to figure 1 below. Figures 2, 3 and 4 depict for aeration only, the developed soil profile and increased pasture growth and cut for measurement. Figures 5 & 6 compare the root development between aerated only soil profile figure 5 and an undisturbed control, figure 6.

*Figure 1 Shows the root curtain plunging into the soil profile shattered by the slipper that passed 280mm below the ground surface. A hand is above the root curtain.*

*Figure 3 Shows, in the evening light, the extra growth above where the slippers aerated the soil profile.*

*Figure 2 Shows a darkened colouration in the soil cross-section outlining the extent of the soil shattered zone that was occupied by the root curtain. The un-shattered zone has less colouration and shallower root profile.*

*Figure 4 Shows the initial harvesting of the extra growth due solely to the aeration.*


Figure 5 Shows where roots, taken from an aerated soil profile have become longer by being able to penetrate the shattered soil profile. The thatch was consumed by the activated soil biology.

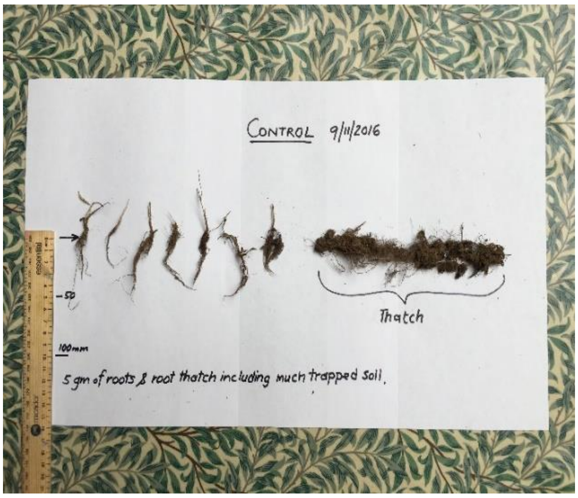


Figure 6 Shows undisturbed soil profile (Control) with short 50mm roots and considerable thatch untouched by the dormant soil biology.

Based on the above the Warrenbayne/Boho Land Protection Group (LandCare) applied for and were successful in receiving a generous 'Beyond SoilCare' grant for a project titled, '*Understanding Microbial/Plant Symbiosis to Double Pasture Production'.* This project was to explore the 'Proof of Concept' findings, above, in rigorous field trials where not only judicious aeration was tested but also biological amendments applied.

***The hypothesis was that if the slipper was set at double the top soil depth would the carbon, pasture growth and soil depth be doubled in one year and the soil acidity reduced?***

Microscopy was an important aspect of the project since it enabled the project participants to observe, under microscopes, the soil microbes and their transformation during the preparation of the amendments in the bio-reactors. Vermiculture was the main source of biological amendments as it was deemed important that relative small-scale farming operations should not only prepare their own biological amendments and low-pressure delivery systems but do so at low cost.

The grant was to be conducted from February 2017 to April 2018 to test the four objectives outlined below. All the samples were tested for Available/Total nutrients and microbial activity by SWEP and Microbe-Wise microbial laboratories respectively. This project was called the 'CAN Project' which stands for Capturing Airborne Nutrients. Four of the Warrenbayne/Boho Land Protection Group offered their farms to be included in the CAN Project. "Glen Shee', 'Trevista', 'Hillside Manor' and 'Spion Kopje'. The two cattle properties were of relatively medium to high inputs and two sheep properties of relatively low inputs. The size of the properties varied from 100 to 150 Ha. During the trial there were no farm inputs on the trial plots at 'Glen Shee', 'Testiva' and 'Spion Kopje'. At 'Hillside Manor' both lime and Gooram Rock was spread on the trial paddock at a rate of 1.0 tonne/Ha each in January 2016 together with an application of EM (Effective Microbes) and an application vermiculture liquid. These were applied in December 2015 and March 2016 respectively.

## Weather History

| Annual Rainfall History in the Warrenbayne/Boho/Benalla Area of Study | | | | | |
|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | Long-term Average |
| Benalla Airport Station No. 82170 Opened 2006 | 611.1 | 471.8 | 810.4 | 590.1 | 637.8 |
| Strathbogie Station No. 82042 Opened 1902 | 765.0 | 686.6 | 1174.8 | 1013.6 | 965.0 |

'Glen Shee' is approximately 6km SE of the Benalla Airport Meteorological Station. 'Hillside Manor' and 'Trevista' are approximately 19 km SE of the Benalla Airport Meteorological Station and could receive, in addition to the Benalla readings, about two thirds of the difference between the registered rainfall at Benalla Airport and Strathbogie Station. 'Spion Kopje' could receive the average Strathbogie Station rainfall.

The rainfall experienced in the 2016 'Proof of Concept' experimentation year of 2016 at 'Hillside Manor' was noticeably above the long-term averages for both stations.

## Soil Type and Trial Plot Location for 'Glen Shee'.

'Glen Shee' is located 6km SE of Benalla and has several soil types. Broken River flats and rocky spurs. The trial plot has Chromosol type soil located on a gravelly reef spur. The top soil has a light loamy texture intermixed with gravel and rocks, it drains poorly and sets like concrete in summer. Of the four farm trial sites 'Glen Shee' has the least homogeneous trial plots as demonstrated in the SWEP nutrient analysis.

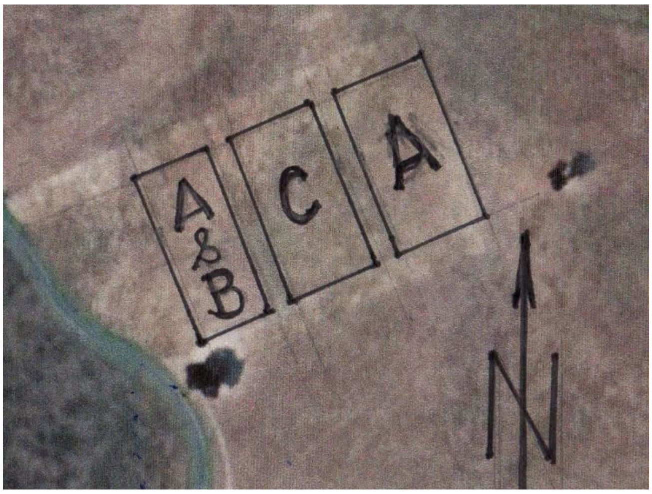


*Figure 7 Shows the three 'Glen Shee' 50m x 100m trial plots. The separations are 10m wide. 'A&B' is Aeration and Biology, 'C' is Control and 'A' is Aeration only.*

## Objectives:

Objective One – *To Double the Soil Carbon in one year.*
Objective Two – *To Double the Soil Depth in one year.*
Objective Three – *To noticeably decrease Soil Acidity in one year.*
Objective Four – *To Double the Pasture Growth in one year.*

## Sub-Objective:

Sub-Objective One - *Roots and Microbial Action.*
Sub-Objective Two - *Microbial Populations*
Sub-Objective Three – *Soil Chemistry*
Sub-Objective Four – *Soil Physics*
Sub-Objective Five – *Comparative costs*

## Methodology

1. The aim was to observe and measure the four objectives over the annual plant life cycle of one year.
2. Select where possible three similar trial 0.5Ha sites for each farm. At 'Spion Kojpe' the trial plots were reduced to 0.3Ha each.
3. The central plot was the Control (C) and the other two plots were the Aeration and Biology (A & B) and Aeration (A).
4. Each of the 0.5Ha plots were 50 x 100m in plan and were divided into a 10 x 10m grid. Samples were taken from a set pattern of 8 sample sites on the grid to provide an averaged sample for laboratory analysis. The 0.3Ha site (Spion Kopje) had 10 set sampling points.
5. All four sites were benchmarked. i.e. A representative average 'C' sample was sent to SWEP for nutrient analysis from the four sites. The returned results are dated 23/03/2017. The only property where the entire three plots were sampled for analyses, prior to commencing the plot treatments, was 'Glen Shee' since it was reasoned this would enable a check on the uniformity of the soil across a chosen site. There were insufficient funds to benchmark all twelve plots, however it was reasoned the uniformity of the plots for each of the properties could be assumed following our initial inspection and site choice. All samples were analysed for both Available and Total Nutrients present and microbial presence.
6. Aeration Activity – A 130HP tractor pulled the custom-built aeration plough. The plough was setup with three shanks/slippers spaced at 900mm and set to run at about 280mm deep. The tractor would do a second pass to split the previous run and so provided an aeration shank at 450mm spacing giving a partial shattering of the soil profile to a depth of about 280mm. Between the shanks the depth of the shattering was reduced to about one third due to the upward slope of the shattered floor in the soil.
7. Soil aeration was applied to two plots per farm trial. i.e. Aeration and Biology (A & B) and Aeration (A).
8. The microscopes were used to ascertain the existing microbial populations in numbers and categories using the Elaine Ingham's Primer (USA) (Google: *Elaine Ingham Soil Biology Primer*) and simple biological reactors were constructed and used to breed the necessary microbial populations. Mr Tim Wilson's Primer (USA) (Google: *Tim Wilson Microbe Organics*) were used to guide the microbial breeding activities.
9. The microbes were applied after the autumn break and into a moist soil. The microbes were delivered in the late afternoon preferably when rain was due or occurring.
10. The microbes were dispersed with very low-pressure pumps or gravity feed distributors to minimise the mortality of the microbes.
11. Biology was applied to only one plot per farm trial.
12. A second application of biology was applied in August/September more as a folia spray that a soil microbial amendment.

13. Final soil sampling was conducted in November and December 2017 and sent to SWEP and Microbial-Wise for laboratory analyses.
14. The project progress was communicated to the farming community through two Field Days Demonstration/Presentations and a regular commentary in the Landcare Newsletter.
15. The findings were reported in a Summary Final Report presented at the Boho CFA Fire Station Boho Church Road on Saturday 5th May 2018. A report of the detailed findings for each of the farms was prepared under four separate covers for loading onto the respective websites.

## Trial Measurements and Observations/Comments/Findings for 'Glen Shee'

### Objective One –*To Double the Soil Carbon in one year.*

Comments: The increase in Organic Carbon %C from March 2017 to November 2017 in A&B for the 0-100mm depth was 16% and 117& for the 100-200mm depth. The increase in A (aeration only) for the same period was 15% and 230% for the 100-200mm depth. The decrease in %C for the control C from March 2017 to November 2017 was 12% with an increase of 74% in the 100-200mm depth.

*Table 1 The percentage Organic Matter and/or Organic Carbon for each of the three-trial plots and for two depths: 0-100mm and 100-200mm.*

| Date | Variable | A & B | | C | | A | | Comments |
|---|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 | |
| 23/03/2017 | %OM | 10.8 | 2.89 | 11.3 | 2.7 | 11.7 | 2.17 | |
| | %OC | 5.4 | 1.45 | 6.65 | 1.35 | 5.85 | 1.09 | |
| 20/11/2017 | %OM | 12.3 | 6.3 | 11.7 | 4.7 | 13.5 | 7.2 | |
| | %OC | 6.15 | 3.15 | 5.85 | 2.35 | 6.75 | 3.6 | |

### Objective Two – *To Double the Soil Depth in one year.*

Comment: Compared to the control C, the soil depth in A&B and A have increased by about 82% and 45% respectively. Due to the rocky, reefy ridge and dry conditions in March 2017 the tractor had difficulty in maintaining the 280-300mm target depth and maintaining a consistent spacing of 450mm as can be seen in figures 8 and 9.


*Figure 8 Shows the CAN's Project first attempt at aeration ploughing at aeration ploughing. 3rd February 2017.*

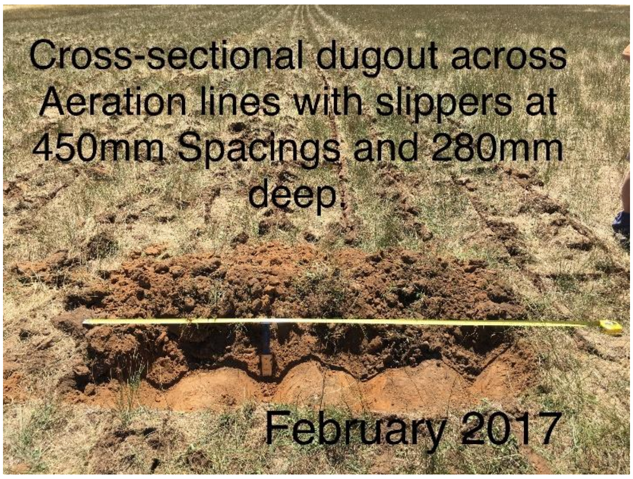


*Figure 9 Shows a cross-sectional dig-out of the first attempt at aeration ploughing. Note the large valleys and humps.*

*Figure 10 Measuring the depth of aeration.*

*Figure 11 Taking soil samples and benchmarking the depth of the root profile in the soil.*

*Table 2 The increase in soil depth near the aeration line for each of the two trial plots. The soil slipper target depth for these conditions was 280mm. It was observed at 'Glen Shee' the bottom of the 'valley' would be noticeably softer than the humps as if the infiltration water concentrated at the bottom of the valleys.*

| Date | Variable | A & B | C | A |
|---|---|---|---|---|
| 24/01/2018 | Average approximate soil depth mm | 200 | 110 | 160 |

A schematic of the idealised and actual plough aeration performance is shown in figure 12. The shattered soil in the valleys can be readily dug by hand and this shattering enables the roots tips to be unimpeded by compacted soil, go deeper and be accompanied by activated bacteria.

The aerator slipper was set at a target depth of 280/300mm and the tines set at a 900mm spacing. Refer to (a) in figure 12 below which shows the expected valleys and humps for those settings. Note the aerated soil and the compacted soil. To achieve a greater depth of uniform aeration the tractor made a second pass at a 450mm offset to produce an improved aeration zone as shown 'tan' in (b). This sketch is idealised as in practice the peaks are rounded off and are not regular as the tines tend to wander (about 100-150mm) from compaction soil to the easier going so the outcome is generally as shown 'blue' in (c) where there are larger valleys and humps. Greater horse power would allow more tines to be included in the ploughing, one tractor pass and still maintain a tine behind each rear wheel of tractor.

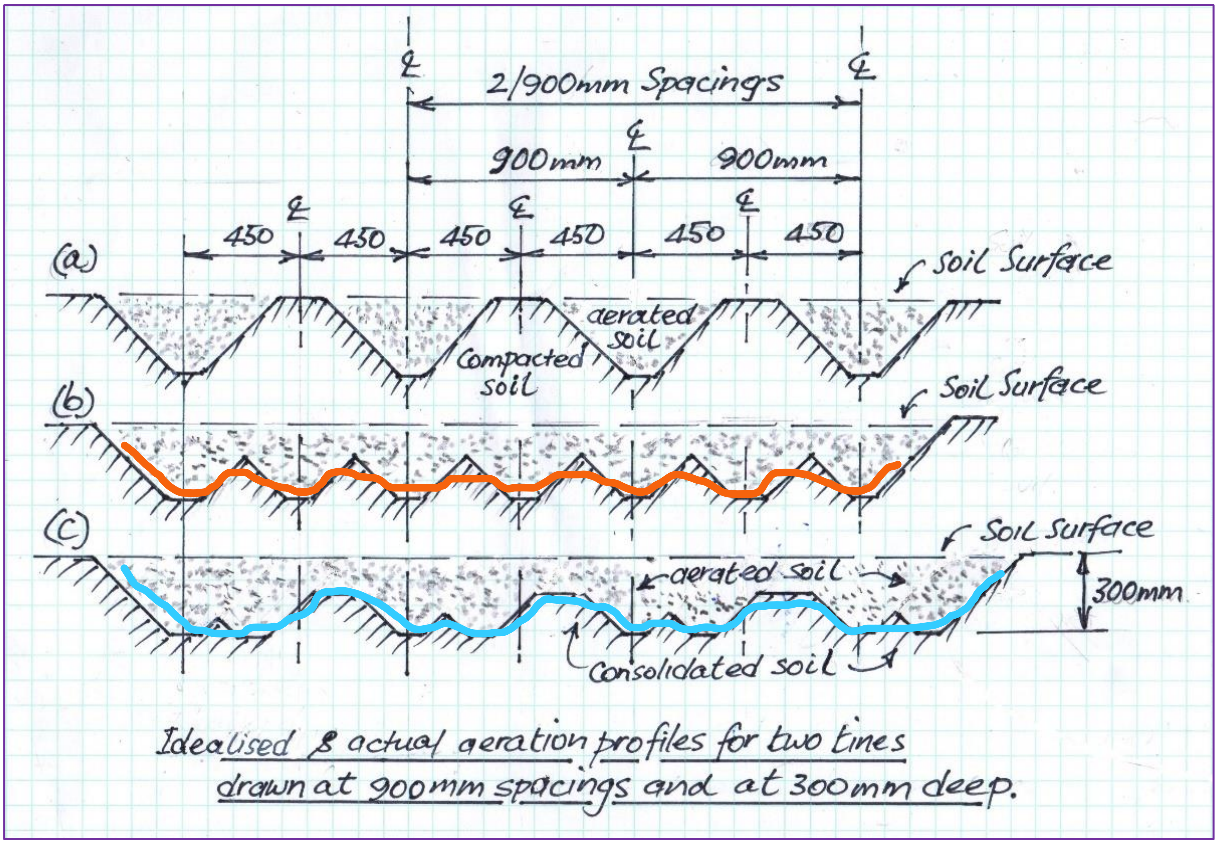


*Figure 12 Idealised 'Tan' and actual 'Blue' aeration/compaction zones left after aeration ploughing.*

### Objective Three – *To noticeably decrease Soil Acidity in one year.*

The pHwater values in November 2017 range from 5.4 to 5.6 in the 0-100mm depth and 5.2 to 5.4 in the 100-200mm depth. The March 2017 pHwater values ranging from 4.8 to 5.0 in the 0-100mm depth signal previous limited pasture growth and it is heartening to see the current pHwater value in the A&B trial plot currently at 5.6: this is where the maximum pasture production was grown.

The H %. Adjusted Cation Exchange Capacity levels in the 0-100mm and 100-200mm depths have decreased by 10% or more from March 2017 to November 2017 and there has been no lime added during the trial period. This is an indication of the soil becoming less acid and is possibly mainly due a 10% increase in Available Ca and to a lesser extent the aeration and biology treatments. **This outcome supports 'Objective Three – pH change in Soil Acidity in one year'.**

The fertiliser history of the trial paddock is as below:

2008 – Single Super
2009 – Lime 1 tonne/acre
2011 – Single Super
2015 - Single Super
2016 – Single Super

*Table 3 The percentage change on pHw/pHca for each of the three-trial plots and for two depths: 0-100 and 100-200mm.* Note: [X] Denotes Extractable Aluminium at a potentially toxicity level.

| Date | Variable | A & B | | C | | A | | Comment |
|---|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 | |
| 23/03/ 2017 | pH Water/Ca | 4.9/4.33 | 5.1/4.51 [X] | 5.0/4.4 | 5.1/4.54 [X] | 4.8/4.16 [X] | 5.1/4.52 [X] | |
| 20/11/ 2017 | pH Water/Ca | 5.6/4.95 (14%) | 5.4/4.75 [X] (6%) | 5.5/4.93 (10%) | 5.2/4.64 [X] (6%) | 5.5/4.94 (15%) | 5.4/4.76 [X] (6%) | |

**Objective Four** – ***To Double the Pasture Growth in one year. (Earlier germination of rye grasses.)***

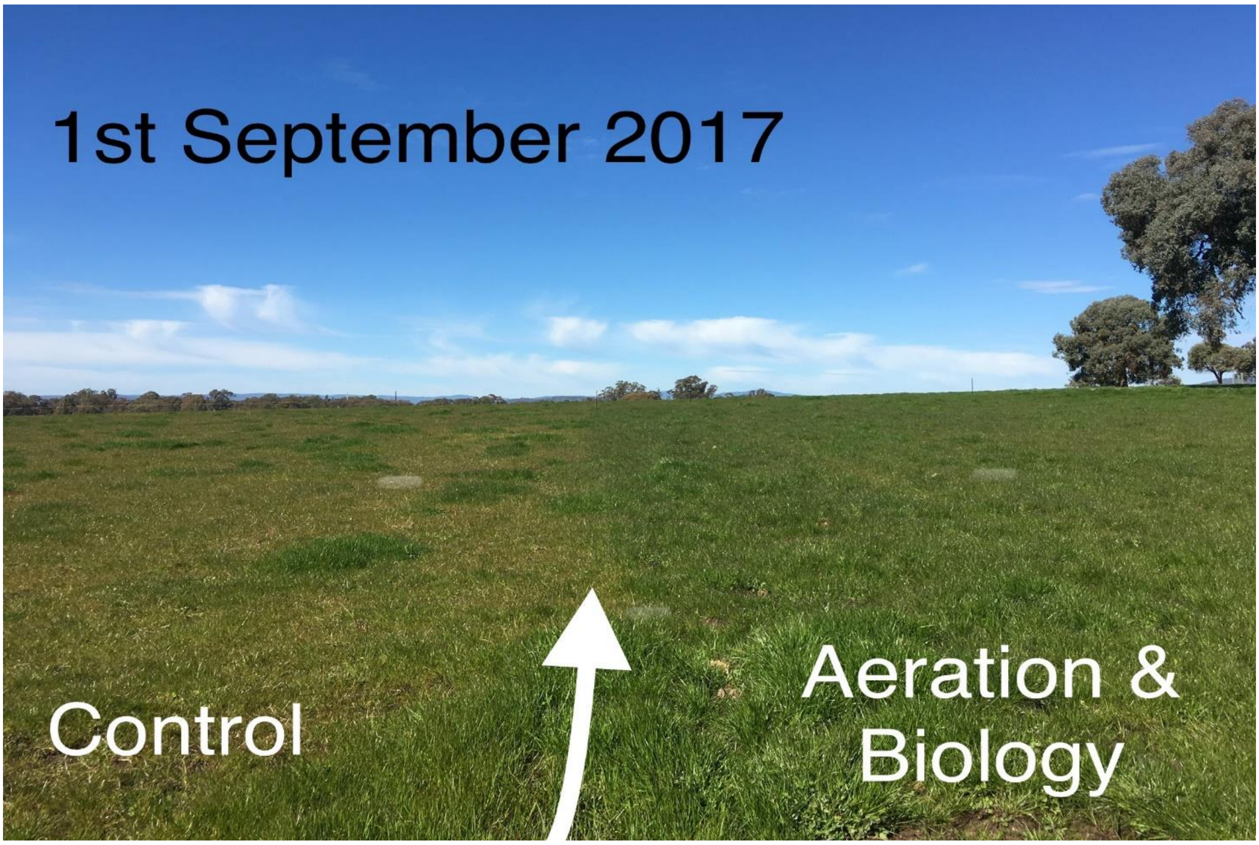


*Figure 13 The white arrow illustrates where the aeration and biology trial plot meet the control area. Note the cow pad grass exuberance – the green patches.*

Figure 13 above shows the early germination and emergence of the rye and phalaris grasses on the A&B trial plot compared to the control C.  Early germination and emergence was also observed for trial plot A. The trial plot area was fenced in July 2017.


*Figure 14 The white arrow illustrates where the lodged rye grass in the  aeration and biology trial plot adjoins the control area. Note the cow pads grass exuberance in the foreground.*

Pasture cuts were conducted on 1/11/2017 and the outcomes together with some feed test results are given in in Table 4. The pasture cuts were all done on the same day and could have been done a week earlier as much of the rye grass had already lodged.

*Table 4 Shows the Dry Matter derived from pasture cuts and the feed test results.*

| Date | Variable | A & B | C | A |
|---|---|---|---|---|
| 1/11/2017 | Dry Matter Kg DM/Ha | 5385 | 2516 | 4093 |
| | % greater than C | 114% | Control | 63% |
| | | | | |
| 10/112017 | Dry Matter (%) | 36.1 | 32.4 | 36.3 |
| | Moisture (%) | 63.9 | 67.6 | 63.7 |
| | Digestibility (DOMD) (Calc. % of Dry Matter) | 53.5 | 55.0 | 55.8 |
| | Est. Metabolized Energy (Calc.) MJ/Kg DM) | 7.8 | 8.2 | 8.3 |
| | Water Soluble Carbohydrates (% of DM) | 11.1 | 12.7 | 11.0 |
| | Ash (% of dry matter) | 7.5 | 5.6 | 4.4 |

The cattle had a strong preference for grazing on the A&B and A trial plots before the plots were fenced off, once the fences were removed the rye grass was the favoured pasture to be grazed by the cattle.

**Sub-Objective One -** ***Roots and Microbial Action.***

Comments: The roots along the aeration lines plunged down into the aerated zone for both A&B and A whereas the root depth in C remained at approximately 120mm deep. In the A&B trial plot many of the roots near the surface appeared like 'dreadlocks'. These 'dreadlocks' comprised a central root structure with innumerable hair-roots which gave the impression of 'dreadlocks'. When viewed under the microscope the hair-roots were inhabited with "zillions" of bacteria in comparison to the sparely populated bacteria in adjacent soil particles distant from any roots. Such a differentiation was not seen or could not present itself in the 'Microbe-Wise' Microbial Populations, Soil Indicators and Key Microbe Groups due to the aggregation of the sampling. It is postulated that many of the observed "zillions" of hair-root bacteria were *Acotobacter chroococcum* which are considered to promote 'nitrogen-binding' in the hair-root zone of grasses when in the presence of adequate oxygen. i.e. a bacterium that becomes involved in Capturing Airborne Nutrients (CAN).

*Figure 15 Examining root development along an aeration line at 'Glen Shee'. 25/05/2017*

*Figure 16 'Dreadlocks' dug from an aeration line on trial plot A&B.* 25/05/2017


*Figure 17 Comparison of trial plot root development as at 3/11/2017.*

**Sub-Objective Two - *Microbial Populations* 'Microbe-Wise' Soil Indicators and Key Microbe Groups: 'Glen Shee':**

**Comments on Microbial Populations, Soil Indicators and Key Groups:** Microbial Diversity and Bacterial Stress are the indicator variables that can be improved. The other variables for both depths appear to be meeting the Guide values. Aeration and biological amendment did not seem to influence the indicators; however, it is to be remembered the cattle preferentially grazed the treated trial plots compared to the remainder of the paddock.

Also, it should be noted that although 'Microbial Populations, Soil Indicators and Key Groups' of microbes in soils are an essential guide to the makeup of the soil biomass they do not necessarily forebode a productive soil since microbes need to be actively involved in a symbiosis process with plants/Sun which can be readily inhibited by soil compaction and their need for respiration.

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 20/11/2017 | Overall Microbial Balance (Guide) | 95.3 (100) | 90.9 (100) | 96.9 (100) | 85.3 (100) | 96.7 (100) | 96.0 (100) |
| Comment: The Overall Microbial Balance decreases with depth. The 100-200mm 'C' has the least. | | | | | | | |
| 20/11/2017 | Nutrient Cycling Rate % | 100 (100) | 100 (100) | 100 (100) | 88.7 (100) | 100 (100) | 100 (100) |
| Comment: The Nutrient Recycling Rate decreases with depth. The 100 -200mm 'C' has the least. | | | | | | | |
| 20/11/2017 | Microbial Diversity (Guide) | 53.6 (80) | 53.3 (80) | 57.9 (80) | 57.2 (80) | 56.0 (80) | 59.3 (80) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Comment: The Microbial Diversity Microbial Diversity is substantially below the Guide leaving capacity for increased diversity. | | | | | | | |
| 20/11/2017 | Fungi : Bacteria Ratio (Guide 2.3) | 2.7 (2.3) | 2.4 (2.3) | 2.4 (2.3) | 2.3 (2.3) | 2.8 (2.3) | 2.2 (2.3) |
| Comment: The Fungi:Bacteria Ratio decreases with depth. The Guide value is 2.3. There is more fungi where there has been treatment. | | | | | | | |
| 20/11/2017 | Bacterial Stress (Guide < 0.5) | 0.6 (< 0.5) | 0.8 (< 0.5) | 0.6 (< 0.5) | 0.9 (< 0.5) | 0.6 (< 0.5) | 0.7 (< 0.5) |
| Comment: All the Bacterial Stress values are above 5. The 100-200mm depth layer is under bacterial stress. Greater Microbial Diversity could improve this stress interpretation. | | | | | | | |

## Sub-Objective Three – *Soil Chemistry* - 'SWEP' Nutrient Analyses and Comments: 'Glen Shee'

**Comments on the H %. Adjusted Cation Exchange Capacity:** The H %. Adjusted Cation Exchange Capacity levels in the 0-100mm and 100-200mm depths have decreased by 10% or more from March 2017 to November 2017 and there has been no lime added during the trial period. This is an indication of the soil becoming less acid. **This outcome confirms 'Objective Three – pH change in Soil Acidity in one year'.**

*Table 5 The Hydrogen Percentage Adjusted Cation Exchange Capacity (CEC) for each of the three trial lots and for two depths: 0-100mm and 100-200mm.*

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 23/03/2017 | H %. Adjusted CEC | 53.5 | 64.6 | 58.7 | 71.5 | 54.5 | 73.4 |
| 20/11/2017 | H %. Adjusted CEC | 40.6 | 54.3 | 45.8 | 63.3 | 40.6 | 55.5 |

**Comments on the Available Calcium as a Ratio to the Totals** The % Available Ca levels in the 0-100mm and 100-200mm depths have increased by 10% or more from March 2017 to November 2017 and there has been no lime added during the trial period. The available Ca in November 2017 was in greater than of 90% available whereas on March 2017 it was 70 to 85% available. Why? Could the 10% increase in Available Calcium been responsible for increasing the pHwater from 4.8/4.9 to 5.5? Refer to table 3. Was more of the Total Calcium dissolved by the wet weather during the year?

*Table 6 The Calcium Available/Total ratio in ppm. The ratio of available Calcium is shown as a percentage for each of the three trial plots and for two depths: 0-100 and 100-200mm. The Desirable level was given at around 2000ppm.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | Ca Available/Total ppm (% avail. of Total) | 992/1410 70.4 | 288/357 80.1 | 946/1260 75.1 | 180/218 82.6 | 1076/1270 84.7 | 174/215 80.9 |
| 20/11/2017 | Ca Available/Total ppm (% avail. of Total) | 1302/1390 93.6 | 722/733 98.5 | 1162/1170 99.3 | 416/506 82.2 | 1360/1480 91.9 | 668/730 91.5 |

**Comments on the Available Magnesium as a Ratio to the Totals:** All % Available Mg levels and ratios have increased from March 2017 to November 2017. Could this be attributed to the biological amendments?

*Table 7 The Magnesium Available/Total ratio in ppm. The ratio of Available Magnesium is shown as a percentage for each of the three trial plots and for two depths: 0-100 and 100-200mm*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/ 2017 | MgAvailable/Total ppm (% avail. of Total) | 187/915 20.4 | 143/690 20.7 | 139/850 16.4 | 74/634 11.7 | 131/741 17.7 | 61/595 10.3 |
| 20/11/ 2017 | MgAvailable/Total ppm (% avail. of Total) | 205/763 26.9 | 205/858 23.9 | 140/729 19.2 | 76/545 14.0 | 199/868 22.9 | 140/810 17.2 |

**Comment on the Calcium/Magnesium Ratio:** The Ca/Mg Ratios are below the GUIDE Ratio of 8:1 in the top 0-100mm for A&B, C and A but above the limiting values of 2.

*Table 8 The Calcium/Magnesium Ratio for each of the three trial plots for two depths: 0-100mm and 100-200mm. All ratios greater than 2 in the November 2017 sample results whereas the March 2017 results show ratios less than 2 for 100-200mm depths.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | Ca/Mg Ratio | 3.18 | 1.21 | 4.08 | 1.46 | 4.94 | 1.72 |
| 20/11/2017 | Ca/Mg Ratio | 3.81 | 2.11 | 4.97 | 3.3 | 4.1 | 2.85 |

**Comments: on % Exchangeable Cation Ratio Ca/Mg:** The Exchangeable Cation Ratio Ca/Mg is greater than 2 for the 0-100mm deep layers. The Ca/Mg Ratio in March 2017 was below 2 for all trial plot samples in the 100-200mm depth layer but this is not the case in November 2017. Ca/Mg less than 2 can cause soils to be dispersive.

*Table 9 The % Exchangeable Cation Ratio Ca/Mg for each of the three trial plots for two depths: 0-100mm and 100-200mm*

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 23/03/ 2017 | % Exchangeable Cation Ratio Ca/Mg | 31.7/10 3.7 | 16.9/13.9 1.2 | 29.8/7.3 4.1 | 13.5/9.3 1.6 | 34.8/7.1 4.9 | 13.8/8.0 1.7 |
| 20/11/ 2017 | % Exchangeable Cation Ratio Ca/Mg | 43.3/11.4 3.8 | 27.8/13.2 2.1 | 41.7/8.4 5.0 | 24.9/7.7 3.2 | 43.8/10. 7 4.1 | 29.8/10.5 2.8 |

**Comments on the Available Nitrogen as a Ratio to the Totals:** The available N has been reduced for both depths over the period March 2017 to November 2017 while the Total N in the 100-200mm depth layer has substantially increased. These values do not account for nitrogen metabolised into the plant tissue and there are significant reserves of N. In fact, the reserves of N in the 100-200mm depth layer have noticeably increased with no added N to the trial plots during the trial period.

The question does arise as to whether this is due to the stimulation caused by aeration or inoculation with additional Acotobacter bacteria; the data would suggest perhaps both. It is known that stimulated Acotobactor bacteria does capture more Nitrogen from the atmosphere when more oxygen is readily available to these 'nitrogen-binding' bacteria and so of the critical importance to reduce compaction in the soil profile. **This is a potentially critical explanation of the supply of**

**Nitrogen and justification for aeration and biological amendments as another pathway for capturing nitrogen from the atmosphere.**

*Table 10 The Available Nitrogen to Total Ratio in ppm. The percentage of Available to Total is shown in brackets.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/ 2017 | N Available/Total ppm (% avail. of total) | 71.4/4400 1.6 | 11.3/868 1.3 | 77.7/4690 1.6 | 11.5/840 1.4 | 62/4790 1.2 | 8.7/672 1.3 |
| 20/11/ 2017 | N Available/Total ppm (% avail. of total) | 3.9/4420 0.1 | 3.8/2420 0.2 | 3.5/4190 0.1 | 2.4/1290 0.2 | 4.1/5180 0.1 | 3.3/2550 0.1 |

**Comments on the Available Phosphorus as a Ratio to the Totals:** The available P values are relatively small. These values have all decreased from March 2017 to November 2017 where some of the P would have been consumed due to the large crop of rye grass. The Total P in the reserves are substantial.

*Table 11 The Phosphorus Available/Total Ratio in ppm of Available to Total is shown in brackets.28/11/2016*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/ 2017 | P Available/Total ppm (% avail. of total) (Olsen) | 8.13/382 2.1 | 0.1/119 0.1 | 6.7/367 1.8 | 0.2/130 0.2 | 8.54/352 2.4 | 0.1/102 0.1 |
| 20/11/ 2017 | P Available/Total ppm (% avail. of total) (Olsen) | 4.3/381 1.1 | 2.9/224 1.3 | 4.1/340 1.2 | 2.4/160 1.5 | 9.1/397 2.3 | 1.9/247 0.8 |

**Comments on the Extractable Aluminium:** Over all there has been an approximate halving of the extractable aluminium level from March 2017 to November 2017 which corresponds with an overall increase in pHwater. The Extractable Aluminium levels are elevated in the 0-100mm depth level and more so for C. Extractable Aluminium levels in the 100-200mm depth levels are high and if it were not for the readily available Calcium the soil would be more acid and unduly limit the pasture production. The pHwater values in November 2017 range from 5.4 to 5.6 in the 0-100mm depth and 5.2 to 5.4 in the 100-200mm depth. A pHwater value of 5.6 mitigates against pasture growth inhibiting levels of extractable aluminium: the lower the number the lesser the germination of species and growth of plants.

The March 2017 pHwater values ranging from 4.8 to 5.0 in the 0-100mm depth signals previous limited pasture growth and it is heartening to see the current pHwater value in the A&B trial plot currently at 5.6: this is where the maximum pasture production was grown.

*Table 12 Extractable Aluminium in ppm. Note the 0-100mm soil depth values are low and the 100-200mm depths are high which indicate Aluminium soil toxicity that will inhibit plant root growth*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | Al Extractable ppm | 27.4 | 77.1 | 41.8 | 100 | 18.1 | 93.1 |
| 20/11/2017 | Al Extractable ppm | 9.6 | 51.2 | 22.6 | 66.5 | 10.8 | 59 |

**Sub-Objective Four –** ***Soil Physics*** - ***Infiltration tests and Penetrometer Tests.***

The aeration activities drastically improved the soil infiltration capabilities which have remained substantially improved over the trial period. It is anticipated the near immediate root curtain development phenomenon in the soil profile will lead to improved soil structure and ongoing improved infiltration rates over time provided the soils are not unduly subjected to soil compaction forces. Penetrometer cross-sectional readings have confirmed the substantive reduction in soil compaction to the depth of the slipper passage: generally, about 280mm.

**Sub-Objective Five –** ***Comparative costs***

A general cost comparison has been made between conventional pasture production and the aeration/biological amendment methodology used in these four farm trials. The high input farms have higher pasture production and grazed cattle with higher returns, the lower input pasture producers graze sheep.

For 'Glen Shee' the pasture production was not continuously measured so it was impossible to draw any definitive comparison between conventional pasture production and the aeration/biological amendment methodology. However, if at least comparable pasture production of the two practices was assumed over a period of nine years the aeration/biological amendment methodology would be about a 1/3$^{rd}$ the cost of conventional production. The estimated comparison costs assumed all the work would be conducted by contractors at contractor's rates. The nine-year period assumed three cycles of liming with annual applications of phosphorous, nitrogen and other elements as needed by the conventionally farmer properties compared to a three-yearly aeration and bi-annually application of biological amendments. This finding was based on a single year and ongoing experimentation would be essential to confirm or otherwise these preliminary finding remain representative over the assumed test period.

**Appendix:** The 'Glen Shee' questionnaire/survey for the 'CAN Project' farm trial 2017 – 2018.

**Trial Participant Feedback.**

As part of the CAN Project, it is valuable to have feedback from those whose properties were involved in the trial. The following questions are provided as a guide to assist you in providing this feedback. A copy of the draft report for your property will be prepared for your consideration and comments before a final report is written and later submitted in April/March 2018.

1. **What is the input/amendment record over the past years (10 years if possible) for your trial? Please supply copies if possible. (if you have soil test data, please include. If you have already given this information to John, put 'Already supplied')**

   2008 Single Super
   2009 1 Tonne Lime/Ac
   2011 Single Super
   2015 Single Super
   2016 Single Super

2. **What is the grazing record for the trial over 2017?**

   With the Autumn Break and the application of biology the entire trial area was fenced off, so from May 2017 there was no grazing.

In November 2017 when it was removed the cattle showed significant preference to graze on A + B. The trial was then intermittently grazes up until the end of the trial period.

3. **What are your major observations from the trial?**

   After the rain in April 2017 plus two applications of biology A + B had grown that was noticeably greener with germination of mainly Rye.

   At this stage deep root penetration was noted compared to A and C. In A Rye had also germinated but with a lesser extent with clover that looked healthier than the same in C.

   The heavy, quality of Rye grass in A + B dried off earlier than the other 3 farms.

4. **From your experience in this trial, to what extent do you intend to apply any of the findings to your current farming practice?**

   In our view the aeration and application of biology did add to the pasture growth. However, in our case without the infrastructure we will only use biology on our pastures.

5. **If the above is in the affirmative, what are you thinking of doing and why?**

   To spread the commercial biology “WormHit” and then later spray with “NutriSoil” as a foliate.

6. **In your view is the trial worthy of extending?  If so, do you have specific suggestions as to what should be done?**

   Possibly if the aeration slipper had the addition of a prickle-roller to smooth the area.

   A practical lesson on the actual making and the ingredients of the biology would make application by the farm owners easier to apply at the appropriate times.

7. **In your view, how do you think the microscopes have added benefit, (or otherwise), to the trial?  Do you have any suggestions for their use into the future?**

   The introduction of the microscope was a new experience and an education to a whole new world of organisms. It will benefit farmers in the future as a tool to monitor soil health.

8. **Please add any comments/observations you may have of the other farms that have participated in the trial.**

   Observation with A+B was that the Rye germinated so quickly it took over from all other species. As our plots were not grazed it did not portray a true growth pattern for normal animal grazing. All farms reported stock preference to graze A+B where biology had been sprayed.

   We experimented with a commercial biology (worm based - NutriSoil) outside the trial area and achieved the same result however it was a different soil type.

9. **If possible, please record your observation of the trial over 2017, in terms of germination, seasonal influences, growth patterns, grazing, colour, pasture type, ripening, etc.**

| **Season** | **A & B** | **C** | **A** | **Genera** |
|---|---|---|---|---|
| Autumn | Good rain saw germination begin with predominant Rye | Rye, Clover and flat weed | Healthier result than C | |
| Winter | By June 2017 significant growth after biology stood out in green colour from A and C | | | |
| Spring | Dense growth of Rye Observed significant root growth | Sparser cover of Rye, clover (although stunted) and weeds. | Medium cover of Rye and Clover and weeds. | |
| Summer | By February 2018 Rye dried and collapsed | Sparse cover with patches of bare earth. | Rye dry but held on. | |

# CAN Project

(Capturing Airborne Nutrients)

Final Report of the 'Hillside Manor' farm trial.

Saturday 5th May 2018

Boho CFA Fire Shed – Boho Church Road

*Aeration and Aeration & Biological Amendments for soil health and low-cost pasture production*

## Acknowledgements:

'Glen Shee' - Peter and Meg Johnson
'Trevita' – Ken and May Heywood
'Hillside Manor' – Marg Davis
'Spion Kopje' – Ethne Green
Secretary/Treasurer Warrenbayne/Boho Land Protection Group - Ethne Green 0408 287 976
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Iain Atkin Chairperson Warrenbayne/Boho Land Protection Group
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Greg Bekker Agriculture Victoria – Benalla
Kerri Robson Landcare Project Officer
Neil and Nick Bromley
Warrenbayne Hall Committee and Boho CFA Fire Brigade

K.E.V. Engineering Kevin Long - Bendigo, Robby Hodge Biological Practitioner – Euroa,
La Trobe University and NutriSoil – Wodonga. Victoria.

*This project is supported by the Goulburn Broken CMA, through funding from the Federal Government's National Landcare programme*.

## Contents:

## CAN Project Summary and specific Summary of the 'Hillside Manor' - CAN Project farm trial 2017/2018 - Observations/Comments/Findings

Elements of the Objectives for the CAN Project (Capturing Airborne Nutrients) that arose from the 2016 'Proof of Concept' experimentation have been fulfilled within the 2017 'Beyond SoilCare' grant and other objectives only partially fulfilled.

The most striking finding pertaining to the four farming properties was that the treatments (aeration and biological amendments) significantly influenced the plant growth (quantity, quality, varietal-expression and growing period) and this finding was attributed to a specific bacteria *Acotobacter chroococumm* that facilitates 'nitrogen-binding' in the root-hair zone of grasses when it is not starved of oxygen. This finding was irrespective of aluminium and pHwater levels indicating an activated localised community of bacterium working in close symbiosis with the plant roots.

The most striking finding specific to 'Hillside Manor' was the vigorous root and hair-root development below 120mm that ameliorated plant toxic levels of Extractable Aluminium that had levels consistently greater than 100ppm and soil acidity at pHwater 4.9.

## A summary of the Objectives

## Objectives:

**Objective One – *To Double the Soil Carbon in one year*.** Aeration and biological amendments produced **a 77% increase in organic carbon** in the first 100mm of soil. This would have been greater if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Two – *To Double the Soil Depth in one year*.** Aeration and biological amendments produced about a **50% increase in soil depth**. This would have been greater if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Three – *To noticeably decrease Soil Acidity in one year.*** The pHWater shifted for soil depth 0-100mm **from 5.3 to 6.5** for both A&B and A compared to control C from the period November 2016 to January 2018. It is of importance to note that during this period the control C value shifted **from 5.3 to 6.0**. Of special interest to these outcomes is that the paddock that held the three trial plots was treated with the lime and other amendments in addition to the Aeration (A) and Aeration and Biology (A&B) described in the methodology and still delivered 0.5 pHwater units greater than the control C indicating an additional outcome attributable to the A and A&B treatments. **If this observation can be repeated the above is an outstanding outcome.**

Below 100mm deep the soil pHw was 5.1 in control C at 23/3/2017 as shown in Table 3 and rose to pHw 5.5 in A&B by 22/01/2018. This indicated that the aeration zone had facilitated the amelioration of the aluminium toxicity enabling significant root development below a soil depth of 100mm. **If this observation can be repeated the above is an outstanding outcome.**

It is to be noted the Exchangeable Hydrogen Cation Percentages shifted in a correspondingly inverse proportion to the increased pHwater values. **This was an expected, but confirming, outcome.**

**Objective Four – *To Double the Pasture Growth in one year.*** It is **not known** whether the pasture growth was doubled in one-year since the trial plot areas were not fenced off and were periodically grazed by sheep. It was observed that the treated pastures were preferentially grazed by the sheep at every opportunity: this made the task of estimating the comparative pasture production impossible.

## Sub-Objectives:

**Sub-Objective One - *Roots and Microbial Action*.** In the A&B trial plot many of the roots near the surface appeared like 'dreadlocks'. These 'dreadlocks' comprised a central root structure with innumerable hair-roots which gave the impression of 'dreadlocks'. When viewed under the microscope the hair-roots were inhabited with "zillions" of bacteria in comparison to the sparely populated bacteria in adjacent soil particles distant from any roots. It is postulated that many of the observed "zillions" of hair-root bacteria were *Acotobacter chroococcum* which is considered to promote 'nitrogen-binding' in the hair-root zone of grasses when in the presence of adequate oxygen: a bacterium that becomes involved in Capturing Airborne Nutrients (CAN).

**Sub-Objective Two - *Microbial Populations.*** The Aeration and Biological amendment treatments (A & B) have returned nearly identical values of Microbial Populations and Soil Indicators when compared to the control C. It is to be remembered the sheep preferentially heavily grazed the treated trial plots to the extent of leaving some grass matter uneaten in the control C.

**Sub-Objective Three – *Soil Chemistry*** Aeration and Biology has possibly increased the Available Mg. Any possible increase in Ca is unknown since lime and Gooram Rock was added to the trial plot paddock and an increase in Ca would have been expected.

The Ca/Mg Ratio is above the GUIDE Ratio of 8:1 in the top 0-100mm for A&B, C and A. The Exchangeable Cation Ratio Ca/Mg is greater than 2 in all cases.

Both the Available and Total Nitrogen levels have significantly increased since November 2016: there has been no added nitrogen. The maximum Available and Total Nitrogen is in the top 100mm of the A&B trial plot for the January 2018 trial plots. The activation of the *Actobacter chroococumm* **is a credible explanation for the increased nitrogen in the soil profile and offers another pathway for capturing airborne nutrients (CAN), in this case nitrogen, from the atmosphere.**

Aluminium toxicity exists below 100mm depth, however, where there has been aeration the aluminium's presence is not toxic to root development since the aeration activity has demonstrated accelerated root and root-hair growth in similarly challenged environments. **This poses a conundrum: can soils with what is described traditionally as a toxic level of aluminium be ameliorated by the application of aeration and biological amendments in acid soils?**

**Sub-Objective Four – *Soil Physics*** – Aeration markedly facilitated deep root penetration (whenever there was substantive rainfall) and a significate reduction in compaction was confirmed through penetrometer cross-sectional readings of the A&B and A trial plots on this and the other three farms.

**Sub-Objective Five – *Comparative costs*** – For 'Hillside Manor' the pasture production was not continuously measured so it was impossible to draw any definitive comparison between conventional pasture production and that due to the aeration/biological amendment methodology. However, if comparable pasture production of the two practices was assumed over a period of nine years the aeration/biological amendment methodology would be about a 1/3^rd^ the cost of conventional production. The estimated comparison costs assumed all the work would be conducted by contractors at contractor's rates.

## Introduction

For many years it has been well known that judicious aeration of the soil and applications of biological amendments could enhance soil fertility, promote plant growth, build soil resilience and over a period reduce the reliance on artificial inputs. The Yeomans and Wallace ploughs attest to the success of soil aeration and the application of many and varied biological amendments have demonstrated their efficacy over the years.

Dr John Russell of La Trobe University applied a modified Wallace Aerator (slippers at 12 inches spacings and run at 280mm deep) in a loamy soil at a property in the Western District south of Ararat in 2004: just the aeration produced an increase in dry matter of over 50% for four consecutive years confirming the earlier achievements of P. A. Yeoman of Richmond NSW and Geoff Wallace of Kiewa Valley Victoria in the development, manufacturing and sales of numerous soil aerators. At this point it is necessary to distinguish a difference between aeration and deep ripping as they are similar activities with significantly different applications and therefore outcomes. Aeration 'slippers' lift and shatter the consolidated soil profile into small discrete pieces whereas deep ripping fractures the soil into large lumps along lines of weakness.

In January 2016 the modified Wallace Aerator was trialled in granite pluton derived soils at 'Hillside Manor' Warrenbayne on the mild northern slopes of the Strathbogie Ranges. This initial trial, which has become to be known as the 'Proof of Concept', delivered some exceptional results by the years end: a near doubling of the carbon content in the aerated soil profile, nearly double the pasture growth and the top soil depth deepened to the depth of the underside of the slipper - was this fortuitous or could it be repeated in a formalised research trial? It is to be remembered that 2016 was an exceptionally wet year and January 2016 turned out to be a wet month (66 mm of local rainfall in January 2016) that initiated a plunging root curtain to the depth of the aeration slipper in just six weeks. Refer to figure 1 below. Figures 2, 3 and 4 depict for aeration only, the developed soil profile and increased pasture growth and cut for measurement. Figures 5 & 6 compare the root development between aerated only soil profile figure 5 and an undisturbed control, figure 6.

*Figure 1 Shows the root curtain plunging into the soil profile shattered by the slipper that passed 280mm below the ground surface. A hand is above the root curtain.*

*Figure 2 Shows a darkened colouration in the soil cross-section outlining the extent of the soil shattered zone that was occupied by the root curtain. The un-shattered zone has less colouration and shallower root profile.*

*Figure 3 Shows, in the evening light, the extra growth above where the slippers aerated the soil profile.*

*Figure 4 Shows the initial harvesting of the extra growth due solely to the aeration.*


*Figure 5 Shows where roots, taken from an aerated soil profile have become longer by being able to penetrate the shattered soil profile. The thatch was consumed by the activated soil biology.*

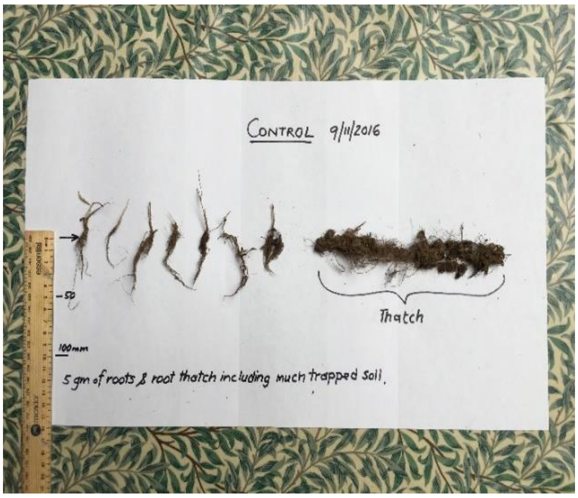


*Figure 6 Shows undisturbed soil profile (Control) with short 50mm roots and considerable thatch untouched by the dormant soil biology.*

Based on the above the Warrenbayne/Boho Land Protection Group (LandCare) applied for and were successful in receiving a generous 'Beyond SoilCare' grant for a project titled, '*Understanding Microbial/Plant Symbiosis to Double Pasture Production'.* This project was to explore the 'Proof of Concept' findings, above, in rigorous field trials where not only judicious aeration was tested but also biological amendments applied.

***The hypothesis was that if the slipper was set at double the top soil depth would the carbon, pasture growth and soil depth be doubled in one year and the soil acidity reduced?***

Microscopy was an important aspect of the project since it enabled the project participants to observe, under microscopes, the soil microbes and their transformation during the preparation of the amendments in the bio-reactors. Vermiculture was the main source of biological amendments as it was deemed important that relative small-scale farming operations should not only prepare their own biological amendments and low-pressure delivery systems but do so at low cost.

The grant was to be conducted from February 2017 to April 2018 to test the four objectives outlined below. All the samples were tested for Available/Total nutrients and microbial activity by SWEP and Microbe-Wise microbial laboratories respectively. This project was called the 'CAN Project' which stands for Capturing Airborne Nutrients. Four of the Warrenbayne/Boho Land Protection Group offered their farms to be included in the CAN Project. "Glen Shee', 'Trevista', 'Hillside Manor' and 'Spion Kopje'. The two cattle properties were of relatively medium to high inputs and two sheep properties of relatively low inputs. The size of the properties varied from 100 to 150 Ha. During the trial there were no farm inputs on the trial plots at 'Glen Shee', 'Vestiva' and 'Spion Kopje'. At 'Hillside Manor' both lime and Gooram Rock was spread on the trial paddock at a rate of 1.0 tonne/Ha each in January 2016 together with an application of EM (Effective Microbes) and an application vermiculture liquid. These were applied in December 2015 and March 2016 respectively.

## Weather History

| **Annual Rainfall History in the Warrenbayne/Boho/Benalla Area of Study** | | | | | |
|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | Long-term Average |
| Benalla Airport Station No. 82170 Opened 2006 | 611.1 | 471.8 | 810.4 | 590.1 | 637.8 |
| Strathbogie Station No. 82042 Opened 1902 | 765.0 | 686.6 | 1174.8 | 1013.6 | 965.0 |

'Hillside Manor' and 'Trevista' are approximately 19 km SE of the Benalla Airport Meteorological Station and could receive, in addition to the Benalla readings, about two thirds of the difference between the registered rainfall at Benalla Airport and Strathbogie Station. 'Spion Kopje' could receive the average Strathbogie Station rainfall. 'Glen Shee' is approximately 6km SE of the Benalla Airport Meteorological Station.

The rainfall experienced in the 2016 'Proof of Concept' experimentation year of 2016 at 'Hillside Manor' was noticeably above the long-term averages for both stations.

## Soil Type and Trial Plot Location for 'Hillside Manor'.

'Hillside Manor' is located on the mild norther slopes of the Strathbogie Ranges, it has several soil types. The trial plot is positioned on a Chromosol type soil. The top soil has a light loamy texture, drains very well and sets like concrete in summer beneath the 120mm root zone.

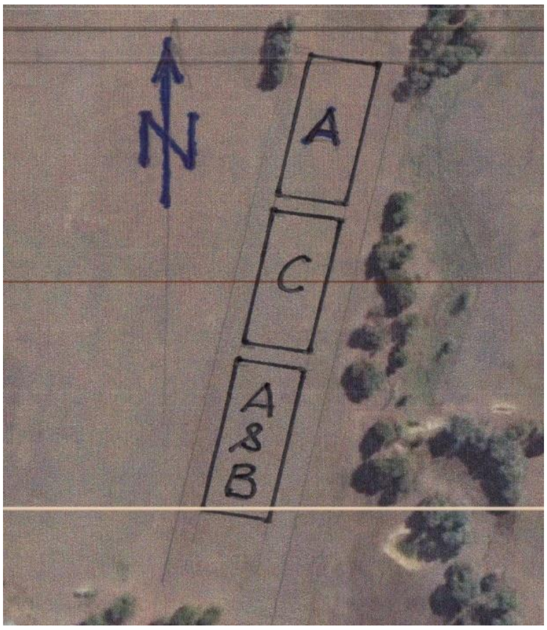


*Figure 7 Shows the three 'Hillside Manor' 50m x 100m trial plots. The separations are 10m wide. 'A' is Aeration, 'C' is Control and 'A&B' is Aeration and Biol*

## Objectives:

Objective One – *To Double the Soil Carbon in one year.*
Objective Two – *To Double the Soil Depth in one year.*
Objective Three – *To noticeably decrease Soil Acidity in one year.*
Objective Four – *To Double the Pasture Growth in one year.*

## Sub-Objective:

Sub-Objective One - *Roots and Microbial Action.*
Sub-Objective Two - *Microbial Populations*
Sub-Objective Three – *Soil Chemistry*
Sub-Objective Four – *Soil Physics*
Sub-Objective Five – *Comparative costs*

## Methodology

1. The aim was to observe and measure the four objectives over the annual plant life cycle of one year.
2. Select where possible three similar trial 0.5Ha sites for each farm. At 'Spion Kojpe' the trial plots were reduced to 0.3Ha each.
3. The central plot was the Control (C) and the other two plots were the Aeration and Biology (A & B) and Aeration (A).
4. Each of the 0.5Ha plots were 50 x 100m in plan and were divided into a 10 x 10m grid. Samples were taken from a set pattern of 8 sample sites on the grid to provide an averaged sample for laboratory analysis. The 0.3Ha site (Spion Kopje) had 10 set sampling points.
5. All four sites were benchmarked. i.e. A representative average 'C' sample was sent to SWEP for nutrient analysis from the four sites. The returned results are dated 23/03/2017. The

only property where the entire three plots were sampled for analyses, prior to commencing the plot treatments, was 'Glen Shee' since it was reasoned this would enable a check on the uniformity of the soil across a chosen site. There were insufficient funds to benchmark all twelve plots, however it was reasoned the uniformity of the plots for each of the properties could be assumed following our initial inspection and site choice. All samples were analysed for both Available and Total Nutrients present and microbial presence.

6. Aeration Activity – A 130HP tractor pulled the custom-built aeration plough. The plough was setup with three shanks/slippers spaced at 900mm and set to run at about 280mm deep. The tractor would do a second pass to split the previous run and so provided an aeration shank at 450mm spacing giving a partial shattering of the soil profile to a depth of about 280mm. Between the shanks the depth of the shattering was reduced to about one third due to the upward slope of the shattered floor in the soil.
7. Soil aeration was applied to two plots per farm trial. i.e. Aeration and Biology (A & B) and Aeration (A).
8. The microscopes were used to ascertain the existing microbial populations in numbers and categories using the Elaine Ingham's Primer (USA) (Google: *Elaine Ingham Soil Biology Primer*) and simple biological reactors were constructed and used to breed the necessary microbial populations. Mr Tim Wilson's Primer (USA) (Google: *Tim Wilson Microbe Organics*) were used to guide the microbial breeding activities.
9. The microbes were applied after the autumn break and into a moist soil. The microbes were delivered in the late afternoon preferably when rain was due or occurring.
10. The microbes were dispersed with very low-pressure pumps or gravity feed distributors to minimise the mortality of the microbes.
11. Biology was applied to only one plot per farm trial.
12. A second application of biology was applied in August/September more as a folia spray that a soil microbial amendment.
13. Final soil sampling was conducted in November and December 2017 and sent to SWEP and Microbial-Wise for laboratory analyses.
14. The project progress was communicated to the farming community through two Field Days Demonstration/Presentations and a regular commentary in the Landcare Newsletter.
15. The findings were reported in a Summary Final Report presented at the Boho CFA Fire Station Boho Church Road on Saturday 5th May 2018. A report of the detailed findings for each of the farms was prepared under four separate covers for loading onto the respective websites.

## Trial Measurements and Observations/Comments/Findings for 'Hillside Manor'

### Objective One –*To Double the Soil Carbon in one year.*

Comments: The increase in Organic Carbon %C of A&B compared to C in January 2018 was 77%: less than doubled. The increase in A compared to C was 37% - aeration only. The increase in %C for the control C from March 2017 to January 2018 was 4.8%. The 'Proof of Concept' values are presented and dated 28/12/2016. These samples were taken for 0-150mm and it was deduced if the slipper had been run deeper the root-curtain would have been deeper with consequential higher %OC values: the justification for the hypothesis.

*Table 1 The percentage Organic Matter and/or Organic Carbon for each of the three-trial plots and for two depths: 0-100mm and 100-200mm. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| Date | Variable | A & B | | C | | A | | Comments |
|---|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 | |
| 28/12/2016 | %OM<br>%OC | 7.31*<br>3.66* | | 5.24*<br>2.62* | | | | * 0-150mm |
| 23/03/2017 | %OM<br>%OC | 5.62<br>2.81 | 1.81<br>0.91 | 5.62<br>2.81 | 1.81<br>0.91 | 5.62<br>2.81 | 1.81<br>0.91 | |
| 22/01/2018 | %OM<br>%OC | 10.4<br>5.2 | 3.77<br>1.89 | 5.89<br>2.95 | 2.76<br>1.36 | 8.04<br>4.02 | 3.32<br>1.66 | |

**Objective Two – *To Double the Soil Depth in one year.***

Comment: Compared to the control C, the soil depth in A&B and A have increased by about 50% and 33% respectively. Given the hard-dry conditions for aeration in March 2017 the tractor had difficulty in maintaining the target 280mm depth and maintaining a consistent spacing of 450mm as can be seen in figure 8. In this figure note the valleys created by the slippers leaving the consolidated soil profile represented as a hump. The shattered soil in the valleys can be readily dug by hand. In nearly all cases vigorous roots have occupied the aerated zones with markedly more roots than in the consolidated zones where there are few roots. All eight grid positioned samples were taken along an aeration line which afforded the highest %C values.

It is speculated that if the aeration slippers were set at 300mm spacings the entire soil depth would have been occupied by vigorous root formations: the limitation was in the horsepower of the tractor and the setting of the spacings and depth of the tines/slippers.

*Table 2 The increase in soil depth near the aeration line for each of the tw0 trial plots. The soil slipper target depth for these conditions was 280mm. It was observed at 'Hillside Manor' the bottom of the 'valley' would be noticeably softer than the humps as if the infiltration water concentrated at the bottom of the valleys.*

| Date | Variable | A & B | C | A |
|---|---|---|---|---|
| 24/01/2018 | Average approximate soil depth mm | 180 | 120 | 160 |

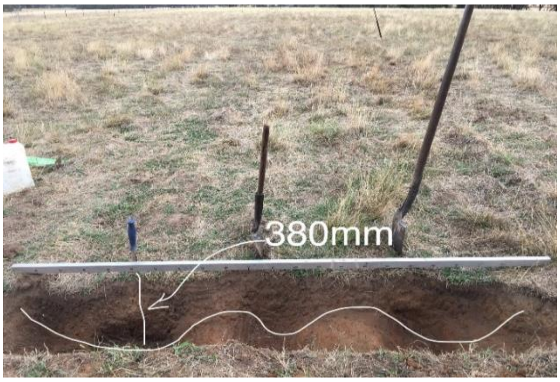


*Figure 8 "Hillside Manor' looking north. Note the valleys created by the passage of the slippers and the humps of compacted subsoil. This is a cross-section of trial plot A&B. The white line delineates the shattered aeration zone. Maximum depth 380mm. Average depth 180mm.*

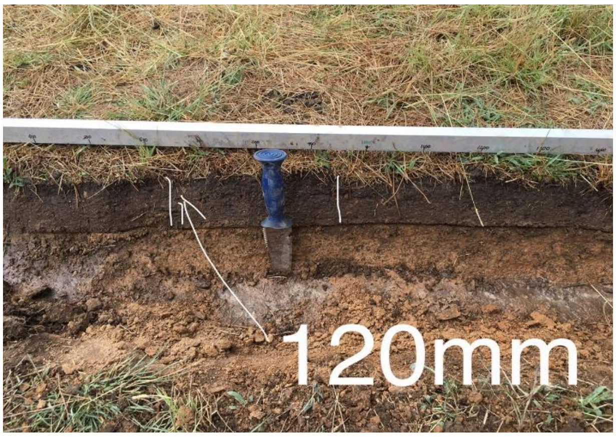


*Figure 9 Soil cross-section of C. The soil depth is approximately a consistent 120mm. The trowel is 300mm long and the handle 150mm.*


*Figure 10 Soil cross-section of A. The white line delineates the shattered aeration zone . Maxiumum depth 380mm. Average depth 160mm.*

Figure 11 below is an explanation for the valleys and humps shown as white lines in figures 8 and 10. To achieve Objective Two “Double the soil depth in one year” it was necessary to aerate the soil profile to double the depth of the existing soil profile. This would enable the roots tips to be unimpeded by compacted soil, go deeper and be accompanied by activated bacteria. The slipper was set at a target depth of 280/300mm and the tines set at a 900mm spacing. Refer to (a) in figure 11 below which shows the expected valleys and humps for those settings. Note the aerated soil and the compacted soil. To achieve a greater depth of uniform aeration the tractor made a second pass at a 450mm offset to produce an improved aeration zone as shown ‘tan’ in (b). This sketch is idealised as in practice the peaks are rounded off and are not regular as the tines tend to wander (about 100-150mm) from compaction soil to the easier going so the outcome is generally as shown ‘blue’ in (c) where there are large valleys and humps. Greater horse power would allow more tines to be included in the ploughing, one tractor pass and still maintain a tine behind each rear wheel of tractor.

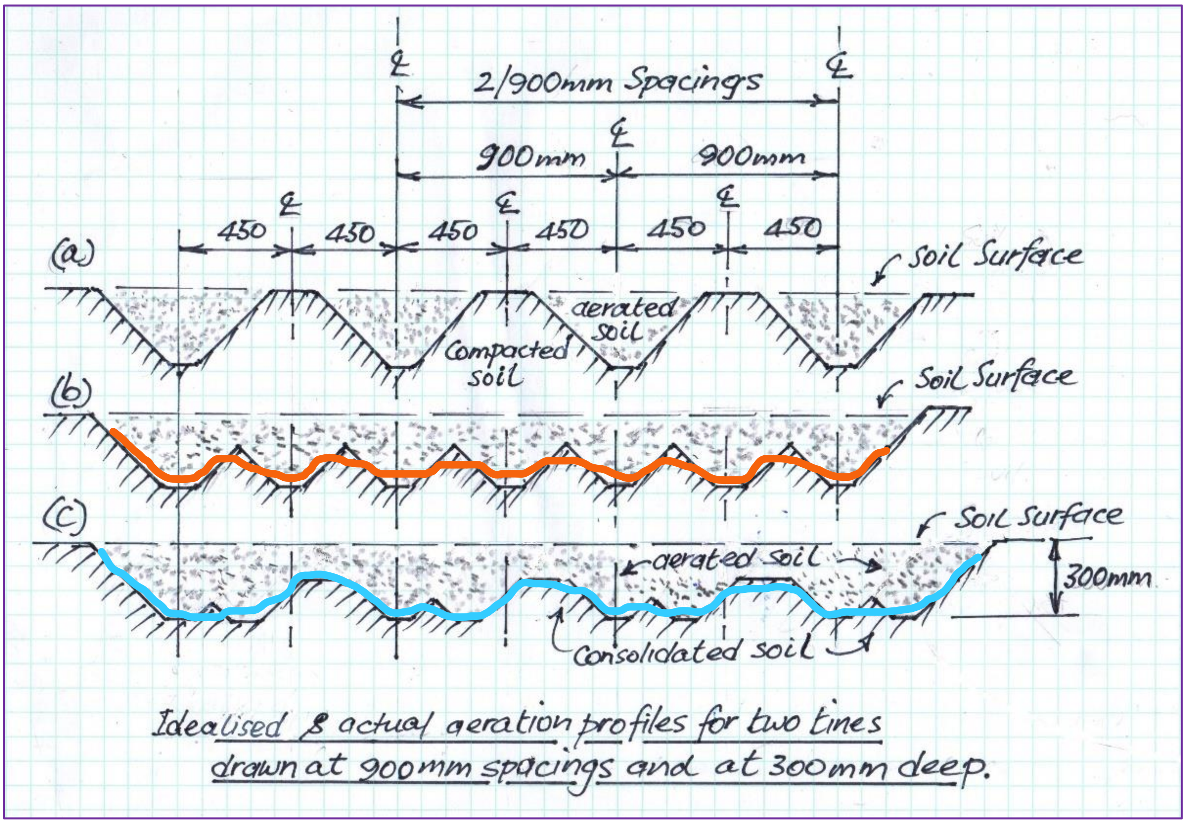


*Figure 11 Idealised ‘Tan’ and actual ‘Blue’ aeration/compaction zones left after aeration ploughing.*

**Objective Three – *To noticeably decrease Soil Acidity in one year.***

Comments: The 'Proof of Concept' November 2016 SWEP results are included and show movement in pHWater from 5.3 to 6.5 for both A&B and A compared to control C from the period November 2016 to January 2018. It is of importance to note that during this period the control C value shifted from 5.3 to 6.0. The above was for 0-100mm depth.

Below 100mm deep the soil pHw was 5.1 in control C at 23/3/2017 as shown in Table 3 and rose to pHw 5.5 in A&B by 22/01/2018. This indicated that the aeration zone had facilitated the amelioration of the aluminium toxicity enabling significant root development below a soil depth of 100mm. **If this observation can be repeated the above is an outstanding outcome.**

Of special interest to these outcomes is that the paddock that held the three trial plots was treated with the amendments below in addition to the Aeration (A) and Aeration and Biology (A&B) described in the methodology and still delivered 0.5 pHwater units greater than the control C in the 0-100mm soli depth. **This is an outstanding outcome.**

- 26th December 2015 and 24th March 2016 two applications of EM (Effective Microbes)/ Vermiculture liquid.
- !6th January 2016 one tonne of Lime and one tonne of Gooram Rock-dust/Ha.

It is to be noted, for the 0-100mm soil depth, that the Exchangeable Hydrogen Cation Percentage, corresponded inversely to the increase in pHwater values. i.e. November 2016 - 62%, March 2017 - 43% and January 2018 - 16% where the Desirable Hydrogen Exchangeable Cation is 10%. **This was an expected but confirming outcome.** This confirms 'Objective Three – pH change in Soil Acidity in one year'.

*Table 3 The percentage change on pHw/pHca for each of the three-trial plots and for two depths: 0-100 and 100-200mm including the 'Proof of Concept' values to be used for an earlier comparison. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.* Note: $^{XX}$ Denotes Extractable Aluminium at 3.16 ppm indicating aluminium toxicity is not a concern and will not inhibit plant growth. $^{X}$ Denotes Extractable Aluminium 85.8 ppm indicating aluminium toxicity is a concern and will inhibit plant growth.

| Date | Variable | A & B | | C | | A | | Comment |
|---|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 | |
| 28/11/2016 | pH Water/Ca | 5.7/5.09* | | 5.3/4.74* | | | | * 0-150mm Aeration only |
| 23/03/2017 | pH Water/Ca | $5.8^{XX}$/5.16 | $5.1^{X}$/4.46 | $5.8^{XX}$/5.16 | $5.1^{X}$/4.46 | $5.8^{XX}$/5.16 | $5.1^{X}$/4.46 | $^{X}$ Refer Extractable Aluminium note. |
| 22/01/2018 | pH Water/Ca | 6.5/5.97 | 5.5/4.89 | 6.0/5.35 | 5.3/4.73 | 6.5/5.99 | 5.6/4.95 | |

**Objective Four – *To Double the Pasture Growth in one year.***

Comments: It is not known whether the pasture growth was doubled in one-year since the pasture production was not measured for the three trial plots as the trial plot areas were not fenced off and were periodically grazed by sheep. It was observed the treated pastures were preferentially grazed by the sheep, at every opportunity, which made the task of estimation comparative pasture production impossible. The grasses in A&B and A initiated earlier germination and growth (predominantly rye, silver grass and white clover) however pasture in the control C caught up latter in the season, remained greener longer and it appeared to exceeded pasture growth in A&B in the end. In 2017, compared to 2016, there was significantly less cape weed in the paddock that contained the trial plots.

*Figure 12 This figure shows the pasture growth in the cage as at 25th October 2017 for A&B.*

*Figure 13 This figure shows the pasture growth in the cage as at 25th October 2017 for C.*

*Figure 14 This figure shows the pasture growth in the cage as at 25th October 2017 for A.*

*Figure 15 Plan view of pasture cage for A&B.*

*Figure 16 Plan view of pasture cage for C.*

*Figure 17 Plan view of pasture cage for A.*

### Sub-Objective One - *Roots and Microbial Action.*

Comments: The roots along the aeration lines plunged down into the aerated zone for both A&B and A whereas the root depth in C remained at approximately 120mm deep. In the A&B trial plot many of the roots near the surface appeared like 'dreadlocks'. These 'dreadlocks' comprised a central root structure with innumerable hair-roots which gave the impression of 'dreadlocks'. When viewed under the microscope the hair-roots were inhabited with "zillions" of bacteria in comparison to the sparely populated bacteria in adjacent soil particles distant from any roots. Such a differentiation was not seen or could not present itself in the 'Microbe-Wise' Microbial Populations, Soil Indicators and Key Microbe Groups due to the aggregation of the sampling. It is postulated that many of the observed "zillions" of hair-root bacteria were *Acotobacter chroococcum* which are considered to promote 'nitrogen-binding' in the hair-root zone of grasses when in the presence of adequate oxygen. i.e. a bacterium that becomes involved in Capturing Airborne Nutrients (CAN).

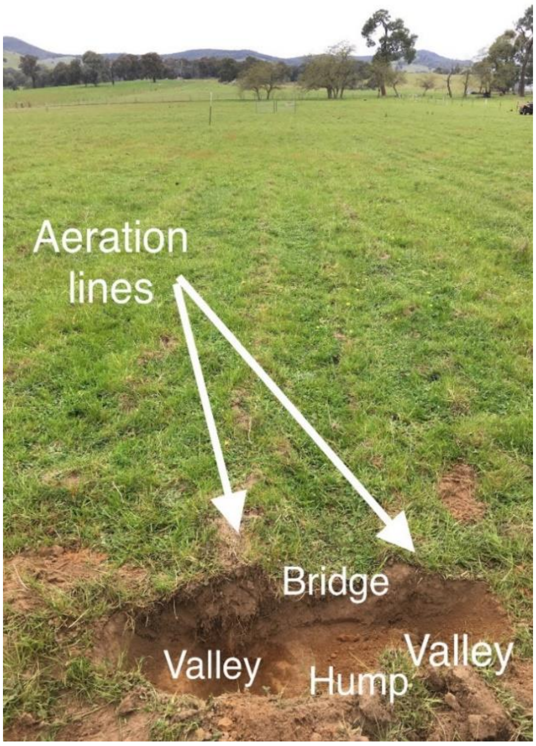


*Figure 18 Shows the roots development in the valleys along the aeration lines and restricted root development on the 'bridge' which bridges the hump from each of the valleys created by the aeration slipper as of 5/10/2017.*


*Figure 19 Shows the extent of root development in an A&B aeration line as at 20th July 2017.*
*When the soil is not totally wet the hair-roots are stripped off as the plant is stripped from the soil.*

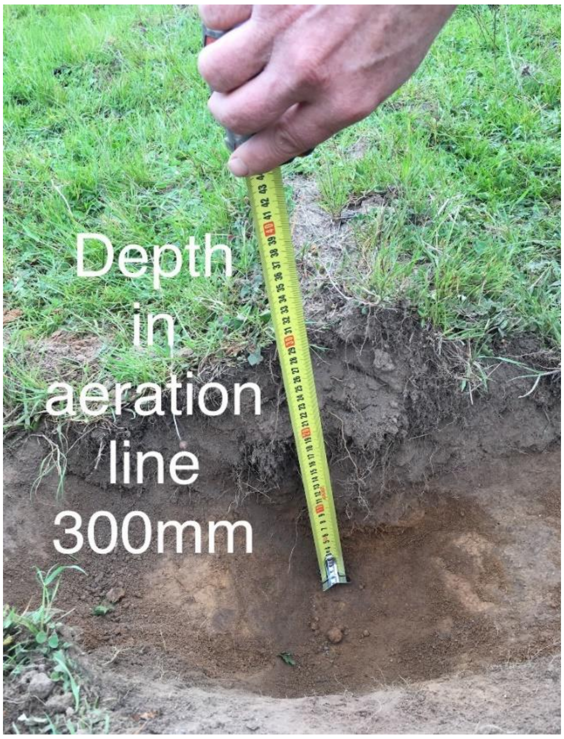


*Figure 20 Shows the root development along an aeration lines as of 5/10/2017. Note the 'Dreadlock' roots close to the surface.*


*Figure 21 Shows the restricted root development at a 'bridge' due to the compacted soil as of 5/10/2017. The root depth of 150mm and has increased 30mm in root depth due to the subtle shattering of the consolidated soil below the 'bridge'.*

**Sub-Objective Two - *Microbial Populations* 'Microbe-Wise' Soil Indicators and Key Microbe Groups: 'Hillside Manor':**

Comments on Microbial Populations, Soil Indicators and Key Groups:

In summary, the Aeration and Biological amendment treatments (A & B) have returned nearly identical values of Microbial Populations and Soil Indicators when compared to the control C with A the lesser except for Bacterial Stress.

A near 100% presence of desirable 'Microbial Populations, Soil Indicators and Key Groups' in the 0-100mm would indicate the mere presence of assessed genetic material is not a guide to active nutrient recycling and consequently good pasture growth. However, the 'Overall Microbial Balance' for the three trial plots was indicative of the observer's evaluation of the trial as it progressed. i.e. the control C, where there were no treatments, did as well as trial plot A&B and better than A in 'Overall Microbial Balance'. It is to be remembered the sheep preferentially heavily grazed the treated trial plots to the extent of leaving some grass matter uneaten in the control C.

Also, it should be noted that although 'Microbial Populations, Soil Indicators and Key Groups' of microbes in soils are an essential guide to the makeup of the soil biomass they do not necessarily forebode a productive soil since microbes need to be actively involved in a symbiosis process with plants/Sun which can be readily inhibited by soil compaction and their need for respiration.

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 1/12/2017 | Overall Microbial Balance (Guide) | 96.2 (100) | 77.3 (100) | 96.2 (100) | 70.2 (100) | 91.4 (100) | 71.8 (100) |
| Comment: The Overall Microbial Balance decreases with depth. The Control 'A' has the least. | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1/12/2017 | Nutrient Cycling Rate % | 100% | 85.8% | 100% | 77.1% | 92.9% | 76.7% |
| Comment: The Nutrient Recycling Rate decreases with depth. The Control 'A' has the least at depth. | | | | | | | |
| 1/12/2017 | Microbial Diversity (Guide) | 52.4 (80) | 50.5 (80) | 52.5 (80) | 48.4 (80) | 49.2 (80) | 50.5 (80) |
| Comment: The Microbial Diversity decreases with depth. The Aeration 'A' has the least. Microbial Diversity is substantially below the Guide leaving capacity for increased diversity. | | | | | | | |
| 1/12/2017 | Fungi : Bacteria Ratio (Guide 2.3) | 4.4 (2.3) | 2.9 (2.3) | 4.2 (2.3) | 3.4 (2.3) | 5.1 (2.3) | 3.7 (2.3) |
| Comment: The Fungi:Bacteria Ratio increases with depth. The Aeration 'A' has the largest F:B Ratio. Trial plot C at 4.2 is closest to the Guide value of 2.3 for 0-100mm depth. | | | | | | | |
| 1/12/2017 | Bacterial Stress (Guide < 0.5) | 0.4 (<0.5) | 0.8 (<0.5) | 0.5 (<0.5) | 0.9 (<0.5) | 0.4 (<0.5) | 0.6 (<0.5) |
| Comment: The Bacterial Stress values for A&B and A are less than 0.5 for the 0-100mm depth. Greater Microbial Diversity could improve this stress interpretation. Trial plots A&B and A have returned the lowest Bacterial Stress value of 0.4 against a guide value <0.5 and high Fungi:Bacteria Ratio in the 4's and 5's compared to a GUIDE value of 2.3. These microbial Indicators confirm that the control C trial plot was not fully representative within the trial plot area since the microbial indicators are very similar. | | | | | | | |

**Sub-Objective Three – *Soil Chemistry* - 'SWEP' Nutrient Analyses and Comments: 'Hillside Manor'**

## Summary of the comments on Soil Chemistry:

In summary the Aeration and Biology (A & B) and Aeration (A) only treatments did effectively change the pH levels in the soil profiles. This was strongly reflected in a corresponding lesser H % Adjusted Cation Exchange Capacity. **This is an outstanding result and confirms 'Objective Three – pH change in Soil Acidity in one year'.**

Aeration and Biology has possibly increased the Available Mg. Any possible increase in Available Ca is unknown since lime and Gooram Rock was added to the trial plot paddock and an increase would be expected.

The Ca/Mg Ratio is above the GUIDE Ratio of 8:1 in the top 0-100mm for A&B, C and A.

The Exchangeable Cation Ratio Ca/Mg is greater than 2 in all cases.

The maximum Available and Total Nitrogen is in the top 100mm of A&B trial plot as measured in January 2018. Note the increase in both Available and Total Nitrogen since November 2016: there was no added nitrogen. **This is a credible explanation for the increased Nitrogen and justification for aeration and biological amendments as another pathway for capturing airborne nutrients (CAN), in this case nitrogen, from the atmosphere.**

Extractable Aluminium was uniformly low for the 0-100m soil profile with 10 to 60-fold increased values with depth. At these increased levels of aluminium, the root growth in the 100-200mm depth would, under usual circumstances, be inhibited since the pHwater is currently around 4.8/4.9 and the aluminium present would have a toxic effect on root growth. Refer to Table 3. However, where there has been aeration the aluminium's presence is not toxic to root development since the aeration has demonstrated accelerated root and root-hair growth in similar challenged environments. ('Spion Kopje' Final Report May 2018) **This poses a conundrum: can soils with what is described traditionally as a toxic level of aluminium be ameliorated by the application of soil aeration in acid soils?**

**Comments on the H %. Adjusted Cation Exchange Capacity:** 1. The 2018 H% Adjusted CEC for A&B and A are both 16% in the 0-100 depth compared to C which is still relatively high at 41%. This strongly reflects the pHwater changes at this depth. i.e. The control C is 0.5 pHwater units more acidic than A&B and A. Refer to Table 3. **This outcome confirms 'Objective Three – pH change in Soil Acidity in one year'.**

*Table 4 The Hydrogen Percentage Adjusted Cation Exchange Capacity (CEC) for each of the three trial lots and for two depths: 0-100mm and 100-200mm. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 23/03/2017 | H %. Adjusted CEC | 45 | 74 | 45 | 74 | 45 | 74 |
| 22/01/2018 | H %. Adjusted CEC | 16 | 64 | 41 | 68 | 16 | 54 |

**Comments on the Available Calcium as a Ratio to the Totals:** 1. One tonne of Lime/Ha and one tonne of Gooram Rock/Ha was applied in the test paddock and this is reflected in an increase in all Calcium levels at both depths although the increased amounts are not uniform over the trial plots. The Available Ca levels in the 0-100mm depths have increased more than 50% for A&B and A compared to C which has increased 61%.

*Table 5 The Calcium Available/Total ratio in ppm. The ratio of available Calcium is shown as a percentage for each of the three trial plots and for two depths: 0-100 and 100-200mm. * 0-150mm deep. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28/11/ 2016 | Ca Available/Total ppm (% avail. of total) | 646/877* 26% | | 396/503* 20% | | | |
| 23/03/ 2017 | Ca Available/Total ppm (% avail. of Total) | 984/1170 16% | 204/256 20% | 984/1170 16% | 204/256 20% | 984/1170 16% | 204/256 20% |
| 22/01/ 2018 | Ca Available/Total ppm (% avail. of Total) | 1418/1920 26% | 400/580 31% | 1070/1510 41% | 286/372 23% | 1722/2270 24% | 726/823 12% |

**Comments on the Available Magnesium as a Ratio to the Totals:** All Available Mg levels and ratios have increased with time. A&B and A are 26% and 23% greater when compared to C at 21% for January 2018. Could this be attributed to the biological amendments?

*Table 6 The Magnesium Available/Total ratio in ppm. The ratio of Available Magnesium is shown as a percentage for each of the three trial plots and for two depths: 0-100 and 100-200mm. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28/11/ 2016 | MgAvailable/Total ppm (% avail. of total) | 69/418 17% | | 53/367 14% | | | |
| 23/03/ 2017 | MgAvailable/Total ppm (% avail. of Total) | 62/1170 5% | 38/368 10% | 62/1170 5% | 38/368 10% | 62/1170 5% | 38/368 10% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 22/01/ 2018 | MgAvailable/Total ppm (% avail. of Total) | 117/446 26% | 69/367 19% | 83/402 21% | 43/277 16% | 109/480 23% | 65/376 17% |

**Comment on the Calcium/Magnesium Ratio:** The Ca/Mg Ratio is above the GUIDE Ratio of 8:1 in the top 0-100mm for A&B, C and A.

*Table 7 The Calcium/Magnesium Ratio for each of the three trial plots for two depths: 0-100mm and 100-200mm. All ratios greater than 2. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28/11/2016 | Ca/Mg Ratio | 9:1 | | 8:1 | | | |
| 23/03/2017 | Ca/Mg Ratio | 16:1 | 16:1 | 16:1 | 16:1 | 16:1 | 16:1 |
| 22/01/2018 | Ca/Mg Ratio | 12:1 | 6:1 | 13:1 | 7:1 | 16:1 | 11:1 |

**Comments: on % Exchangeable Cation Ratio Ca/Mg:** The Exchangeable Cation Ratio Ca/Mg is greater than 2 in all cases.

*Table 8 The % Exchangeable Cation Ratio Ca/Mg for each of the three trial plots for two depths: 0-100mm and 100-200mm. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| Date | Variable | A & B | | C | | A | | Comment |
|---|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 | |
| 28/11/ 2016 | % Exchangeable Cation Ratio Ca/Mg | 43/7.7* 5.6 | | 29.2/6.5* 4.5 | | | | * 0-150mm Aeration only |
| 23/03/ 2017 | % Exchangeable Cation Ratio Ca/Mg | 49.1/5.1 9.6 | 17.7/5.4 3.3 | 49.1/5.1 9.6 | 17.7/5.4 3.3 | 49.1/5.1 9.6 | 17.7/5.4 3.3 | |
| 22/01/ 2018 | % Exchangeable Cation Ratio Ca/Mg | 69.4/9.6 7.2 | 25.5/7.3 3.5 | 49.3/6.4 7.7 | 23.2/5.8 4.0 | 72.8/7.7 9.5 | 37.8/5.7 6.6 | |

**Comments on the Available Nitrogen as a Ratio to the Totals:** The maximum Available and Total Nitrogen is in the top 100mm of A&B trial plot as measured in January 2018. Note the increase in both Available and Total Nitrogen since November 2016: there was no added nitrogen. These values do not account for nitrogen metabolised into the plant tissue. The question does arise as to whether this is due to the stimulation caused by aeration or inoculation with additional Acotobacter bacteria; the data would suggest perhaps both. It is known that stimulated Acotobactor bacteria does capture more Nitrogen from the atmosphere when more oxygen is readily available to these 'nitrogen-binding' bacteria and so of the critical importance to reduce compaction in the soil profile. **This is a potentially critical explanation of the increased Nitrogen and justification for aeration and biological amendments as another pathway for capturing nitrogen from the atmosphere.**

*Table 9 The Available Nitrogen to Total Ratio in ppm. The percentage of Available to Total is shown in brackets. * Sample depth 0-150mm and aeration only. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28/11/ 2016 | N Available/Total ppm (% avail. of total) | 0.6/2110* (0.02%) | | 0.12/1430* (0.01%) | | | |
| 23/03/ 2017 | N Available/Total ppm (% avail. of total) | 11/2220 (0.5%) | 2.3/573 (0.4%) | 11/2220 (0.5%) | 2.3/573 (0.4%) | 11/2220 (0.5%) | 2.3/573 (0.4%) |
| 22/01/ 2018 | N Available/Total ppm (% avail. of total) | 16.5/3350 (0.5%) | 3.4/1190 (0.3%) | 8.7/2360 (0.4%) | 3.4/881 (0.4%) | 6.1/2820 (0.2%) | 6.2/1170 (0.5%) |

**Comments on the Available Phosphorus as a Ratio to the Totals:** The available P in January 2018 for the three-trial plot are similar and substantially more that the November 2016 and March 2017 values. **The question arises as to what the operative influence was to increase the P (Olsen) 80-fold?** The Totals P in reserves are substantial.

*Table 10 The Phosphorus Available/Total Ratio in ppm of Available to Total is shown in brackets.28/11/2016 For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 28/11/ 2016 | P Available/Total ppm (% avail. of total) (Olsen) | 0.1/288 (0.04) | | 0.1/227 (0.04) | | | |
| 23/03/ 2017 | P Available/Total ppm (% avail. of total) (Olsen) | 2.39/278 (0.86) | 0.1/123 (0.08) | 2.39/278 (0.86) | 0.1/123 (0.08) | 2.39/278 (0.86) | 0.1/123 (0.08) |
| 22/01/ 2018 | P Available/Total ppm (% avail. of total) (Olsen) | 8.03/337 (2.4) | 7.74/181 (4.3) | 8.44/595 (1.4) | 7.75/127 (6.1) | 6.47/284 (2.3) | 5.77/162 (3.6) |

**Comments on the Extractable Aluminium:** Extractable Aluminium was uniformly low for the 0-100m soil profile with 10 to 60-fold increased values with depth. At these increased levels of aluminium, the root growth in the 100-200mm depth would, under usual circumstances, be inhibited when pHwater is around 4.8/4.9 and the aluminium present would have a toxic effect on root growth. Refer to Table 3. However, where there has been aeration the aluminium's presence is not toxic to root development since the aeration has demonstrated accelerated root and root-hair growth in similar challenged environments. ('Spion Kopje' Final Report May 2018) **This poses a conundrum: can soils with what is described traditionally as a toxic level of aluminium be ameliorated by the application of soil aeration in acid soils?**

*Table 11 Extractable Aluminium in ppm. Note the 0-100mm soil depth values are low and the 100-200mm depths are high which indicate Aluminium soil toxicity that will inhibit plant root growth. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | Al Extractable ppm | 3.16 | 85.8 | 3.16 | 85.8 | 3.16 | 85.8 |
| 22/01/2018 | Al Extractable ppm | 2.24 | 44 | 2.39 | 53.3 | 1.4 | 13 |

### Sub-Objective Four – *Soil Physics* - *Infiltration tests and Penetrometer Tests.*

The aeration activities drastically improved the soil infiltration capabilities which have remained substantially improved over the trial period. It is anticipated the near immediate root curtain development phenomenon in the soil profile will lead to improved soil structure and ongoing improved infiltration rates over time provided the soils are not unduly subjected to soil compaction forces. Penetrometer cross-sectional readings have confirmed the substantive reduction in soil compaction to the depth of the slipper passage: generally, about 280mm.

### Sub-Objective Five – *Comparative costs*

A general cost comparison has been made between conventional pasture production and the aeration/biological amendment methodology used in these four farm trials. The high input farms have higher pasture production and grazed cattle with higher returns, the lower input pasture producers graze sheep.

For 'Hillside Manor' the pasture production was not continuously measured so it was impossible to draw any definitive comparison between conventional pasture production and the aeration/biological amendment methodology. However, if at least comparable pasture production of the two practices was assumed over a period of nine years the aeration/biological amendment methodology would be about a 1/3rd the cost of conventional production. The estimated comparison costs assumed all the work would be conducted by contractors at contractor's rates. The nine-year period assumed three cycles of liming with annual applications of phosphorous, nitrogen and other elements as needed by the conventionally farmer properties compared to a three-yearly aeration and bi-annually application of biological amendments. This finding was based on a single year and ongoing experimentation would be essential to confirm or otherwise these preliminary finding remain representative over the assumed test period.

**Appendix:** The 'Hillside Manor' questionnaire for the 'CAN Project' farm trial 2017 – 2018.

HillsideManorCAN
Questionaire-Survey N

# CAN Project

## (Capturing Airborne Nutrients)

## Final Report of the *'Spion Kopje'* farm trial.

## Saturday 5th May 2018

Boho CFA Fire Shed – Boho Church Road

*Aeration and Aeration & Biological Amendments for soil health and low-cost pasture production*

## Acknowledgements:

'Glen Shee' - Peter and Meg Johnson
'Trevita' – Ken and May Heywood
'Hillside Manor' – Marg Davis
'Spion Kopje' – Ethne Green
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Warrenbayne Hall Committee and Boho CFA Fire Brigade

K.E.V. Engineering Kevin Long - Bendigo, Robby Hodge Biological Practitioner – Euroa,
La Trobe University and NutriSoil – Wodonga. Victoria.

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## Contents:

## CAN Project Summary and specific Summary of the ''Spion Kojpe' - CAN Project farm trial 2017/2018 - Observations/Comments/Findings

Elements of the Objectives for the CAN Project (Capturing Airborne Nutrients) that arose from the 2016 'Proof of Concept' experimentation have been fulfilled within the 2017 'Beyond Soilcare' grant: other objectives partially fulfilled, and others not even partially achieved.

The most striking finding pertaining to the four farming properties was that the treatments (aeration and biological amendments) significantly influenced the plant growth (quantity, quality, variety and seasonal timing) and this finding was attributed to a specific bacteria *Acotobacter chroococumm* that facilitates 'nitrogen-binding' in the root-hair zone of grasses when it is not starved of oxygen. This finding was irrespective of aluminium and pHwater levels indicating an activated localised community of bacterium working in close symbiosis with the plant roots.

The most striking finding specific to 'Spion Kopje' was the vigorous root and hair-root development along the aeration lines where the sampled data recorded plant toxic levels of Extractable Aluminium consistently greater than 100ppm and soil acidity at pHwater 4.9.

The 'Spion Kopje' aeration and biological amendments noticeably accentuated the growth of the monocotyledon (grasses – silver grass). The aeration immediately enhanced the root tip penetration and its development throughout the shattered soil aeration zone while the biological amendments stimulated the plant growth as shown captured in the pasture cages. The existing monocotyledon grasses germinated and reached maturity earlier. The existing pasture in the Control (C) was predominately dicotyledons (flat-weeds) and remained greener into the summer due to its effective tap root. The pasture growth in all three trial plots was inhibited to some degree. White clover remained present in the three trial plots.

## A summary of the Objectives

## Objectives:

**Objective One – *To Double the Soil Carbon in one year*.** Aeration and biological amendments produced **a 2% decrease in organic carbon** in the first 100mm of soil and **a 5% increase** for the 100-200mm depth. Given the enlarger root mass in the treated A&B and A trial plots a larger percentage of OC% was expected compared to C. The reason could to be attributed to the existence of a thick root matt, on the control, just below the soil surface and none on A&B as this organic matter had been consumed by the activated biology during the year.

This OC% would have been greater if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Two – *To Double the Soil Depth in one year*.** Aeration and biological amendments produced about a **500% increase in soil depth**. This was so large an increase because the initial effective soil depth was so small and would have been more general if the aeration slippers had been set closer and deeper enabling a single pass of the tractor resulting in a homogeneous aeration zone.

**Objective Three – *To noticeably decrease Soil Acidity in one year.*** The acidity of the soil remained basically unchanged at pHWater 4.9. The H% Adjusted Cation Exchange

Capacity for the three trial plots has remained basically unchanged at around 79% which corresponds to a small increase in soil acidity.

**Objective Four – *To Double the Pasture Growth in one year.*** It is **not known** whether the pasture growth was doubled in one-year since the pasture production was not measured for the three trial plots as the trial areas were not fenced off and were grazed by sheep, kangaroos and deer. On the 21/9/2017 small pasture cages were installed to enable the monitoring of the growth for the two treatments against the control plot. The aeration initiated earlier germination and growth of the existing grasses (predominantly silver grass) to what appeared to be a greater height than for grasses in C. The grasses in A&B and A quickly out-competed the flat-weed grasses in C. It was observed the treated pastures were preferentially grazed by the animals. The treated pastures started earlier and finished earlier. The root depth and root structure in A&B and A was significantly deeper and more robust than that in control C.

## Sub-Objectives:

**Sub-Objective One - *Roots and Microbial Action*.** The roots along the aeration lines plunged down into the aerated zone for both A&B and A whereas the root depth in C remained at approximately 40mm. In the A&B trial plot many of the roots near the surface appeared like 'dreadlocks'. These 'dreadlocks' comprised a central root structure with innumerable hair-roots which gave the impression of 'dreadlocks'. These hair-roots in turn were inhabited with "zillions" of bacteria compared to minimal bacteria associated with adjacent soil particles. It is postulated that many of the "zillions" of hair-root bacteria were *Acotobacter chroococcum* that attribute to 'nitrogen-binding' in the hair-root zone of grasses.

**Sub-Objective Two - *Microbial Populations.*** The Aeration and Biological amendment treatments (A & B) have returned enhanced values of Microbial Populations and Soil Indicators compared to Aeration only with the Control the least. A near 100% presence of desirable 'Microbial Populations, Soil Indicators and Key Groups' in the 0-100mm would indicate the mere presence of assessed genetic material: is not a guide to active nutrient recycling and consequently good pasture growth.

**Sub-Objective Three – *Soil Chemistry*** The Aeration and Biology (A & B) and Aeration (A) only treatments did not effectively change the pH levels in the soil profiles in the treated trial plots. If anything, the soil became more acid. The H% Adjusted Cation Exchange Capacity for the three trial plots has remained basically unchanged at around 79% which corresponds to a small increase in the soil acidity.

The treatments have not increased the available Calcium whereas the treatments have increased Magnesium by 25%. The Ca/Mg Ratio has remained constant around 4:1.

The higher percentages of Ca and P that remain in the 0-100mm depth of the soil profile could be a 'hangover' from past inputs during cultivation in the 1960s. The percent Available/Total Phosphorus Ratio (P%) was similar for all plots, 0-100mm deep, in January 2018.

The greater amount of Nitrogen in the 0-100mm depth in the A & B trial plot could be attributed to the stimulation of *Acotobactor chroococcum* and subsequent 'nitrogen-binding' from the atmosphere. A bacterium contributing to CAN.

Aluminium is at toxic levels and would inhibit plant root growth at pHw 4.9, however where there has been aeration the root growth has demonstrated accelerated root and root-hair growth which poses a conundrum: **can soils with what is described traditionally as toxic level of aluminium be ameliorated by the application of soil aeration in acid soils?**

**Sub-Objective Four – *Soil Physics*** – Aeration markedly facilitated deep root penetration (whenever there was substantive rainfall) and a significate reduction in compaction was confirmed through penetrometer cross-sectional readings of the A&B and A trial plots on this and the other three farms.

**Sub-Objective Five – *Comparative costs*** – For 'Sp[on Kopje' the pasture production was not continuously measured so it was impossible to draw any definitive comparison between conventional pasture production and that due to the aeration/biological amendment methodology. However, if comparable pasture production of the two practices was assumed over a period of nine years the aeration/biological amendment methodology would be about a 1/3rd the cost of conventional production. The estimated comparison costs assumed all the work would be conducted by contractors at contractor's rates.

## Introduction

For many years it has been well known that judicious aeration of the soil and applications of biological amendments could enhance soil fertility, promote plant growth, build soil resilience and over a period reduce the reliance on artificial inputs. The Yeomans and Wallace ploughs attest to the success of soil aeration and the application of many and varied biological amendments have demonstrated their efficacy over the years.

Dr John Russell of La Trobe University applied a modified Wallace Aerator (slippers at 12 inches spacings and run at 280mm deep) in a loamy soil at a property in the Western District south of Ararat in 2004: just the aeration produced an increase in dry matter of over 50% for four consecutive years confirming the earlier achievements of P. A. Yeoman of Richmond NSW and Geoff Wallace of Kiewa Valley Victoria in the development, manufacturing and sales of numerous soil aerators. At this point it is necessary to distinguish a difference between aeration and deep ripping as they are similar activities with significantly different applications and therefore outcomes.

In January 2016 the modified Wallace Aerator was trialled in granite pluton derived soils at 'Hillside Manor' Warrenbayne on the mild northern slopes of the Strathbogie Ranges. This initial trial, which has become to be known as the 'Proof of Concept', delivered some exceptional results by the years end: a near doubling of the carbon content in the aerated soil profile, nearly double the pasture growth and the top soil depth deepened to the depth of the underside of the slipper - was this fortuitous or could it be repeated in a formalised research trial? It is to be remembered that 2016 was an exceptionally wet year and January 2016 turned out to be a very wet month (106 mm of local rainfall in January 2016) that initiated a plunging root curtain to the depth of the aeration slipper in just six weeks. Refer to figure 1 below. Figures 2, 3 and 4 depict for sole aeration, the developed soil profile and increased pasture growth and cut for measurement. Figures 5 & 6 compare the root development between an undisturbed control, figure 6, and aerated only soil profile figure 5.

*Figure 1 Shows the root curtain plunging into the soil profile shattered by the slipper that passed 280mm below the ground surface. A hand is above the root curtain.*

*Figure 2 Shows a darkened colouration in the soil cross-section outlining the extent of the soil shattered zone that was occupied by the root curtain. The un-shattered zone has less colouration and shallower root profile. The colouration depicts carbon deposition.*

*Figure 3 Shows, in the evening light, the extra growth above where the slippers aerated the soil profile.*

*Figure 4 Shows the initial harvesting of the extra growth due solely to the aeration.*

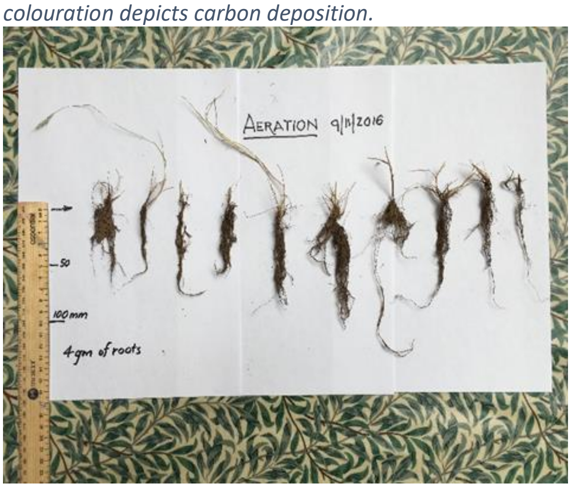


*Figure 5 Shows where roots, taken from an aerated soil profile have become longer by being able to penetrate the shattered soil profile. The thatch was consumed by the activated soil biology.*


*Figure 6 Shows undisturbed soil profile (Control) with short 50mm roots and considerable thatch untouched by the dormant soil biology.*

Based on the above the Warrenbayne/Boho Land Protection Group (Landcare) applied for and were successful to receive a generous 'Beyond SoilCare' grant for a project titled, '*Understanding Microbial/Plant Symbiosis to Double Pasture Production'.* This project was to explore the 'Proof of Concept' findings, above, in rigorous field trials where not only judicious aeration was tested but also biological amendments applied.

***The hypothesis was that if the slipper was set at double the top soil depth would the carbon, pasture growth and soil depth be doubled in one year and the soil acidity reduced?***

Microscopy was an important aspect of the project since it enabled the project participants to observe, under microscopes, the soil microbes and their transformation during the preparation of the amendments in the bio-reactors. Vermiculture was the main source of biological amendments as it was deemed important that relative small-scale farming operations should not only prepare their own biological amendments and low-pressure delivery systems but do so at low cost.

The grant was to be conducted from February 2017 to April 2018 to test the four objectives outlined below. All the samples were tested for Available/Total nutrients and microbial activity by SWEP and Microbe-Wise microbial laboratories. This project was called the 'CAN Project' which stands for Capturing Airborne Nutrients.

Four of the Warrenbayne/Boho Land Protection Group offered their farms to be included in the CAN Project. "Glen Shee', 'Trevista', 'Hillside Manor' and 'Spion Kopje'. The two cattle properties were of relatively medium to high inputs and two sheep properties of relatively low inputs. The size of the properties varied from 100? to 150? Ha. There were no farm inputs on the trial plots at 'Glen Shee', 'Vestiva' and 'Spion Kopje'. At 'Hillside Manor' lime and Gooram Rock was spread to the trial paddock at a rate of 1.0 tonne/Ha in January 2016 together with two applications EM (Effective Microbes) and vermiculture liquid applied in December 2015 and March 2016.

## Weather History

| **Annual Rainfall History in the Warrenbayne/Boho/Benalla Area of Study** | | | | | |
|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | Long-term Average |
| Benalla Airport Station No. 82170 Opened 2006 | 611.1 | 471.8 | 810.4 | 590.1 | 637.8 |
| Strathbogie Station No. 82042 Opened 1902 | 765.0 | 686.6 | 1174.8 | 1013.6 | 965.0 |

"Glen Shee' is approximately 6km SE of the Benalla Airport Meteorological Station. 'Trevista' and 'Hillside Manor' are approximately 19 km SE of the Benalla Airport Meteorological Station and could receive, in addition to the Benalla readings, about two thirds of the difference between the registered rainfall at Benalla Airport and Strathbogie Station. 'Spion Kopje' could receive the average Strathbogie Station rainfall.

The rainfall experienced in the 2016 'Proof of Concept' experimentation year of 2016 at 'Hillside Manor' was noticeably above the long-term averages for both stations.

## Soil Type and Trial Plot Location for 'Spion Kopje'.

The Strathbogie Plateau (500m) is a granite pluton with Red Kurosol soils.

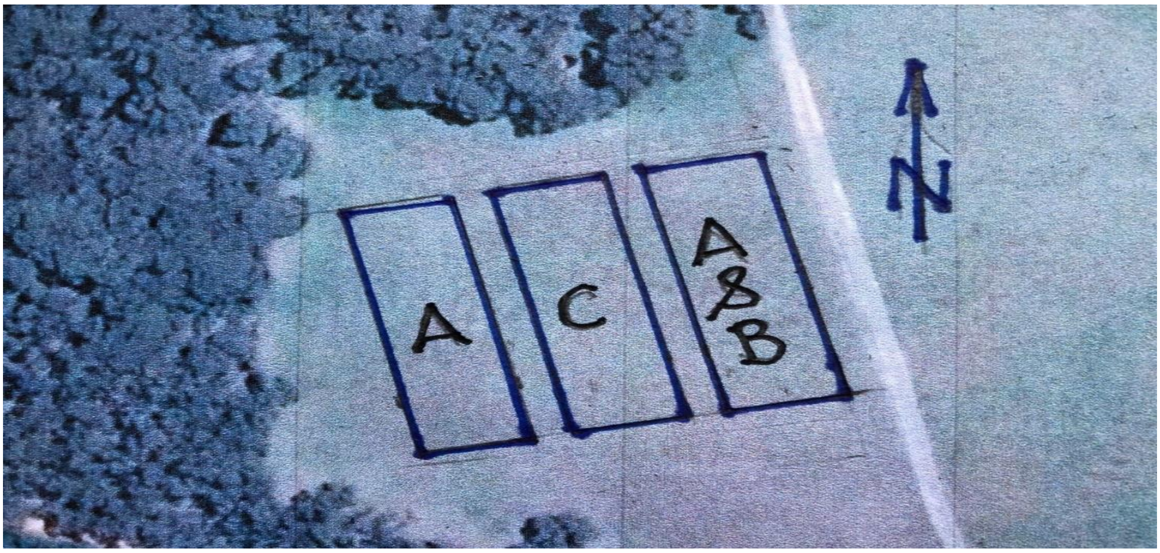


*Figure 7 Shows the three 'Spion Kopje' 30m x 100m trial plots. The separations are 10m wide. 'A' is Aeration, 'C' is Control and 'A&B' is Aeration and Biology.*

## Objectives:

Objective One – *To Double the Soil Carbon in one year.*
Objective Two – *To Double the Soil Depth in one year.*
Objective Three – *To noticeably decrease Soil Acidity in one year.*
Objective Four – *To Double the Pasture Growth in one year.*

## Sub-Objective:

Sub-Objective One - *Roots and Microbial Action.*
Sub-Objective Two - *Microbial Populations*
Sub-Objective Three – *Soil Chemistry*
Sub-Objective Four – *Soil Physics*
Sub-Objective Five – *Comparative costs*

## Methodology

1. The aim was to observe and measure the four objectives over the annual plant life cycle of one year.
2. Select where possible three similar trial 0.5Ha sites for each farm. At 'Spion Kojpe' the trial plots were reduced to 0.3Ha each.
3. The central plot was the Control (C) and the other two plots were the Aeration and Biology (A & B) and Aeration (A).
4. Each of the 0.5Ha plots were 50 x 100m in plan and were divided into a 10 x 10m grid. Samples were taken from a set pattern of 8 sample sites on the grid to provide an averaged sample for laboratory analysis. The 0.3Ha site (Spion Kopje) had 10 set sampling points.
5. All four sites were benchmarked. i.e. A representative average 'C' sample was sent to SWEP for nutrient analysis from the four sites. The returned results are dated 23/03/2017. The only property where the entire three plots were sampled for analyses, prior to commencing the plot treatments, was 'Glen Shee' since it was reasoned this would enable a check on the

uniformity of the soil across a chosen site. There were insufficient funds to benchmark all twelve plots, however it was reasoned the uniformity of the plots for each of the properties could be assumed following our initial inspection and site choice. All samples were analysed for both Available and Total Nutrients present and microbial presence.

6. Aeration Activity – A 130HP tractor pulled the custom-built aeration plough. The plough was setup with three shanks/slippers spaced at 900mm and set to run at about 280mm deep. The tractor would do a second pass to split the previous run and so provided an aeration shank at 450mm spacing giving a near complete shattering of the soil profile to a depth of 280mm. Between the shanks the depth of the shattering was reduced to about one third due to the upward slope of the shattered floor in the soil.
7. Soil aeration was applied to two plots per farm trial. i.e. Aeration and Biology (A & B) and Aeration (A).
8. The microscopes would be used to ascertain the existing microbial populations in numbers and categories using the Elaine Ingham's (USA) methodology (include web address) and simple biological reactors were constructed and used to breed the necessary microbial populations. Mr Tim Wilson's Primers (USA) were used to guide the microbial breeding activities. (include web address)
9. The microbes were applied after the autumn break and into a moist soil. The microbes were delivered in the late afternoon preferably when rain was due or occurring.
10. The microbes were dispersed with very low-pressure pumps or gravity feed distributors to minimise the mortality of the microbes.
11. Biology was applied to only one plot per farm trial.
12. A second application of biology was applied in August/September more as a folia spray that a soil microbial amendment.
13. Final soil sampling was conducted in November and December 2017 and sent to SWEP and Microbial-Wise for laboratory analyses.
14. The project progress was communicated to the farming community through two Field Day Demonstration/Presentations and a regular commentary in the Landcare Newsletter.
15. The findings were reported in a Summary Final Report presented at the Boho CFA Fire Station Boho Church Road on Saturday 5th May 2018. A report of the detailed findings for each of the farms was prepared under four separate covers for loading onto the respective websites.

## Trial Measurements and Observations/Comments/Findings for 'Spion Kopje'

### Objective One –*To Double the Soil Carbon in one year.*

**Comments:** In C the OC% (Organic Carbon %) has decreased from March 2017 to January 2018 and there has been a 2% decrease in OC% for the A&B treatment over C in the January 2018 samples with a 5% increase in the 100-200mm depth. Given the enlarger root mass in the treated A&B and A trial plots a larger percentage of OC% was expected compared to C. The reason could to be attributed to the existence of a thick thatch on the control C and none on A&B.

*Table 1 The percentage Organic Matter or Organic Carbon for each of the three-trial plots and for two depths: 0-100mm and 100-200mm. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 23/03/2017 | OM %/OC% | 10.3/5.2 | 4.0/2.0 | 10.3/5.2 | 4.0/2.0 | 10.3/5.2 | 4.0/2.0 |
| 22/01/2018 | OM %/OC% | 10.1/5.1 | 4.2/2.1 | 9.0/4.5 | 3.4/1.7 | 8.8/4.4 | 4.4/2.2 |

**Objective Two – *To Double the Soil Depth in one year.***

Comment: Compared to the control C, the soil depth in A&B and A have increased in by about 500% and 450% respectively due to the effective root depth of approximately 40mm. Given the hard-dry conditions for aeration in March 2017 the tractor had difficulty in maintaining the target 280mm depth and maintaining a consistent spacing of 450mm as can be seen in figure 8. In this figure note the valleys created by the slippers leaving the consolidated soil profile represented as a hump. All ten grid positioned samples were taken along an aeration line which would offer the highest %C value. The functional active soil depth was approximately 40mm since the roots did not effectively extend into the much earlier (potatoes) cultivation which reveals a 'hang-over' cultivation depth. Refer to figure 11 The plough slipper had a target depth of 280mm. Variations in the effective slipper aeration depth are illustrated in the 'green' pasture lines indicative of a much shallower aeration which caused a 'bridging' effect between the lines of aeration that did not accelerate the germination of the grasses and provided the opportunity fir the flat-weed to persist and prosper into the summer where the compacted subsoil still had moisture.

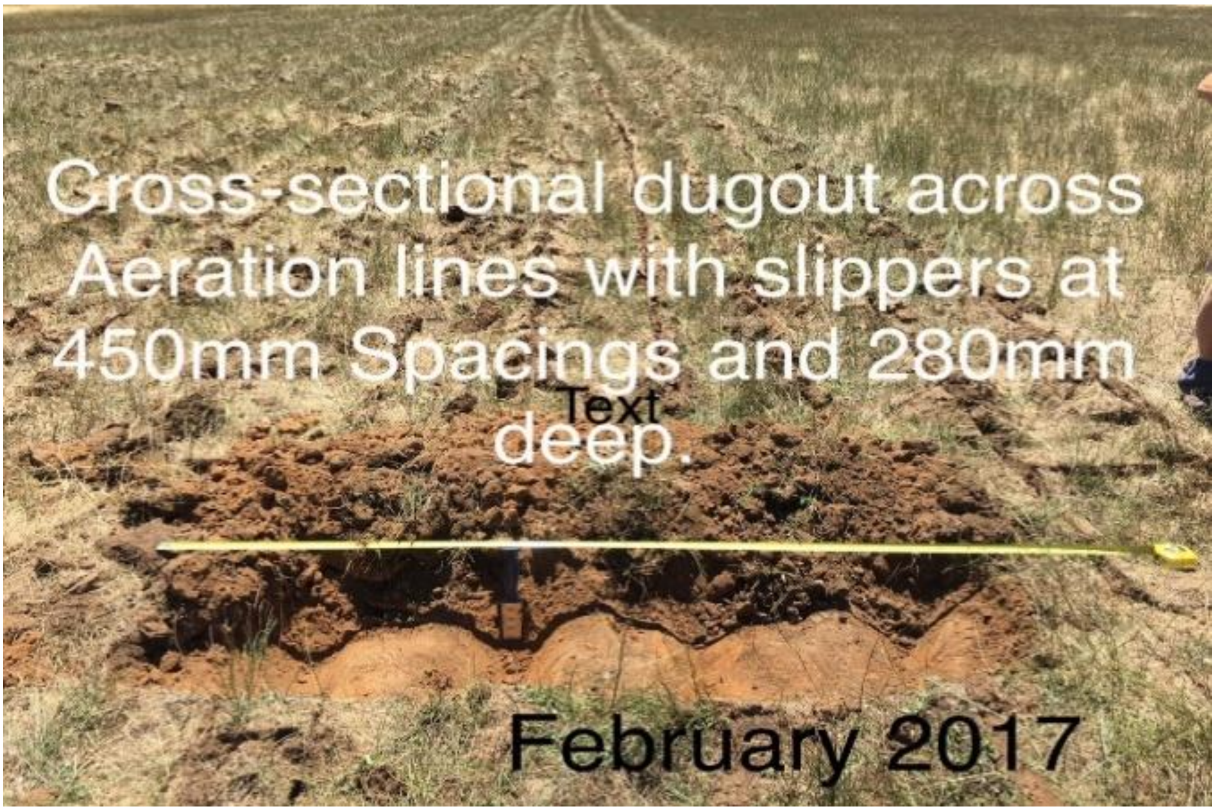


*Figure 8 Shows the valleys and the humps left after a double pass of the aeration plough in February 2017.*

*Table 2 The increase in soil depth, near the aeration line, for each of the three trial plots. The soil slipper target depth for these conditions was 280mm.*

| Date | Variable | A & B | C | A |
|---|---|---|---|---|
| 22/01/2018 | mm | 240 | 40 | 220 |

*Figure 9 "Spion Kopje" looking NNE. Note the green pasture lines a characteristic of the shallower aeration zone where there has been less seasonal growth and now relatively more moisture in the shallower compacted soil.*


*Figure 10 Soil cross-section of A&B. The white line delineates the shattered aerated zone with a maximum depth of approximately 280mm.*

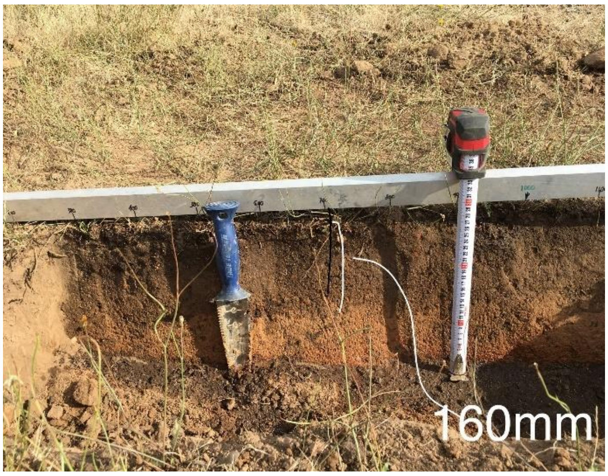


Figure 11 *Soil cross-section of C. The soil depth of 160mm illustrated the old plough depth of a much earlier cultivation. Figure 12 depicts the now active topsoil layer and figure 13 the existing compaction layer.*

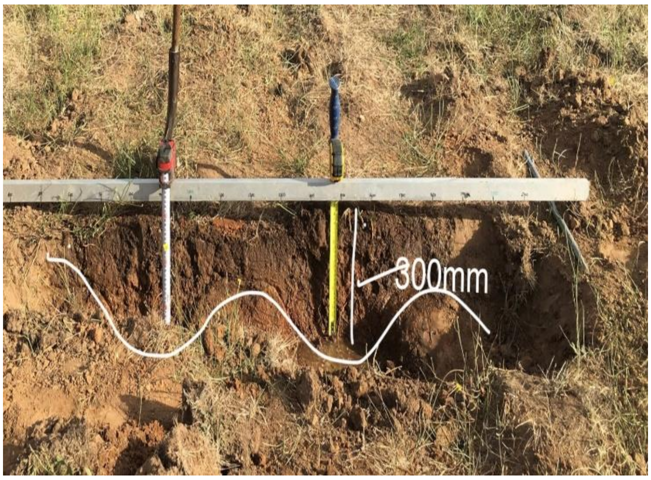


Figure 12 *Soil cross-section of A. The white line delineates the shattered aerated zone with a maximum depth of approximately 300mm. Here there are no layers and a much higher predominance of roots.*

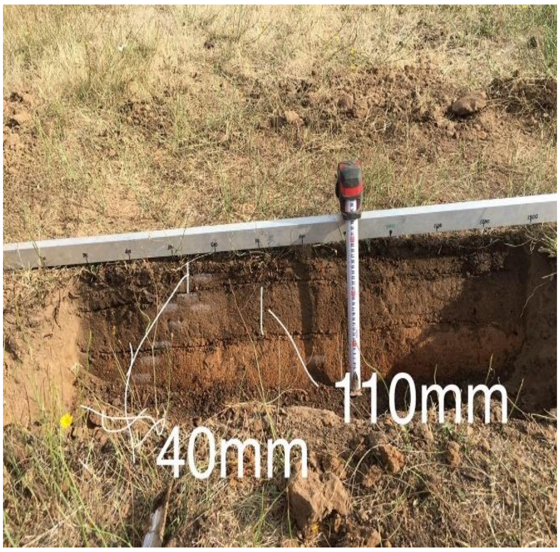


*Figure 13 Depicts the now active 40mm top soil layer and the 110mm top soil 'memory' of earlier cultivation. The scored lines drawn in the soil profile delineate the layers.*

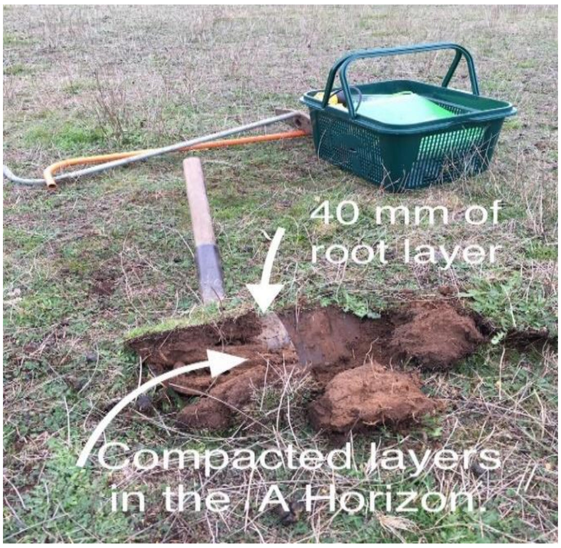


*Figure 14 Depict the current 40mm root layer and multiple compacted layers in the A horizon.*

### Objective Three – *To noticeably decrease Soil Acidity in one year.*

Comments: Compared to the control pH value of C in March 2017 the soil acidity of the soil in January 2018 has increased by 0.1 pHwater units for A&B and 0.2 units for A. The acidity has similarly increased in the 100-200mm depth. It is important to note that the ten 'random grid' samples were always taken along the aeration lines and given the vigorous root and hair-root development along these lines it would be expected that the soil readings to be less acid!

*Table 3 The percentage change on pHw/pHca for each of the three-trial plots and for two depths: 0-100 and 100-200mm.*

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 23/03/2017 | pH Water/Ca | | | 4.9/4.3 | 4.9/4.3 | | |
| 22/01/2018 | pH Water/Ca | 4.8/4.2 | 4.8/4.2 | 4.7/4.1 | 4.9/4.3 | 4.7/4.1 | 4.8/4.2 |

### Objective Four – *To Double the Pasture Growth in one year.*

Comments: It is not known whether the pasture growth was doubled in one-year since the pasture production was not measured for the three trial plots as the trial areas were not fenced off and were grazed by sheep, kangaroos and deer. On the 21/9/2017 small pasture cages were installed to enable the monitoring of the growth for the two treatments against the control plot. The aeration initiated earlier germination and growth of the existing grasses (predominantly silver grass) to what appeared to be a greater height than for grasses in C. The grasses in A&B and A germinated earlier and quickly out-competed the flat-weed grasses. It was observed the treated pastures were preferentially grazed by the animals. The treated pasture started earlier and finished earlier as shown by the figures 15, 16 and 17. The root depth and root structure were significantly deeper than that of the control in figure 23, as a contrast refer to figures 20 (A&B) and (A) figure 26.

Figure 15  This photograph shows the early germination in the A&B trial plot as a different shade of green. The blue tank contains the first biological amendment. 26th May 2017

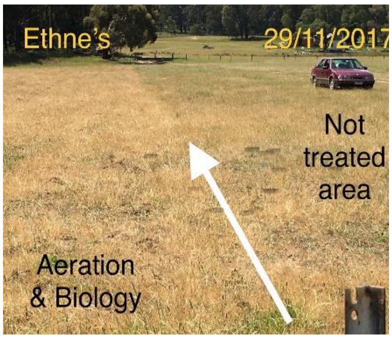


Figure 16 Photograph was taken from a similar position and clearly shows the delineation of the treated and non-treated pasture. 29th November 2018

Figure 17 Photograph shows the graze-out pasture towards the end of summer. The animals did not consume the flat-weed stems and theses can be seen to the right of the steel stake in the non-treated area. 1st March 2018

Figures 18, 19 and 20 are a series of photographs which show for A&B the pasture cage and soil cross-section, the height of the pasture growth as at 26th October 2017 and the penetration of the roots into the aerated shattered zone. The average height of the pasture is approximately 280mm and the maximum depth of the roots is approximately 180mm as of 25th October 2017.

Figure 18 Photograph shows the pasture cage and soil profile cross-section where the deepest roots had reached approximately 180mm deep. The plough slipper was set to run at 280mm deep.

Figure 19 Photograph shows the height of pasture at about 280mm. Mostly grasses (monocotyledons) with white clover on the floor.

a

Figure 20 The white line in this photograph roughly delineates the perimeter of the developing roots.

Figures 21, 22 and 23 are a series of photographs which show for C the pasture cage and soil cross-section, the height of the pasture growth as at 26th October 2017 and the roots confined by the compaction zone. The average height of the pasture is approximately 160mm and the maximum depth of the roots is approximately 40mm as of 26th October 2017.

*Figure 21 This photograph shows the pasture cage and soil profile cross-section where the roots were confined to approximately 40mm deep below which was a defined compaction zone.*

*Figure 22 Shows the height of the pasture at about 160mm. The trowel is 300mm long. The pasture was mainly flat-weed with white clover on the floor*

*Figure 23 The white line in this photograph delineates the root layer from the clearly defined compacted zone. The root depth is approximately 40mm.*

Figures 24, 25 and 26 are a series of photographs which show for A the pasture cage and soil cross-section, the height of the pasture growth as at 26th October 2017 and the penetration of the roots into the aerated shattered zone. The average height of the pasture is approximately 180mm and the maximum depth of the roots is approximately 300mm as of 26th October 2017.

*Figure 24 This photograph shows the pasture cage and soil profile cross-section for the A trial plot where the aeration soil shattered zone is like that of A&B.*

*Figure 25 Shows the height of the pasture at approximately 180xmm. The trowel is 300mm long. The pasture was mainly grasses with white clover on the floor.*

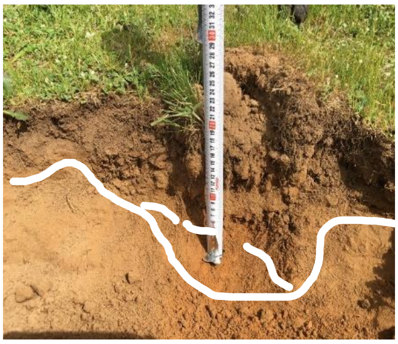

*Figure 26 The solid white line in this photograph delineates the extent of the shattered aeration zone and the dashed white line is the boundary of the root penetration*

The two figures below, figures 27 and 28, clearly illustrate the transformational influence of aeration on the pasture growth at ‘Spion Kojpe’. Figure 26 shows green strips of the less palatable flat-weed that have persisted to grow in the compacted soil left as a ‘bridge’ between the aeration lines which are centred between the green strips. The ‘slippers’ of the aeration plough were set at 900mm spacings and a second passage of the tractor split this setting into 450mm with the intention of aerating a full width to a depth of about 280mm. Obviously this is not the case since the angle of shatter is approximately 40 degrees leaving a ‘bridge’ of partially disturbed top soil which is the preferred environment for flat-weed to flourish.


*Figure 27 This figure shows green strips of the less palatable flat-weed in the A&B trial plot.*

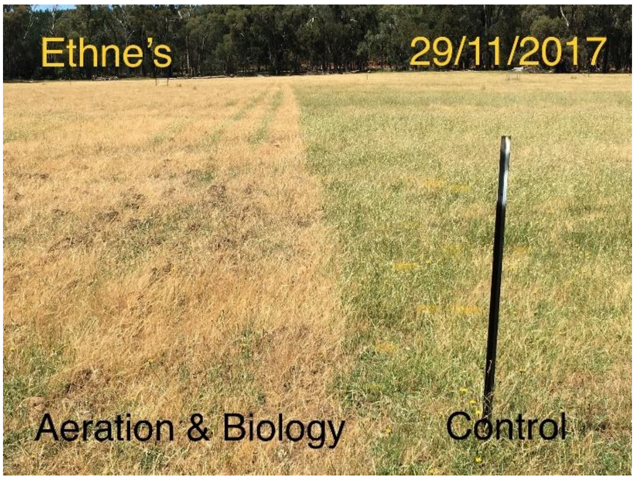


*Figure 28 This figure delineates the pasture growth: flat-weeds persistent in the C and a predominance of existing pasture grasses in the A&B trial plot.*

The following three figures depict the pasture cages where each of the trial plot predominant pastures we able to grow to maturity. In C the green flat-weed is dominant, and its deep roots were still drawing moisture from the compacted soil profile whereas in trial plots A&B and A there are predominantly grasses with little flat-weed. A&B had the most pasture growth. Feed Tests were carried out on the pastures in the three trial plots.

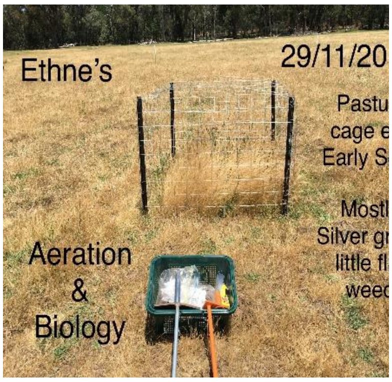


*Figure 29 Shows the extent of the pasture grasses protected in the pasture cages for the A&B trial plot.*

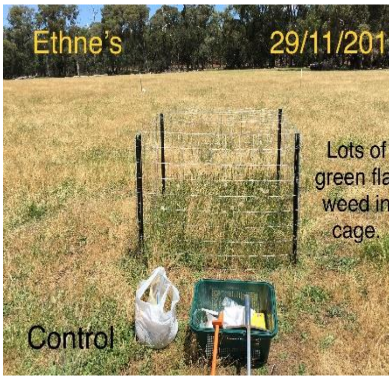


*Figure 30 Shows the exuberant 'green' flat-weed in the pasture cage. Note the 'green' tinge in the remainder of the C trial plot.*


*Figure 31 Shows the pasture grasses in the pasture cage for the A trial plot.*

## Sub-Objective

### Sub-Objective One - *Roots and Microbial Action.*

Comments: The roots along the aeration lines plunged down into the aerated zone for both A&B and A whereas the root depth in C remained at approximately 40mm. In the A&B trial plot many of the roots near the surface appeared like 'dreadlocks'. These 'dreadlocks' comprised a central root structure with innumerable hair-roots which gave the impression of 'dreadlocks'.


Figure 32 Shows as of 21/09/2017 the depth of the root development in the aeration line of the A&B trial plot. The root depth in C was approximately 40mm as of 25th October 2018. Refer figures 20 and 22. Note in the top left-hand corner the 'dreadlock' roots which are roots enlarged with innumeral hair root: the habitat of Acotobacter bacteria.


Figure 33 as for the previous figure except this photograph is of aeration (A) only where the deepened roots are visible emerging from the initial roots zone with no indication of hair roots as in the previous figure indicating an absence of Acotobacter bacteria.

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These hair-roots in turn were inhabited with "zillions" of bacteria when viewed under the microscope and compared to the bacteria associated with an adjacent soil particle. Such a differentiation was not presented in the 'Microbe-Wise' Microbial Populations, Soil Indicators and Key Microbe Groups due to the aggregation of the sampling.

It is postulated that many of the "zillions" of hair-root bacteria were *Acotobacter chroococcum* attributed to 'nitrogen-binding' in the hair-root zone of grasses.

### Sub-Objective Two - *Microbial Populations* 'Microbe-Wise' Soil Indicators and Key Microbe Groups: 'Spion Kopje':

Comments on Microbial Populations, Soil Indicators and Key Groups:

In summary, the Aeration and Biological amendment treatments (A & B) have returned enhanced values of Microbial Populations and Soil Indicators compared to Aeration only with the Control the least. A near 100% presence of desirable 'Microbial Populations, Soil Indicators and Key Groups' in the 0-100mm would indicate the mere presence of assessed genetic material is not a guide to active nutrient recycling and consequently good pasture growth. Also, It should be noted that although 'Microbial Populations, Soil Indicators and Key Groups' of microbes in soils are an essential guide to the makeup of the soil biomass they do not necessarily forebode a productive soil since microbes need to be actively involved in a symbiosis process with plants/Sun which can be readily inhibited by soil compaction and their need for respiration.

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 1/12/2017 | Overall Microbial Balance (Guide) | 96.3 (100) | 76.2 (100) | 96.0 (100) | 65.2 (100) | 94.8 (100) | 67.7 (100) |
| Comment: The Overall Microbial Balance decreases with depth. The Control 'C' has the least. | | | | | | | |
| 1/12/2017 | Nutrient Recycling Rate % | 100% | 88.9% | 100% | 76.9% | 100% | 86.1% |
| Comment: The Nutrient Recycling Rate decreases with depth. The Control 'C' has the least at depth. | | | | | | | |
| 1/12/2017 | Microbial Diversity (Guide) | 53.5 (80) | 47.2 (80) | 50.9 (80) | 43.8 (80) | 51.8 (80) | 4 (80) |
| Comment: The Microbial Diversity decreases with depth. The Aeration 'A' has the least. And substantially below the Guide leaving capacity for increased diversity. | | | | | | | |
| 1/12/2017 | Fungi : Bacteria Ratio (Guide 2.3) | 2.3 (2.3) | 3.5 (2.3) | 3.2 (2.3) | 4.0 (2.3) | 2.9 (2.3) | 4.5 (2.3) |
| Comment: The Fungi:Bacteria Ratio increases with depth. The Aeration 'A' has the largest F:B Ratio. Trial plot A & B is at the Guide value of 2.3. (Biological amendment had been added.) | | | | | | | |
| 1/12/2017 | Bacterial Stress (Guide < 0.5) | 0.7 (<0.5) | 0.8 (<0.5) | 0.6 (<0.5) | 0.8 (<0.5) | 0.7 (<0.5) | 0.9 (<0.5) |
| Comment: The Bacterial Stress values are all greater than 0.5. Greater Microbial Diversity could correct this stress interpretation. Trial plot A&B have returned the lowest Bacterial Stress value of 0.7 against a guide value <0.5 and the GUIDE Fungi:Bacteria Ratio of 2.3. | | | | | | | |

**Sub-Objective Three – *Soil Chemistry* - 'SWEP' Nutrient Analyses and Comments: 'Spion Kopje'**

Summary of the comments on Soil Chemistry:

In summary the Aeration and Biology (A & B) and Aeration (A) only treatments did not effectively change the pH levels in the soil profiles in the treated trial plots. If anything, the soil became more acid. The H% Adjusted Cation Exchange Capacity for the three trial plots has remained basically unchanged at around 79% which corresponds to a small increase in the soil acidity.

The treatments have not increased the available Calcium whereas the treatments have increased Magnesium by 25%. The Ca/Mg Ratio has remained constant around 4:1.

The higher percentages of Ca and P that remain in the 0-100mm depth of the soil profile could be a 'hangover' from past inputs for potatoes grown many years ago. The percent Available/Total Phosphorus Ratio (P%) was similar for all plots, 0-100mm deep, in January 2018.

The greater amount of Nitrogen in the 0-100mm depth in the A & B trial plot could have resulted from both the aeration and biological amendments which would have stimulated the Acotobactor bacteria to capture more Nitrogen from the atmosphere since more Oxygen was more readily available for these 'nitrogen-binding' bacteria. There is no measure for the Nitrogen consumed by the extra plant growth. The percent Available/Total Nitrogen Ratio (N%) was 1% for all plots, 0-100mm deep, in January 2018.

Aluminium is at a toxic level and would inhibit plant root growth at pHw 4.9.

Comments on the H %. Adjusted Cation Exchange Capacity: 1. The H% Adjusted CEC 2018 samples have effectively not changed for the three trial plots. 2. The H% Adjusted CEC for the three trial plots is approximately 8% higher for the 100 – 200mm depth. 3. These H %. Adjusted CEC values corresponds to the pattern of no-change of pH values in 'Objective Three – pH change in Soil Acidity in one year' - refer above.

*Table 4 The Hydrogen percentage adjusted Cation Exchange Capacity (CEC) for each of the three trial lots and for two depths: 0-100mm and 100-200mm.*

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 23/03/2017 | H %. Adjusted CEC | | | 75.6% | 75.8% | | |
| 22/01/2018 | H %. Adjusted CEC | 78.4% | 86.3% | 79.2% | 87.6% | 79.9% | 87.6% |

Comments on the Available Calcium: 1. Ca levels in the 100-200mm depths are of the same order 200 to 300 ppm whereas the total calcium in the top 0 to 100mm varies from 443 to 719ppm with the % Available essentially unchanged. More calcium is available in A&B at 476ppm – there could be an error in the high Total of 719ppm when it is compared to the values of C and A of 443 and 472ppm respectively. It is to be noted the March 2017 Total Calcium for C is 622 whereas the later value in January 2018 is 443. This remains a conundrum and will be watched into the future.

*Table 5 The Calcium Available/Total ratio in ppm. The ratio of available Calcium is shown as a percentage for each of the three trial plots and for two depths: 0-100 and 100-200mm.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | Ca Available/Total ppm (% avail. Of total) | | | 428/622 69% | 159/260 61% | | |
| 22/01/2018 | Ca Available/Total ppm (% avail. of total) | 476/719 (66%) | 167/294 (57%) | 312/443 (70%) | 124/208 (60%) | 294/472 (62%) | 125/265 (47%) |

Comments on the Available Magnesium as a Ratio to the Totals: Mg Available ratio level of 20% in A&B is higher for the 0-100mm depth when compared to C at 16%. by about double whereas in the case of trial plot A & B there appears to be more made Available at 20% compared to C. Could this due to the biological amendments?

*Table 6 The Magnesium Available/Total ratio in ppm. The ratio of Available Magnesium is shown as a percentage for each of the three trial plots and for two depths: 0-100 and 100-200mm.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | MgAvailable/Total ppm (% avail. of total) | | | 96.4/691 (14.0%) | 37.9/620 (6.1%) | | |
| 22/01/2018 | MgAvailable/Total ppm (% avail. of total) | 116/585 (20%) | 42/533 (8%) | 85.7/533 (16%) | 38.0/508 (8%) | 72/489 (15%) | 35/460 (8%) |

Comment on the Calcium/Magnesium Ratio: The Ca/Mg Ratio appears to be consistently around 4 except for the C value at 0-100mm deep in January 2018.

*Table 7 The Calcium/Magnesium Ratio for each of the three trial plots for two depths: 0-100mm and 100-200mm.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | Ca/Mg Ratio | | | 4.4 | 4.2 | | |
| 22/01/2018 | Ca/Mg Ratio | 4.1 | 4.0 | 3.6 | 4.1 | 4.1 | 3.6 |

Comments on the Available Nitrogen as a Ratio to the Totals: The N % Available of Total is consistently around 1.0. This does not consider the amount of nitrogen metabolised into the plant tissue. Again, for the trial plot A & B there is more N in Available and more in Total than for C and A in the January 2018 samplings. The question does arise as to whether this is due to the stimulation or inoculation of additional Acotobacter bacteria; the data would suggest perhaps both. It is known that stimulated Acotobactor bacteria does capture more Nitrogen from the atmosphere when more oxygen is readily available to these 'nitrogen-binding' bacteria and so the critical importance of reducing compaction in the soil profile.

*Table 8 The Nitrogen to Total Ratio in ppm. the percentage of Available to Total is shown in brackets.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | N Available/Total ppm (% avail. of total) | | | 12/4170 (0.3) | 4/1010 (0.4) | | |
| 22/01/2018 | N Available/Total ppm (% avail. of total) | 40/3930 (1.0) | 12/1210 (1.0) | 33/3270 (1.0) | 7/951 (0.7) | 34/3420 (1.0) | 12/1220 (1.0) |

Comments on the Available Phosphorus: The P (Olsen) levels from March 2017 have been reduced and at that time there was 0.7ppm in the 0-100mm of soil depth. Now in January 2018 the P levels in all trial plots has decreased noticeably with substantially more P being Available. P Total levels in the 100-200mm depths are of the same order 160, 119 and 148ppm respectively, whereas the total P in the 0-100mm varies from 7.6, 7.2 and 8.2ppm respectively. The percentage Available being essentially less in the 0-100mm depth as would be expected since there have been no inputs at 'Spion Kopje' for many years.

*Table 9 The Phosphorus Available/Total Ratio in ppm of Available to Total is shown in brackets.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | P Available/Total ppm (% avail. of total) (Olsen) | | | 0.7/325 (0.2%) | 0.1/136 (0.1%) | | |
| 22/01/2018 | P Available/Total ppm (% avail. of total) (Olsen) | 7.6/288 (2.6%) | 6.6/160 (4.1%) | 7.2/224 (3.2%) | 7.5/119 (6.3%) | 8.2/241 (3.4%) | 8.0/148 (5.4%) |

Comments on the Extractable Aluminium: Aluminium (Extractable) appears to be uniformly disseminated through the 0 to 200mm soil profile with increasing concentrations with depth. At these levels of Aluminium root growth would be inhibited however where there has been aeration the root growth has demonstrated accelerated root and root-hair growth which poses a conundrum: **can soils with what is described traditionally as toxic level of aluminium be ameliorated by the application of soil aeration in acid soils?**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | Al Extractable ppm | | | 110 | 185 | | |
| 22/01/2018 | Al Extractable ppm | 101 | 175 | 141 | 179 | 117 | 180 |

### Sub-Objective Four – *Soil Physics - Infiltration tests and Penetrometer Tests.*

The aeration activities drastically improved the soil infiltration capabilities which have remained substantially improved over the trial period. It is anticipated the near immediate root curtain development phenomenon in the soil profile will lead to improved soil structure and ongoing improved infiltration rates over time provided the soils are not unduly subjected to soil compaction forces. Penetrometer cross-sectional readings have confirmed the substantive reduction in soil compaction to the depth of the slipper passage: generally, about 280mm.

### Sub-Objective Five – *Comparative costs*

For 'Spion Kopje' the pasture production was not continuously measured so it was impossible to draw any conclusions between the comparative cost of conventional pasture production and the aeration/biological amendment methodology.

**Appendix:** The 'Spion Kopje' completed farm survey of the 2017-2018 'CAN Project' farm trial 2017 – 2018.

**Trial Participant Feedback.**

As part of the CAN Project, it is valuable to have feedback from those whose properties were involved in the trial. The following questions are provided as a guide to assist you in providing this feedback. A copy of the draft report for your property will be prepared for your consideration and comments before a final report is written and later submitted in April/March 2018

**Property: "SPION KOP", James Track, Boho**

1. **What is the input/amendment record over the past years (10 years if possible) for your trial? Please supply copies if possible. (if you have soil test data, please include. If you have already given this information to John, put 'Already supplied')**

   *There has been no artificial input in the form of fertiliser or soil amendment to the trial plots in the previous 10 years. Some years have had between 6 months and 12 months of grazing by sheep and therefore consequent addition of manure. Manure from grazing by kangaroos, wombats and deer would be the only other form of input to soil fertility. There has been no cultivation or structure change in that time either.*

2. **What is the grazing record for the trial over 2017?**

   *The trial area has had continual grazing by wild animals including kangaroos, wombats and deer, numbers unknown. Approx. 250 wethers have had access to the pasture for blocks of time. From Jan to end of June, 22 weeks, was the first block, then they were excluded until beginning of October. After 4 weeks they were once again excluded and the only grazing was from the wild animals until 8th January 2018 when sheep returned. They have now been here for 7 weeks*

3. **What are your major observations from the trial?**

   *Any differences between the 3 plots were not very noticeable until the spring. After application of the biology, there did seem to be a difference in the colour of the pasture in both A and A + B, but especially in the latter.*
   *The aeration of the soil has definitely changed the pasture content - balance of species, quantity and palatability. The latter is evidenced by the observation that there is now less pasture on both the A only, and A & B plots when compared with the control. The most successful in terms of change (more feed, better quality) of the three plots is the A+B, the only downside being that this plot dried off sooner than the control. The A only plot was disappointing in that, although the grass showed more vigour than the control, it was of less value, dried off quicker and actually contained less clover than C.*

1. **From your experience in this trial, to what extent do you intend to apply any of the findings to your current farming practice?**

   *I would certainly like to continue with both aeration and application of biology. Aeration certainly helped in rejuvenating pasture growth and it would seem that the biology added even more.*

2. **If the above is in the affirmative, what are you thinking of doing and why?**

   *I would like to extend the aeration to another paddock which has a harder and less porous surface and also to the gully which contains a considerable number of rushes. Assuming that rushes grow in areas that are wet and also in areas that are compacted, I am interested to see if breaking up the soil helps to discourage the rushes. I am also interested to see what impact the aeration has on the movement of water through the soil, which in winter is usually waterlogged. It would be good to take a similar approach and only add biology to given sections of these two areas.*

3. **In your view is the trial worthy of extending? If so, do you have specific suggestions as to what should be done?**

   *Yes, I think the trial is definitely worthy of extension. There are too many questions that have arisen out of this trial that need to be addressed. I'm not sure what should be done to answer the following: -*

   - *Why did the grass dry out quicker on both A and A+B? Is this a desirable outcome? On the assumption that the water is going down into the subsoil further, why are the roots not going down to pick up the water? Is it possible that, with the passage of time and further development of roots and soil micro-organisms, the moisture will be retained longer?*

   - *Is it possible to achieve the same or similar results with biology alone?*

   - *Given the very low pH, if artificial fertilizer was added at aeration, would the effects of aeration and biology be more noticeable?*

   - *What seeds could be sown to provide competition with the low nutrition grasses that exist at present?*

   - *Would it be worthwhile doing further aeration on the existing plots to open up the 'lines' which were missed in the first pass?*

4. **In your view, how do you think the microscopes have added benefit, (or otherwise), to the trial? Do you have any suggestions for their use into the future?**

   *For me personally, I haven't gained anything from the microscopes because I haven't spent enough time developing both slide preparation and microscope technique. I think I need a day or 2 half-day workshops in order to develop some confidence with the former and some help in how to use the microscope, find the subjects and then identify different micro-organisms. As a technique for refining choice of micro-organisms and therefore making the most of each application of biology, microscope work is essential, so I still believe it has tremendous value.*

5. **Please add any comments/observations you may have of the other farms that have participated in the trial.**

   *Those farms that started from a much better pH and fertility level seemed to benefit the most from aeration and especially A + B.*

6. **In your view is the trial worthy of extending? If so, do you have specific suggestions as to what should be done?**

   *Yes, I think the trial is definitely worthy of extension. There are too many questions that have arisen out of this trial that need to be addressed. I'm not sure what should be done to answer the following: -*

   - *Why did the grass dry out quicker on both A and A+B? Is this a desirable outcome? On the assumption that the water is going down into the subsoil further, why are the roots not going down to pick up the water? Is it possible that, with the passage of time and further development of roots and soil micro-organisms, the moisture will be retained longer?*

   - *Is it possible to achieve the same or similar results with biology alone?*

   - *Given the very low pH, if artificial fertilizer was added at aeration, would the effects of aeration and biology be more noticeable?*

   - *What seeds could be sown to provide competition with the low nutrition grasses that exist at present?*

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8. **Please add any comments/observations you may have of the other farms that have participated in the trial.**

   *Those farms that started from a much better pH and fertility level seemed to benefit the most from aeration and especially A + B.*

9. **If possible, please record your observation of the trial over 2017, in terms of germination, seasonal influences, growth patterns, grazing, colour, pasture type, ripening, etc.**

| Season | A & B | C | A | General Comments |
|---|---|---|---|---|
| Autumn | Dandelion stalks appeared to brown off and became less prevalent than in both C & A | | | Nothing much until the rain came |
| Winter | | | | I could see little difference between the plots, except that A + B did appear to be a different and more vibrant or glowing green when compared with C. This was not as obvious in the A only plot. |
| Spring | Growth started here before C, was more vigorous, taller and more dense. Clover was also vigorous although it seemed to be taken over by other grasses later. | Although it got away more slowly, it also hung on longer. Clover was as prevalent as A + B and was more prevalent than A but was certainly not as vigorous | As in A+B, growth started earlier than C but clover was sparse and 'tissue paper' grass grew tall but was insubstantial. This plot appeared to be the least productive as it dried off quicker than C | Plots which had treatment of some kind certainly responded to the change in season more promptly, but equally, petered out earlier than C. The A plot was disappointing although it started out to be promising. |
| Summer | In early summer, flat weeds (dandelions) were prominent and still green in rows which matched where the soil had not been aerated. Dandelions were drier and less prevalent in aeration lines. | This plot looked green in comparison to the others but it was because the dandelion stalks were still green | This plot showed similar characteristics to A + B in relation to flat weed stalks, and appears to have been preferentially grazed because there is less feed than on C | Although I couldn't really observe preferential grazing by animal movement, it does appear to be that A + B, and to some degree A as well have been eaten as a preference. There is much less flatweed (dandelion) in these 2 plots. |

# CAN Project

(Capturing Airborne Nutrients)

Final Report of the 'Trevista' farm trial.

Saturday 5th May 2018

Boho CFA Fire Shed – Boho Church Road

*Aeration and Aeration & Biological Amendments for soil health and low-cost pasture production*

## Acknowledgements:

'Glen Shee' - Peter and Meg Johnson
'Trevista' – Ken and May Heywood
'Hillside Manor' – Marg Davis
'Spion Kopje' – Ethne Green
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Iain Atkin Chairperson Warrenbayne/Boho Land Protection Group
and the Landcare Group Members
Greg Bekker Agriculture Victoria – Benalla
Kerri Robson Landcare Project Officer
Neil and Nick Bromley
Warrenbayne Hall Committee and Boho CFA Fire Brigade

K.E.V. Engineering Kevin Long - Bendigo, Robby Hodge Biological Practitioner – Euroa,
La Trobe University and NutriSoil – Wodonga. Victoria.

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## Contents:

## CAN Project Summary and specific Summary of the 'Trevista' - CAN Project farm trial 2017/2018 - Observations/Comments/Findings

Elements of the Objectives for the CAN Project (Capturing Airborne Nutrients) that arose from the 2016 'Proof of Concept' experimentation have been fulfilled within the 2017 'Beyond SoilCare' grant and other objectives only partially fulfilled.

The most striking finding pertaining to the four farming properties was that the treatments (aeration and biological amendments) significantly influenced the plant growth (quantity, quality, varietal-expression and growing period) and this finding was attributed to a specific bacteria *Acotobacter chroococumm* that facilitates 'nitrogen-binding' in the root-hair zone of grasses when it is not starved of oxygen. This finding was irrespective of aluminium and pHwater levels indicating an activated localised community of bacterium working in close symbiosis with the plant roots.

The most striking finding specific to 'Trevista' was the lack of vigorous root and hair-root development below 120mm and the stressed bacteria below this proximity of the soil profile.

## A summary of the Objectives

## Objectives:

**Objective One – *To Double the Soil Carbon in one year*.** Aeration and biological amendments produced **a 42% increase in organic carbon** in the first 100mm of soil. The increase in %C for the control C from March 2017 to November 2017 was 13%. These percentage increases in carbon are much less than double which was the objective. It is expected this 42-13=29% increase will become larger over time as the identified severely stressed bacteria continue to improve their overall microbial presence and approach normalised community diversity and numbers.

**Objective Two – *To Double the Soil Depth in one year*.** Aeration and biological amendments produced about a **15% increase in soil depth**. It is expected increases will become larger over time as the identified severely stressed bacteria continue to improve their overall microbial presence and approach normalised community diversity and numbers.

**Objective Three – *To noticeably decrease Soil Acidity in one year.***

Overall there has been an increase in the pHwater for the three trial plots for the 0-100mm depth in one year. In the depth 100-200mm the pHwater has decreased in A&B, unchanged in C and increased in A. The pHwater is at a level where aluminium presence should not impair root growth.

It is to be noted the Exchangeable Hydrogen Cation Percentages shifted in a correspondingly inverse proportion to the increased pHwater values. **This was an expected, but a confirming, outcome.**

**Objective Four – *To Double the Pasture Growth in one year.*** Aeration and biological amendments produced a 16% increase in pasture in one year. It is to be noted the high inputs and conducive pHwater values ensured the pasture production what high, however this pasture included a large proportion of flatweed which was less desirable. The pasture root zone was predominantly in the 0-120mm depth where there was an entanglement of roots. The aeration and biological amendments produced a very different pasture: one preferred by both the cattle and the farmer since the flatweed was replaced by a dominance of rye grass and phalaris and emerged earlier in the growing season. An ongoing increase in pasture quantity and quality is expected over time as the identified severely stressed bacteria continue to improve their overall microbial presence and approach normalised community diversity and numbers in the 100 to 200mm depth. **This is a significant finding.**

**Sub-Objective One - *Roots and Microbial Action*.** The plant roots in the 'Trevita' trial paddock was bundles of intertwined roots that did not venture much further than 120mm deep. There was an absence of 'dreadlock' type roots plunging down into the soil profile. Because of the aeration and biological amendments, the roots appeared to penetrate to about 150mm deep then stop: small number of roots went deeper. The reason for this would appear to be a soil layer of severely stressed bacteria with low overall microbial balance and nutrient recycling capability. There are signs of improvement, but such improvement will be a gradual process. It will be of interest to monitor this trial plot over the next few years to see whether aeration and biological treatments do successfully enable deep root development.

**Sub-Objective Two - *Microbial Populations.*** The outstanding feature of the 'Soil Indicators' and 'Key Microbe Groups' was the adequacy of the microbial presence in the 0-100mm depth range and the inadequacy of the microbial presence in the 100-200mm depth range.

**Sub-Objective Three – *Soil Chemistry*** The November 2017 H% Adjusted CEC for the 0-100mm depth is lower for all the trial plots but higher in the 100-200mm depths. This reflects the small increases in pHwater at 0-100mm and effectively no change at the 100-200mm depth. It is important to note the pHwater in the control increased the most, from 5.7 to 6.0. There is no explanation for this large increase at this stage.

The Available Ca levels in the 0-100mm depths are approaching the 'Desirable Level' of 1472ppm. More Calcium is available as a percentage for A&B and A compared to C in the 0-100mm depth. All Available Mg levels and ratios have increased from March 2017 to November 2017. Could this be attributed to the biological amendments?

The Ca/Mg Ratio is below the GUIDE Ratio of 8:1 in the top 0-100mm for A&B, C and A and even more so for the 100-200mm deep. The Exchangeable Cation Ratio Ca/Mg is greater than the minimum threshold of 2 in all cases.

An interpretation of the nitrogen levels is that the high levels of residual nitrogen from the previous high input farming practices were depleted to a new level and that level appears to be characteristic of the active presence of *Actobactor chrrococcum.* i.e. around 8ppm. **This is a potentially critical explanation of the steady Nitrogen level and justification for aeration and biological amendments as another pathway for capturing nitrogen from the atmosphere: Capturing Airborne Nutrients (CAN).**

An interpretation of the phosphorus levels is that the levels of residual phosphorus from the previous high input farming practices were reduced to a new level and that level (around 8ppm) appears to be characteristic of the active presence of bacterium similar to *Actobactor chroococcum.* **This is a potentially critical explanation of the steady phosphorus level and**

**justification for aeration and biological amendments as another pathway for the supply of phosphorus from the soil to growing plants.**

Extractable Aluminium was uniformly low for the 0-100m and 100-200mm soil depths. The aluminium present would have no toxic effect on roots.

**Sub-Objective Four – *Soil Physics*** – Aeration markedly facilitated deep root penetration (whenever there was substantive rainfall) and a significate reduction in compaction was confirmed through penetrometer cross-sectional readings of the A&B and A trial plots on this and the other three farms.

**Sub-Objective Five – *Comparative costs*** – For 'Trevista' the pasture production was continuously measured so it was possible to draw a comparison between conventional pasture production due to the aeration/biological amendment methodology. However, for simplicity, if comparable pasture production of the two practices was assumed over a period of nine years the aeration/biological amendment methodology would be about a 1/3rd the cost of conventional production. The estimated comparison costs assumed all the work would be conducted by contractors at contractor's rates.

## Introduction

For many years it has been well known that judicious aeration of the soil and applications of biological amendments could enhance soil fertility, promote plant growth, build soil resilience and over a period reduce the reliance on artificial inputs. The Yeomans and Wallace ploughs attest to the success of soil aeration and the application of many and varied biological amendments have demonstrated their efficacy over the years.

Dr John Russell of La Trobe University applied a modified Wallace Aerator (slippers at 12 inches spacings and run at 280mm deep) in a loamy soil at a property in the Western District south of Ararat in 2004: just the aeration produced an increase in dry matter of over 50% for four consecutive years confirming the earlier achievements of P. A. Yeoman of Richmond NSW and Geoff Wallace of Kiewa Valley Victoria in the development, manufacturing and sales of numerous soil aerators. At this point it is necessary to distinguish a difference between aeration and deep ripping as they are similar activities with significantly different applications and therefore outcomes. Aeration 'slippers' lift and shatter the consolidated soil profile into small discrete pieces whereas deep ripping fractures the soil into large lumps along lines of weakness.

In January 2016 the modified Wallace Aerator was trialled in granite pluton derived soils at 'Hillside Manor' Warrenbayne on the mild northern slopes of the Strathbogie Ranges. This initial trial, which has become to be known as the 'Proof of Concept', delivered some exceptional results by the years end: a near doubling of the carbon content in the aerated soil profile, nearly double the pasture growth and the top soil depth deepened to the depth of the underside of the slipper - was this fortuitous or could it be repeated in a formalised research trial? It is to be remembered that 2016 was an exceptionally wet year and January 2016 turned out to be a very wet month (66 mm of local rainfall in January 2016) that initiated a plunging root curtain to the depth of the aeration slipper in just six weeks. Refer to figure 1 below. Figures 2, 3 and 4 depict for aeration only, the developed soil profile and increased pasture growth and cut for measurement. Figures 5 & 6 compare the root development between aerated only soil profile figure 5 and an undisturbed control, figure 6.

*Figure 1 Shows the root curtain plunging into the soil profile shattered by the slipper that passed 280mm below the ground surface. A hand is above the root curtain.*

*Figure 2 Shows a darkened colouration in the soil cross-section outlining the extent of the soil shattered zone that was occupied by the root curtain. The un-shattered zone has less colouration and shallower root profile.*

*Figure 3 Shows, in the evening light, the extra growth above where the slippers aerated the soil profile.*

*Figure 4 Shows the initial harvesting of the extra growth due solely to the aeration.*


*Figure 5 Shows where roots, taken from an aerated soil profile have become longer by being able to penetrate the shattered soil profile. The thatch was consumed by the activated soil biology.*

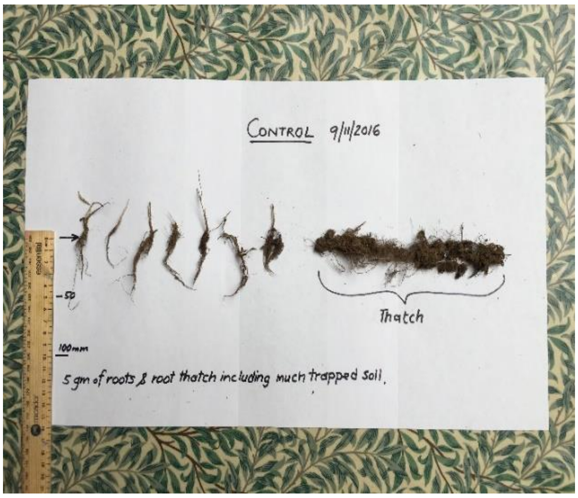


*Figure 6 Shows undisturbed soil profile (Control) with short 50mm roots and considerable thatch untouched by the dormant soil biology.*

Based on the above the Warrenbayne/Boho Land Protection Group (LandCare) applied for and were successful in receiving a generous 'Beyond SoilCare' grant for a project titled, '*Understanding Microbial/Plant Symbiosis to Double Pasture Production'.* This project was to explore the 'Proof of Concept' findings, above, in rigorous field trials where not only judicious aeration was tested but also biological amendments applied.

***The hypothesis was that if the slipper was set at double the top soil depth would the carbon, pasture growth and soil depth be doubled in one year and the soil acidity reduced?***

Microscopy was an important aspect of the project since it enabled the project participants to observe, under microscopes, the soil microbes and their transformation during the preparation of the amendments in the bio-reactors. Vermiculture was the main source of biological amendments as it was deemed important that relative small-scale farming operations should not only prepare their own biological amendments and low-pressure delivery systems but do so at low cost.

The grant was to be conducted from February 2017 to April 2018 to test the four objectives outlined below. All the samples were tested for Available/Total nutrients and microbial activity by SWEP and Microbe-Wise microbial laboratories. This project was called the 'CAN Project' which stands for Capturing Airborne Nutrients. Four of the Warrenbayne/Boho Land Protection Group offered their farms to be included in the CAN Project. "Glen Shee', 'Trevista', 'Hillside Manor' and 'Spion Kopje'. The two cattle properties were of relatively medium to high inputs and two sheep properties of relatively low inputs. The size of the properties varied from 100 to 150 Ha. During the trial there were no farm inputs on the trial plots at 'Glen Shee', 'Trevista' and 'Spion Kopje'. At 'Hillside Manor' both lime and Gooram Rock was spread on the trial paddock at a rate of 1.0 tonne/Ha each in January 2016 together with an application of EM (Effective Microbes) and an application vermiculture liquid. These were applied in December 2015 and March 2016 respectively.

## Weather History

| Annual Rainfall History in the Warrenbayne/Boho/Benalla Area of Study | | | | | |
|---|---|---|---|---|---|
| | 2014 | 2015 | 2016 | 2017 | Long-term Average |
| Benalla Airport Station No. 82170 Opened 2006 | 611.1 | 471.8 | 810.4 | 590.1 | 637.8 |
| Strathbogie Station No. 82042 Opened 1902 | 765.0 | 686.6 | 1174.8 | 1013.6 | 965.0 |

'Trevista' and 'Hillside' are approximately 19 km SE of the Benalla Airport Meteorological Station and could receive, in addition to the Benalla readings, about two thirds of the difference between the registered rainfall at Benalla Airport and Strathbogie Station. 'Spion Kopje' could receive the average Strathbogie Station rainfall. 'Glen Shee' is approximately 6km SE of the Benalla Airport Meteorological Station.

The rainfall experienced in the 2016 'Proof of Concept' experimentation year of 2016 at 'Hillside Manor' was noticeably above the long-term averages for both stations.

## Soil Type and Trial Plot Location for 'Trevista'.

'Trevista' is located on the mild norther slopes of the Strathbogie Ranges, it has several soil types. The trial plot is positioned on a Chromosol type soil. The top soil has a light loamy texture, drains well and sets like concrete in summer beneath the 150mm root zone.

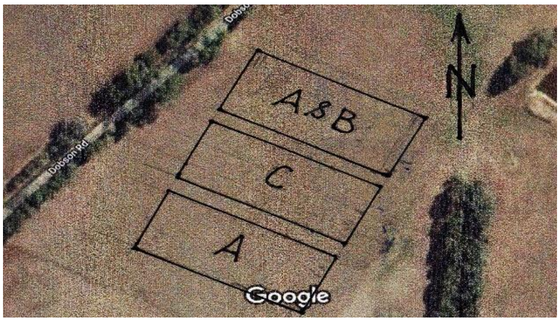


*Figure 7 Shows the three 'Trevista' 50m x 100m trial plots. The separations are 10m wide 'A&B' is Aeration and Biology, 'C' is Control and 'A' is Aeration.*



## Objectives:

Objective One – *To Double the Soil Carbon in one year.*
Objective Two – *To Double the Soil Depth in one year.*
Objective Three – *To noticeably decrease Soil Acidity in one year.*
Objective Four – *To Double the Pasture Growth in one year.*

## Sub-Objective:

Sub-Objective One - *Roots and Microbial Action.*
Sub-Objective Two - *Microbial Populations*
Sub-Objective Three – *Soil Chemistry*
Sub-Objective Four – *Soil Physics*
Sub-Objective Five – *Comparative costs*

## Methodology

1. The aim was to observe and measure the four objectives over the annual plant life cycle of one year.
2. Select where possible three similar trial 0.5Ha sites for each farm. At 'Spion Kojpe' the trial plots were reduced to 0.3Ha each.
3. The central plot was the Control (C) and the other two plots were the Aeration and Biology (A & B) and Aeration (A).
4. Each of the 0.5Ha plots were 50 x 100m in plan and were divided into a 10 x 10m grid. Samples were taken from a set pattern of 8 sample sites on the grid to provide an averaged sample for laboratory analysis. The 0.3Ha site (Spion Kopje) had 10 set sampling points.
5. All four sites were benchmarked. i.e. A representative average 'C' sample was sent to SWEP for nutrient analysis from the four sites. The returned results are dated 23/03/2017. The only property where the entire three plots were sampled for analyses, prior to commencing the plot treatments, was 'Glen Shee' since it was reasoned this would enable a check on the uniformity of the soil across a chosen site. There were insufficient funds to benchmark all twelve plots, however it was reasoned the uniformity of the plots for each of the properties could be assumed following our initial inspection and site choice. All samples were analysed for both Available and Total Nutrients present and microbial presence.

6. Aeration Activity – A 130HP tractor pulled the custom-built aeration plough. The plough was setup with three shanks/slippers spaced at 900mm and set to run at about 280mm deep. The tractor would do a second pass to split the previous run and so provided an aeration shank at 450mm spacing giving a partial shattering of the soil profile to a depth of about 280mm. Between the shanks the depth of the shattering was reduced to about one third due to the upward slope of the shattered floor in the soil.
7. Soil aeration was applied to two plots per farm trial. i.e. Aeration and Biology (A & B) and Aeration (A).
8. The microscopes were used to ascertain the existing microbial populations in numbers and categories using the Elaine Ingham's Primer (USA) (Google: *Elaine Ingham Soil Biology Primer*) and simple biological reactors were constructed and used to breed the necessary microbial populations. Mr Tim Wilson's Primer (USA) (Google: *Tim Wilson Microbe Organics*) were used to guide the microbial breeding activities.
9. The microbes were applied after the autumn break and into a moist soil. The microbes were delivered in the late afternoon preferably when rain was due or occurring.
10. The microbes were dispersed with very low-pressure pumps or gravity feed distributors to minimise the mortality of the microbes.
11. Biology was applied to only one plot per farm trial.
12. A second application of biology was applied in August/September more as a folia spray that a soil microbial amendment.
13. Final soil sampling was conducted in November and December 2017 and sent to SWEP and Microbial-Wise for laboratory analyses.
14. The project progress was communicated to the farming community through two Field Days Demonstration/Presentations and a regular commentary in the Landcare Newsletter.
15. The findings were reported in a Summary Final Report presented at the Boho CFA Fire Station Boho Church Road on Saturday 5th May 2018. A report of the detailed findings for each of the farms was prepared under four separate covers for loading onto the respective websites.

## Trial Measurements and Observations/Comments/Findings for 'Trevista'

### Objective One –*To Double the Soil Carbon in one year.*

Comments: The increase in Organic Carbon %C of A&B compared to C in November 2017 was 42% and the increase in A compared to C was 26%. The increase in %C for the control C from March 2017 to November 2017 was 13%. These percentage increases in carbon are much less than double which was the objective.

*Table 1 The percentage Organic Matter and/or Organic Carbon for each of the three-trial plots and for two depths: 0-100mm and 100-200mm. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 23/03/2017 | OM %/OC% | 6.12/3.06 | 2.1/1.05 | 6.12/3.06 | 2.1/1.05 | 6.12/3.06 | 2.1/1.05 |
| 20/11/2017 | OM %/OC% | 8.7/4.35 | 2.1/1.05 | 6.9/3.45 | 2.1/1.05 | 7.8/3.9 | 2.7/1.35 |

## Objective Two – *To Double the Soil Depth in one year.*

Comment: Compared to the control C, the soil depth in A&B and A have increased by about 33% and 7% respectively. Given the hard-dry conditions for aeration in March 2017 the tractor had difficulty in maintaining the target 300mm depth and maintaining a consistent spacing of 450mm as can be seen in figure 8. The average aeration depth was possibly 280mm and the average soil depth about 200mm. In this figure note the valleys created by the slippers leaving the compacted soil profile represented as a hump. The shattered soil in the valleys can be readily dug by hand. Figure 9 shows a maximum root depth of about 250mm with a depth of perhaps 200mm as the average: for some reason roots have not occupied the full aeration zone. There remains a suspicion that an inhospitable layer starts at a depth of about 150mm. There are few roots in the compacted humps. All eight grid positioned samples were taken along an aeration line which afforded the highest %C values.

*Table 2 The increase in soil depth near the aeration line for each of the three trial plots. The soil slipper target depth for these conditions was 300mm. From observations there remains a suspicion that a chemical/microbial barrier-layer exists starting at a depth of about 150mm inhibiting root development in the soil profile. Refer to the later Sub-Objective discussions on 'Roots and Microbial Actions', 'Microbial Populations' and 'SOIL Chemistry'.*

| Date | Variable | A & B | C | A |
|---|---|---|---|---|
| 20/11/2017 | Average soil depth mm | 150 | 130 | 140 |


*Figure 8 Shows the aeration plough depth in trial plot A&B. The trowel is 300mm long. Note the valleys and humps on the soil surface and the floor. 3rd Feb. 2017*

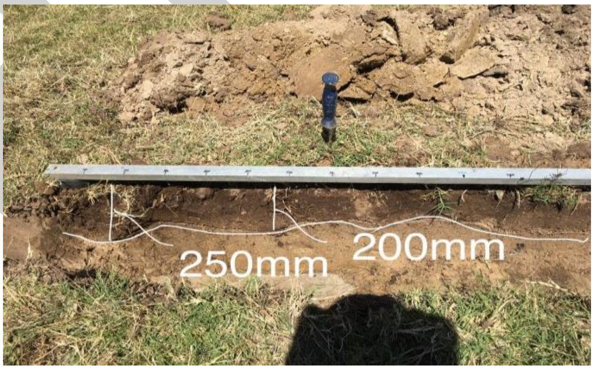


*Figure 9 "Trevista' Looking SE. This is a cross-section of trial plot A&B. Note the valleys created by the slippers and the humps of the compacted soils. Average depth about 150mm.*

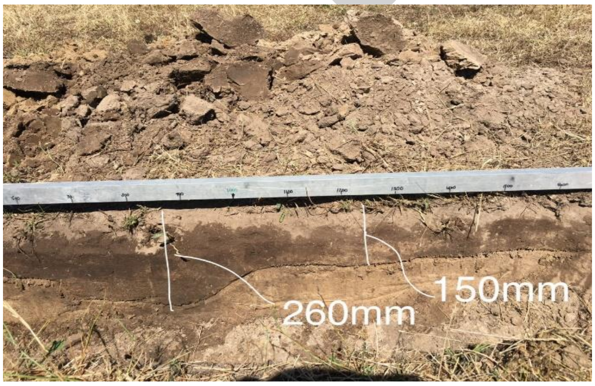


*Figure 10 Soil cross-section of C. The average soil depth is approximately a consistent 130mm deep. The 260mm depth is that of an earlier constructed and filled in drain.*

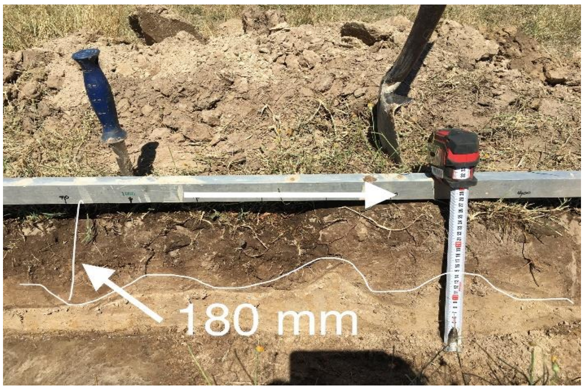


*Figure 11 Soil cross-section of A. Maximum depth of the plough in this harder trial plot was about 200mm. Average soil depth is about 140mm.*

Figure 13 below is an explanation for the valleys and humps shown as white lines in figures 8, 9 and 11. To achieve Objective Two "Double the soil depth in one year" it was necessary to aerate the soil profile to double the depth of the existing soil profile. This would enable the roots tips to be unimpeded by compacted soil, go deeper and be accompanied by activated bacteria. The slipper was set at a target depth of 280/300mm and the tines set at a 900mm spacing.  Refer to (a) in figure 12 below which shows the expected valleys and humps for those settings.  Note the aerated soil and the compacted soil. To achieve a greater depth of uniform aeration the tractor made a second pass at a 450mm offset to produce an improved aeration zone as shown 'tan' in (b). This sketch is idealised as in practice the peaks are rounded off and are not regular as the tines tend to wander (about 100-150mm) from compacted soil to the easier, newly created, aeration line so the outcome is generally as shown 'blue' in (c) where there are larger valleys and humps. Greater horse power would enable one tractor pass, more tines to be included in the ploughing and still maintain a tine behind each rear wheel of tractor.

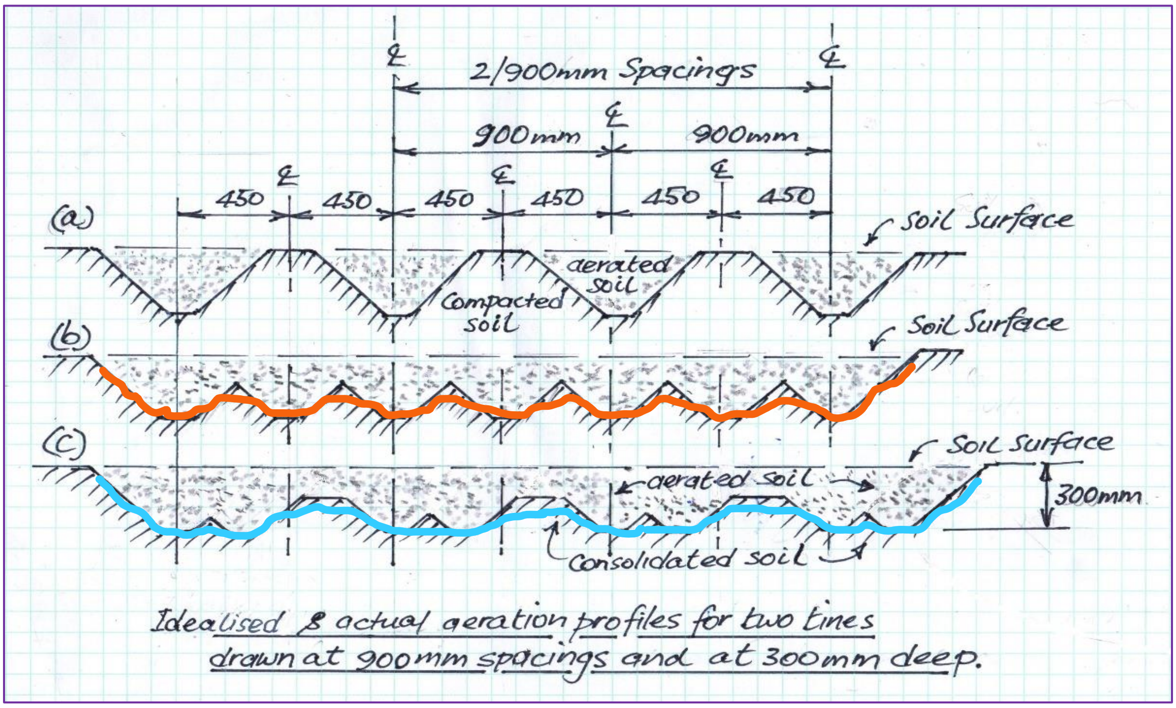


*Figure 12 Idealised and actual aeration/compaction zones left after aeration ploughing.*

### Objective Three – *To noticeably decrease Soil Acidity in one year.*

Comments: Overall there has been an increase in the pHwater for the three trial plots for the 0-100mm depth in one year. In the depth 100-200mm the pHwater has decreased in A&B, unchanged in C and increased in A.  The pHwater is at a level where aluminium presence should not impair root growth. Refer to table 12 for Extractable Aluminium levels.

*Table 3 The change of pHw/pHca for each of the three-trial plots and for two depths: 0-100 and 100-200mm. Extractable Aluminium for all 0-100mm depths are low indicating aluminium toxicity is not a concern for this upper layer and will not inhibit plant growth particularly since the pHwater is 5.6 or above. For all depth between 100-200mm the aluminium toxicity although a little higher should not affect plant growth since the pHwater levels are 5.5/5.6.  For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| Date | Variable | A & B | | C | | A | | Comments |
|---|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 | |
| 23/03/2017 | pH Water/Ca | 5.7/5.11 | 5.6/4.97 | 5.7/5.11 | 5.6/4.97 | 5.7/5.11 | 5.6/4.97 | |
| 20/11/2017 | pH Water/Ca | 5.8/5.22 | 5.5/4.92 | 6.0/5.35 | 5.6/4.99 | 5.9/5.44 | 5.7/5.1 | |

**Objective Four – *To Double the Pasture Growth in one year.*** Aeration and biological amendments produced a 16% increase in pasture in one year. It is to be noted the high inputs and conducive pHwater values ensured the pasture production what high, however this pasture included a large proportion of flatweed which was less desirable. The pasture root zone was predominantly in the 0-120mm depth where there was an entanglement of roots with flatweed tap roots clearly passing through this entanglement to a200mm depth. The aeration and biological amendments produced a very different pasture: one preferred by both the cattle and the farmer since the flatweed was replaced by a dominance of rye grass and phalaris and emerged earlier in the growing season. An ongoing increase in pasture quantity and quality is expected over time as the identified severely stressed bacteria continue to improve their overall microbial presence and approach normalised community diversity and numbers in the 100 to 200mm depth. **This is a significant finding.**

Figure 13 shows the early germination and emergence of the rye and phalaris grasses on the A&B trial plot compared to the control C.  Early germination and emergence was also observed for trial plot A.

Pasture cuts were conducted on 23/11/2017 and the outcomes together with some feed test results are given in in Table 4. The pasture cuts were all done on the same day and the cuts were not made at the most optimum time for each of the plots. Trial plot A was higher up the slope and drained to somewhat heavier/damper soils in C and more particularly A&B. The moisture content in the feed test was the highest in control C where there was a predominance of the deep-rooted flat-weed.

An inspection of the pasture in the three trial plots a day later 24/11/2017 uncovered a significant finding. Trial plot A&B had a predominance of rye, phalaris and clover, (figures 14 and 15). Trial plot A (18 and 19) was mostly a significant stand of rye grass and trial plot C (16 and 17) had a predominance of flat-weed which made up the bulk of control C's dry-matter weight. Refer to figures 14, 16 and 18 to view the differences in the growing pasture, the soil profiles and the different root growth in the three trial plot pastures. It was evident that the flat-weed, (figure 16) which has a tap root, did well in the compacted pasture soil but became out-competed by the rye and phalaris grasses growing in the aerated soil; refer to figure 18.

The cattle had a strong preference for grazing on the A&B and A trial plots before the plots were fenced off, once the fences were removed rye grass and phalaris was the favoured pasture to be grazed by the cattle. In the initial stages, before the fencing off, the trial plot pastures A&B and A were more heavily grazed since there was more of it as it the aeration had advanced its growth by a few weeks.

*Table 4 Shows the Dry Matter derived from pasture cuts and the feed test results of the pasture.*

| Date | Variable | A & B | C | A |
|---|---|---|---|---|
| 20/11/2017 | Dry Matter Kg DM/Ha | 6247 | 5406 | 6371 |
| | % greater than C | 16% | | 17% |
| | | | | |
| 24/112017 | Dry Matter (%) | 31.2 | 30.2 | 38.7 |
| | Moisture (%) | 68.8 | 69.8 | 61.3 |
| | Digestibility (DOMD) (Calc. % of Dry Matter) | 55.5 | 54.9 | 54.2 |
| | Est. Metabolized Energy (Calc.) MJ/Kg DM) | 8.3 | 8.1 | 7.7 |
| | Water Soluble Carbohydrates (% of DM) | 9.1 | 6.3 | 7.7 |

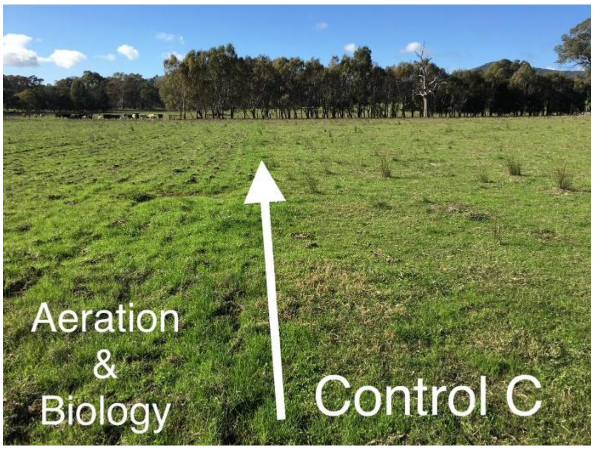


*Figure 13 On the left of this figure the rye grass has germinated, and its growing is advanced. This is attributed to the aeration and biology treatment. On the right of the figure in the Control the ryegrass has not germinated. There was a similar phenomenon in the trial plot A. 2/05/2017*


*Figure 14 Shows a soil cross-section in A&B indicating a single large deep-rooted flat-weed where the stand of rye grass and phalaris is abundant. 25/10/2017.*

*Figure 15 Shows the rye grass and phalaris as at the 24/11/2017 when the average height was about 500mm and there was little lodging.*


*Figure 16 Shows for trial plot C an abundance of clover and flat-weed with some rye grass. The clover and rye grass roots are intertwined and shallow and the flat-weed tap roots are about 150mm deep. 25/10/2017.*

*Figure 17 Shows the trial plot control C in the background as at the 24/11/201. The flat-weed was in flower and looked like a yellow meadow.*


*Figure 18 Shows for trial plot A predominantly rye grass and small clover. Flat-weed is not evident. The roots are working slowly down through the soil profile. 25/10/2017*

*Figure 19 Shows the trial plot A with a predominantly rye pasture severely lodged due to its exuberant growth and lack of competing plants to support it. 24/11/2017.*

**Sub-Objective One - *Roots and Microbial Action.***

On the other three farms the root development along the aeration lines was exuberant and featured roots that appeared like 'dreadlocks' where the main root was enveloped in root hairs covered in small soil particles which were stuck to the hair root surfaces by plant exudate. Microscopic analysis showed these hair roots housed 'zillions' of bacteria, most probably Actobactor *Chrrococuum* that bind nitrogen from the atmosphere when there is adequate oxygen present. An example of such 'dreadlock' roots from one of the other farms, 'Hillside Manor', is shown in figure 20.

In the absence of 'dreadlock' type roots were bundles of intertwined roots limited in depth to about 90 to 110mm deep as can be seen in figures 14, 16 & 18. Note the roots in figure 16, the control (130mm) is even more limited than in figures 14 and 18, A&B and A respectively. It would appear the roots in A&B and A did not venture much further to maybe

150mm deep: a small number went deeper. The reason for this would appear to be because in the 100-200mm depth soil layer there is a severe bacterial stress as can be seen in table 5. An encouraging aspect of this condition is that in A&B and A the roots have partially extended below the root level in the control of C since the bacterial stress has lessened since March 2017, as can be seen in tables 5. It could be presumed that the aeration and biology treatments are having some effect and ameliorating the bacteria stress condition. This could be a gradual process and it will be of interest to monitor this trial plot over the next few years to see whether aeration and biological treatments do successfully enable deeper root development.

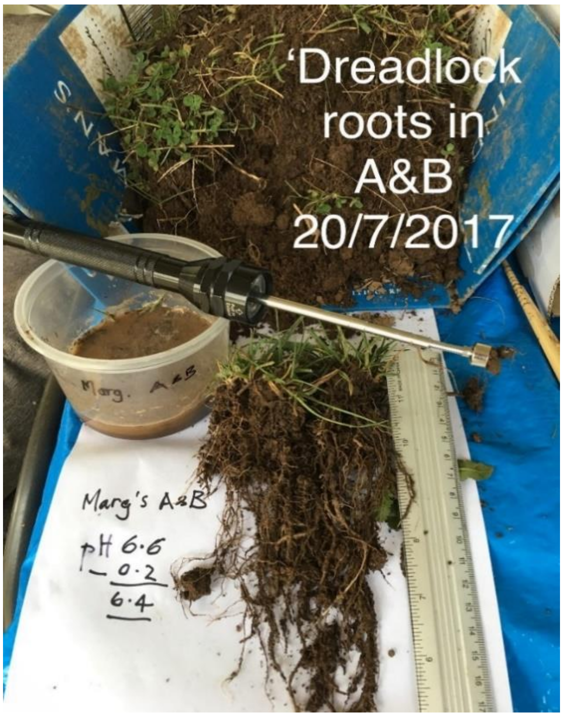


*Figure 20 Shows the extent of root development in an A&B aeration line as at 20th July 2017 at 'Hillside Manor'.* When the soil is not totally wet the hair-roots are stripped off as the plant is stripped from the soil.

### Sub-Objective Two - *Microbial Populations* 'Microbe-Wise' Soil Indicators and Key Microbe Groups: 'Trevista':

The outstanding feature of the 'Soil Indicators' and 'Key Microbe Groups' was the adequacy of the microbial presence in the 0-100mm depth range and the inadequacy of the microbial presence in the 100-200mm depth range. The 'Overall Microbial Balance' for A&B, C and A was 56.7, 46.3 and 63.3 respectively: The Guide was set at 100. Compared to 'Hillside Manor', where there are 'dreadlocks' and significant root development to depth, the 'Trevista' values are on average 20% lower. The Nutrient Recycling Rate % for A&B, C and A was 59.5, 50.1 and 62.0 respectively: The Guide was set at 100. Compared to 'Hillside Manor', where there are 'dreadlocks' and significant root development to depth, the 'Trevista' values are on average 25% lower. The 'Bacteria Stress' for A&B, C and A was 1.1, 0.8 and 0.8 respectively: The Guide was also set at less than 5.

Table 5 *Microbial Populations* 'Microbe-Wise' Soil Indicators and Key Microbe Groups: 'Trevista':

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 7/11/2017 | Overall Microbial Balance (Guide) | 96.7 (100) | 59.5 (100) | 96.3 (100) | 50.1 (100) | 96.3 (100) | 62.0 (100) |
| Comment: The Overall Microbial Balance for the 100mm to 200mm depth is poor. A&B and A have an improved outcome compared to control C. | | | | | | | |
| 7/11/2017 | Nutrient Cycling Rate % | 100% | 56.7% | 100% | 46.3 | 100 | 63.3 |
| Comment: The Nutrient Recycling Rate for the 100mm to 200mm depth is poor. A&B and A have an improved outcome compared to control C. | | | | | | | |
| 7/11/2017 | Microbial Diversity (Guide) | 56.5 (80) | 48.5 (80) | 53.2 (80) | 44.9 (80) | 53.3 (80) | 47.5 (80) |
| Comment: The Microbial Diversity decreases with depth and is substantially below the Guide leaving capacity for an increase in diversity. A&B and A have an improved outcome compared to control C. | | | | | | | |
| 7/11/2017 | Fungi : Bacteria Ratio (Guide 2.3) | 2.6 (2.3) | 2.5 (2.3) | 2.8 (2.3) | 2.4 (2.3) | 2.4 (2.3) | 2.3 (2.3) |
| Comment: The Fungi:Bacteria Ratio decreases with depth. | | | | | | | |
| 7/11/2017 | Bacterial Stress (Guide < 0.5) | 0.5 (<0.5) | 1.1 (<0.5) | 0.4 (<0.5) | 0.8 (<0.5) | 0.4 (<0.5) | 0.8 (<0.5) |
| Comment: The Bacterial Stress values for A&B, C and A are equal to or less than 0.5 for the 0-100mm depth, however, the Bacteria Stress values for 100-200mm deep samples are substantially above the guide values of less than 0.5. | | | | | | | |

**Sub-Objective Three – *Soil Chemistry* - 'SWEP' Nutrient Analyses and Comments: 'Trevista'**

**Comments on the H %. Adjusted Cation Exchange Capacity:** The November 2017 H% Adjusted CEC for the 0-100mm depth is lower for all the trial plots but higher in the 100-200mm depths. This reflects the increase in pHwater at 0-100mm and effectively no change at the 100-200mm depth. **These small changes confirm 'Objective Three – pH change in Soil Acidity in one year'.**

*Table 6 The Hydrogen Percentage Adjusted Cation Exchange Capacity (CEC) for each of the three trial lots and for two depths: 0-100mm and 100-200mm. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| Date | Variable | A & B | | C | | A | |
|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 |
| 23/03/2017 | H %. Adjusted CEC | 33.7 | 45.7 | 33.7 | 45.7 | 33.7 | 45.7 |
| 20/11/2017 | H %. Adjusted CEC | 30.4 | 53.4 | 26.5 | 50.4 | 26.3 | 47.2 |

**Comments on the Available Calcium as a Ratio to the Totals:** The Available Ca levels in the 0-100mm depths are approaching the 'Desirable Level' of 1472ppm. More Calcium is available as a percentage for A&B and A compared to C in the 0-100mm depth.

*Table 7 The Calcium Available/Total ratio in ppm. The ratio of available Calcium is shown as a percentage for each of the three trial plots and for two depths: 0-100 and 100-200mm. * 0-150mm de. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/ 2017 | Ca Available/Total ppm (% avail. of Total) | 1128/1480 76% | 416/541 77% | 1128/1480 76% | 416/541 77% | 1128/1480 76% | 416/541 77% |
| 20/11/ 2017 | Ca Available/Total ppm (% avail. of Total) | 1262/1360 93% | 414/488 85% | 1292/1410 91.5% | 450/495 91% | 1392/1450 96% | 508/1390? 57%? |

**Comments on the Available Magnesium as a Ratio to the Totals:** All Available Mg levels and ratios have increased from March 2017 to November 2017. Could this be attributed to the biological amendments?

*Table 8 The Magnesium Available/Total ratio in ppm. The ratio of Available Magnesium is shown as a percentage for each of the three trial plots and for two depths: 0-100 and 100-200mm. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/ 2017 | MgAvailable/Total ppm (% avail. of Total) | 89/464 19% | 39/355 11% | 89/464 19% | 39/355 11% | 89/464 19% | 39/355 11% |
| 20/11/ 2017 | MgAvailable/Total ppm (% avail. of Total) | 110/479 23% | 53/380 14% | 117/429 27 | 47/293 16% | 113/446 25% | 50/763? 7%? |

**Comment on the Calcium/Magnesium Ratio:** The Ca/Mg Ratio is below the GUIDE Ratio of 8:1 in the top 0-100mm for A&B, C and A and even more so for the 100-200mm deep but are above the minimum threshold of 2.

*Table 9 The Calcium/Magnesium Ratio for each of the three trial plots for two depths: 0-100mm and 100-200mm. All ratios greater than the minimum threshold of 2. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | Ca/Mg Ratio | 7.6:1 | 6.4:1 | 7.6:1 | 6.4:1 | 7.6:1 | 6.4:1 |
| 20/11/2017 | Ca/Mg Ratio | 6.9:1 | 4.7:1 | 6.7:1 | 5.7:1 | 7.4:1 | 6.1:1? |

**Comments: on % Exchangeable Cation Ratio Ca/Mg:** The Exchangeable Cation Ratio Ca/Mg is greater than the minimum threshold of 2 in all cases.

*Table 10 The % Exchangeable Cation Ratio Ca/Mg for each of the three trial plots for two depths: 0-100mm and 100-200mm. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| Date | Variable | A & B | | C | | A | | Comment |
|---|---|---|---|---|---|---|---|---|
| | Depth mm | 0-100 | 100-200 | 0-100 | 100-200 | 0-100 | 100-200 | |
| 23/03/ 2017 | % Exchangeable Cation Ratio Ca/Mg | 54.7/7.2 7.6 | 44.5/7.0 6.4 | 54.7/7.2 7.6 | 44.5/7.0 6.4 | 54.7/7.2 7.6 | 44.5/7.0 6.4 | |
| 20/11/ 2017 | % Exchangeable Cation Ratio Ca/Mg | 57.2/8.3 6.7 | 35.3/7.6 4.6 | 61.3/9.2 6.7 | 39.4/7.0 5.6 | 62.5/8.5 7.4 | 42.9/6.9 6.2 | |

**Comments on the Available Nitrogen as a Ratio to the Totals:** This 'Trevista' trial paddock has a history of high inputs which included nitrogen and the levels as of 23/03/2017, 44ppm, in the control could be representative of such a legacy. The value attributed to the 100-200mm depth is lower at 10ppm. The nitrogen levels as at 20/11/2017 are a fraction of the March 2017 levels but in similar proportions. It is interesting to note the comparative nitrogen values for one of the other farms in the trial ('Hillside Manor'), that displayed 'dreadlocks', deep root development and active biology (most likely *Actobactor chrrococcum*), were A&B, C and A - 16.6, 8.7 and 6.1ppm respectively for the 0-100mm depth. It is of interest to note that the 'Trevista' trial plot A produced a larger N value than C and A was aeration only whereas A&B, which includes biological treatment, had the largest N value of 11.3ppm.

These values do not account for nitrogen metabolised into the plant tissue. The question does arise as to whether this is due to the stimulation caused by aeration or inoculation with additional *Acotobacter bacteria*; the data would suggest perhaps both. It is known that stimulated Acotobactor bacteria does capture more Nitrogen from the atmosphere when more oxygen is readily available to these 'nitrogen-binding' bacteria and so of the critical importance to reduce compaction in the soil profile. **This is a potentially critical explanation of the increased Nitrogen and justification for aeration and biological amendments as another pathway for capturing nitrogen from the atmosphere.**

*Table 11 The Available Nitrogen to Total Ratio in ppm. The percentage of Available to Total is shown in brackets. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/ 2017 | N Available/Total ppm (% avail. of total) | 44/2740 (1.6%) | 10/1110 (0.9%) | 44/2740 (1.6%) | 10/1110 (0.9%) | 44/2740 (1.6%) | 10/1110 (0.9%) |
| 20/11/ 2017 | N Available/Total ppm (% avail. of total) | 11.3/3220 (0.4%) | 3.0/833 (0.4%) | 6.0/2840 (0.2%) | 2.2/677 (0.3%) | 7.4/2900 (0.3%) | 3.12/4420? (0.07%) |

**Comments on the Available Phosphorus as a Ratio to the Totals:** This 'Trevista' trial paddock has a history of high inputs which included phosphorus and the levels as of 23/03/2017, 8.6ppm, in the control, could be representative of such a legacy. The value attribute to the 100-200mm depth is lower at 1.5ppm. The phosphorus levels as at 20/11/2017 were A&B, C and A; 6.4, 5.5 and 6.7ppm respectively for the 0-100mm depth. These values are less than the March 2017 levels but in similar proportions. It is interesting to note the comparative phosphorus values for one of the other farms in the trial ('Hillside Manor'), that displayed 'dreadlocks', deep root development, additional growth and active biology (most likely *Actobactor chroococcum*), are of the same magnitude for the 0-100mm depth. Trial plot A&B, which displayed a slightly smaller value of phosphorus than A, was treated with biological amendments in addition to aeration. A was aeration only. No phosphorus was added to the trial paddock. The Totals P in reserves are substantial.

*Table 12 The Phosphorus Available/Total Ratio in ppm of Available to Total is shown in brackets. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/ 2017 | P Available/Total ppm (% avail. of total) (Olsen) | 8.62/321 (2.7) | 1.48/150 (1.0) | 8.62/321 (2.7) | 1.48/150 (1.0) | 8.62/321 (2.7) | 1.48/150 (1.0) |
| 20/11/ 2017 | P Available/Total ppm (% avail. of total) (Olsen) | 6.43/360 (1.8) | 3.12/145 (2.2) | 5.49/326 (1.7) | 2.34/137 (1.7) | 6.72/340 (2.0) | 3.57/381? (0.9) |

**Comments on the Extractable Aluminium:** Extractable Aluminium was uniformly low for the 0-100m and 100-200mm soil depths. The aluminium present would have no toxic effect on roots.

*Table 13 Extractable Aluminium in ppm. Note the 0-100mm soil depth values are low and the 100-200mm depths are a little higher but should not inhibit plant root growth for a pHwater around 5.5/5.6. For ease of comparison the measured values for C are inserted in A&B and A shown yellow since the control C as at the 23/03/2017 was assumed to be homogeneous across the trial plots.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23/03/2017 | Al Extractable ppm | 2.26 | 4.24 | 2.26 | 4.24 | 2.26 | 4.24 |
| 20/11/2017 | Al Extractable ppm | 2.8 | 12.9 | 2.31 | 8.68 | 2.57 | 4.3 |

### Sub-Objective Four – *Soil Physics* - *Infiltration tests and Penetrometer Tests.*

The aeration activities improved the soil infiltration capabilities which have remained substantially improved over the trial period. It is anticipated progressive root development in the soil profile as the aluminium toxicity decreases will lead to improved soil structure and ongoing improved infiltration rates over time provided the soils are not unduly subjected to soil compaction forces. Penetrometer cross-sectional readings have confirmed the reduction in soil compaction to the depth of the slipper passage: generally, about 280mm.

### Sub-Objective Five – *Comparative costs*

A general cost comparison has been made between conventional pasture production and the aeration/biological amendment methodology used in these four farm trials. The high input farms have higher pasture production and grazed cattle with higher returns, the lower input pasture producers graze sheep.

For 'Trevista' the pasture production was fenced off so it was possible to draw a comparison between conventional pasture production and the aeration/biological amendment methodology. However, if at least comparable pasture production of the two practices was assumed over a period of nine years the aeration/biological amendment methodology would be about a 1/3$^{rd}$ the cost of conventional production. The estimated comparison costs assumed all the work would be conducted by contractors at contractor's rates. The nine-year period assumed three cycles of liming with annual applications of phosphorous, nitrogen and other elements as needed by the conventionally farmer properties compared to a three-yearly aeration and bi-annually application of biological amendments. This finding was based on a single year and ongoing experimentation would be essential to confirm or otherwise these preliminary finding remain representative over the assumed test period.

**Appendix:** The 'Trevista' questionnaire for the 'CAN Project' farm trial 2017 – 2018.

TREVISTA.

## CAN Project Questionnaire

Trial Participant Feedback.

As part of the CAN Project, it is valuable to have feedback from those whose properties were involved in the trial. The following questions are provided as a guide to assist you in providing this feedback. A copy of the draft report for your property will be prepared for your consideration and comments before a final report is written and later submitted in April/March 2018

1. What is the input/amendment record over the past years (10 years if possible) for your trial? Please supply copies if possible. (if you have soil test data, please include. If you have already given this information to John, put 'Already supplied')

| | | |
|---|---|---|
| 2006 | SINGLE SUPER | 125 Kg/Ha. |
| 2007 | LIME | 2500 Kg/Ha. |
| 2008 | SINGLE SUPER | 125 Kg/Ha. |
| 2009 | " " | " |
| 2010 | SUPER/POTASH | 80/40 Kg/Ha. |
| ~~2011~~ | SUPER | 125 Kg/Ha |
| 2011 | SUPER | 125 Kg/Ha |
| 2012 | LIME | 2500 Kg/Ha. |
| 2013 | SUPER/POTASH | 30/90 Kg/Ha. |
| 2014 | SUPER | 125 Kg/Ha. |
| 2015 | " | " |
| 2016 | LIME | 2500 Kg/Ha. |
| | SUPER | 125 Kg/Ha. |

2. What is the grazing record for the trial over 2017?

| | | | |
|---|---|---|---|
| 26.3.17 | 25 COWS | 10 CALVES | 4 DAYS |
| 7.4.17 | " | " | 4 DAYS. |
| 20.4.17 | 25 " | " | 2 DAYS |
| 24.4.17 | " | " | 3 DAYS |
| 13.5.17 | " | " | 2 DAYS |
| 18.7.17 | 14 YEARLING CATTLE | | 5 DAYS |
| 25.8.17 | 25 COWS | 25 CALVES | 3 DAYS |
| 23.9.17 | 15 ~~YEARLINGS~~ CATTLE | | 6 DAYS ½ Ha FENCED OFF. |
| 30.9.17 | 15 YOUNG CATTLE | | 12 DAYS " |
| 19.10.17 | 15 " | " | 6 DAYS |
| 3.11.17 | 15 " | " | 9 DAYS. |

3. What are your major observations from the trial?

IMPROVED MOISTURE ROTENTION
IMPROVED EARLY GROWTH WITH AUTUMN BREAK

CAN Project Questionnaire

4. From your experience in this trial, to what extent do you intend to apply any of the findings to your current farming practice?

I INTEND TO CONTINUE TRIALS WITH DEEP RIPPING AND BIOLOGY.
IN THE TEST AREA WITHOUT APPLYING AND SUPER OR POTASH AND LIME
AND OBSERVE ONGOING RESULTS.

5. If the above is in the affirmative, what are you thinking of doing and why?

DEEP RIPPING IN AJACENT AREA OF TEST PLOT
TO COMPARE WITH THE TEST RIPPING AND AERATION.

6. In your view is the trial worthy of extending? If so, do you have specific suggestions as to what should be done?

YES.
POSSIBLY AERATION TO GREATER DEPTH.
THE BIG PROBLEM WITH THE AERATION RIPPING IS IT LEAVES THE SURFACE FAR TO ROUGH FOR DRIVING OVER AREAS AND ALSO CUTTING HAY AND SILAGE.

7. In your view, how do you think the microscopes have added benefit, (or otherwise), to the trial? Do you have any suggestions for their use into the future?

~~I THOUGHT THAT EARLY GROWTH APPEARED TO GREENER AND STRONGER.~~
I THOUGHT IT WAS GREAT TO SEE THE BIOLOGICAL ACTIVITY.
BUT DID NOT HAVE TIME TO MONITOR ACTIVITY CHANGES.

8. Please add any comments/observations you may have of the other farms that have participated in the trial.

IT APPEARED THAT ROOT DEVELOPMENT WAS MUCH GREATER
AT THE FARMS THAT DID NOT HAVE ONGOING SUPER, LIME AND POTASH HISTORY.
PERHAPS BECAUSE THE ROOTS HAD ACCESS TO SUFFICIENT NUTRIENTS IN THE TOPSOIL.