The Wilmot Project
2019 Report

GHG and Co-Benefits in Grazing Systems

REGEN
NETWORK

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1. ELIGIBILITY

The land included within the project boundary corresponds to temperate grasslands under ***Prescribed Grazing*** (i.e short duration-high density-long recovery grazing), listed within the eligible land management practices from the CDFA Healthy Soils Program[1], in accordance with the Credit Class[2].

2. PROJECT BOUNDARY

2.1. SPATIAL BOUNDARIES

The Wilmot farm is located in eastern New South Wales, Australia (Figure 1). It is divided into 88 parcels, totalling 1852 ha (Figure 2).

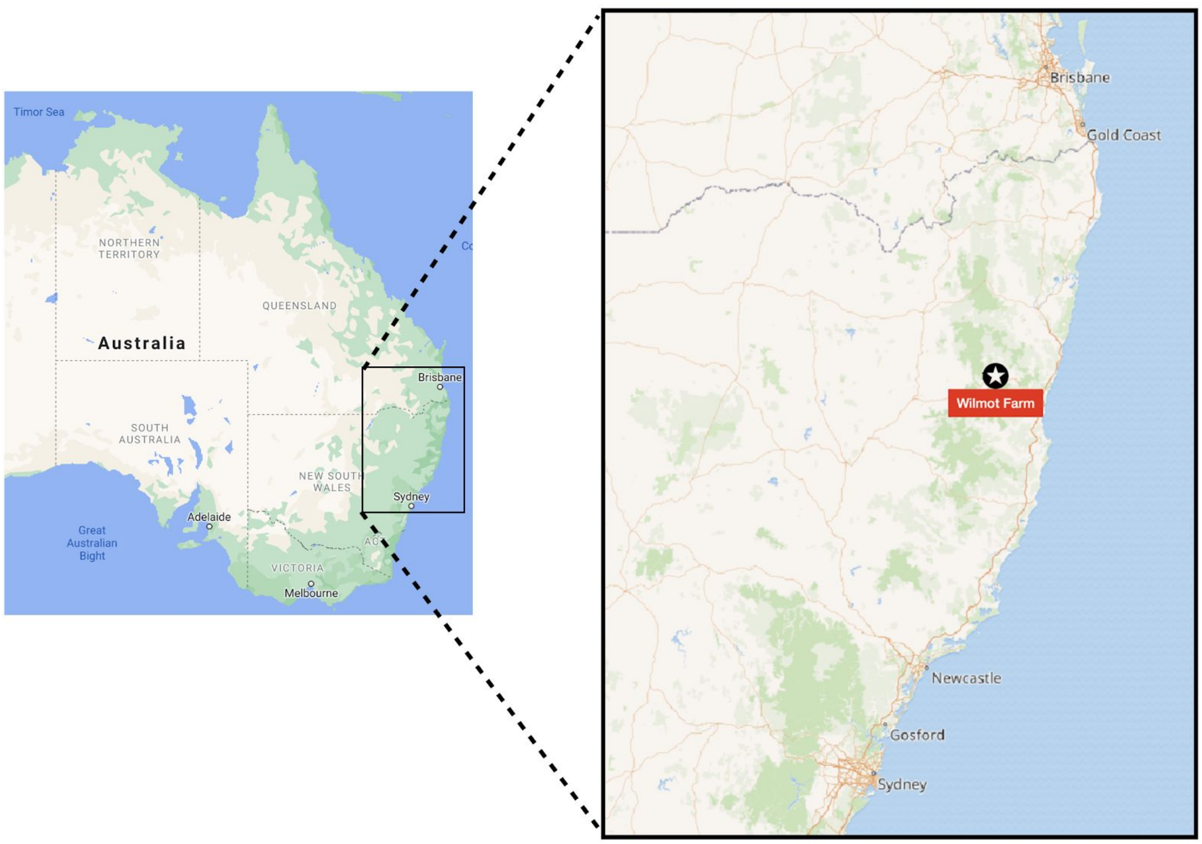

Figure 1. Location of the Wilmot Farm within eastern New South Wales, Australia.

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[1] AGRICULTURAL MANAGEMENT PRACTICES ELIGIBLE FOR FUNDING THROUGH THE CDFA HEALTHY SOILS PROGRAM (HSP)
[2] GHG & Co-Benefits in Grazing Systems Credit Class

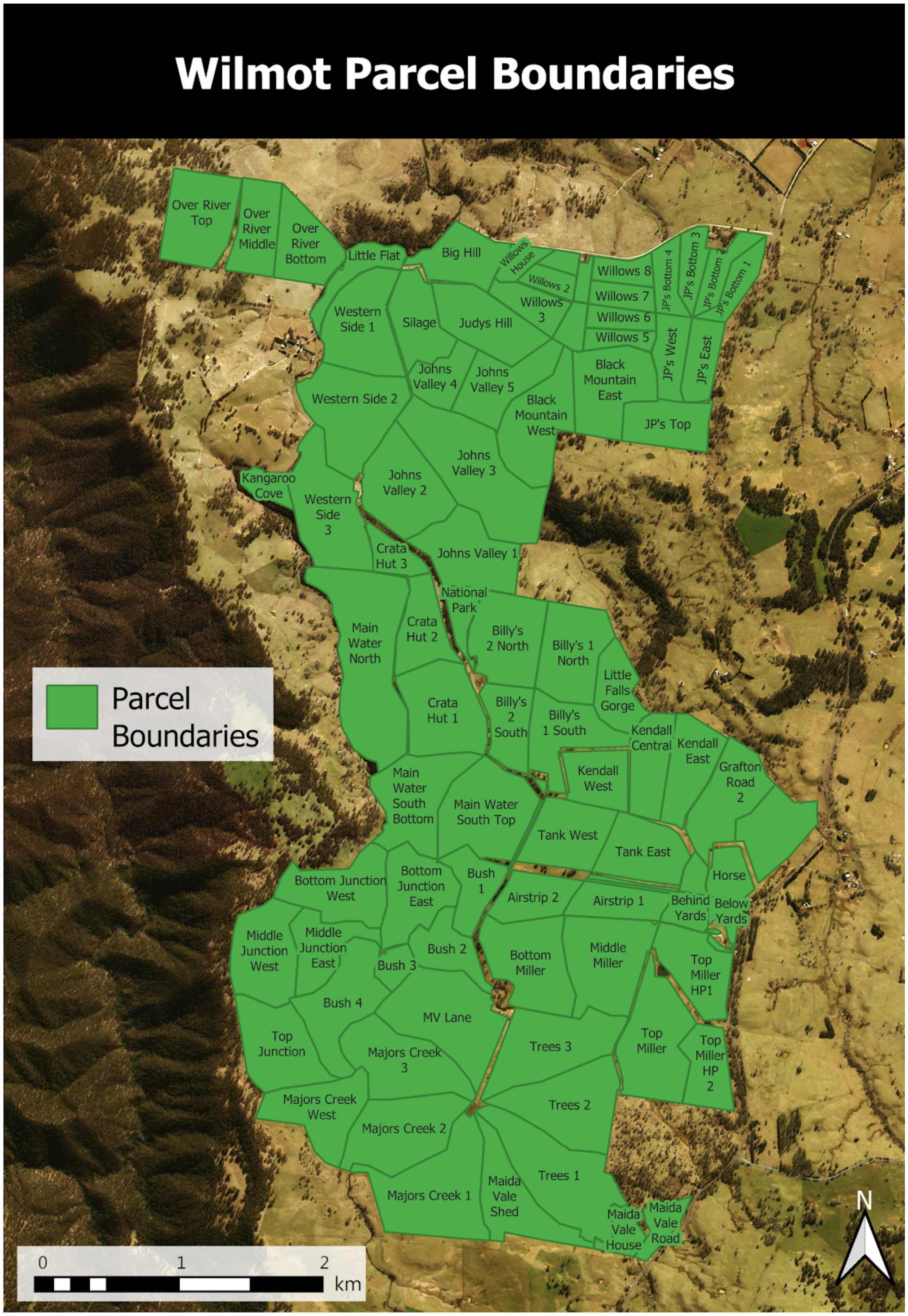


Figure 2. The Wilmot parcels.

To ensure only grasslands were included in the study area, a binary filter created in QGIS using a combination of NDVI and visual inspection was applied to all input rasters to remove any man-made objects, such as roads, and trees. The masked area accounts for only grassland cover and has an estimated area of 1094 ha (Figure 3).

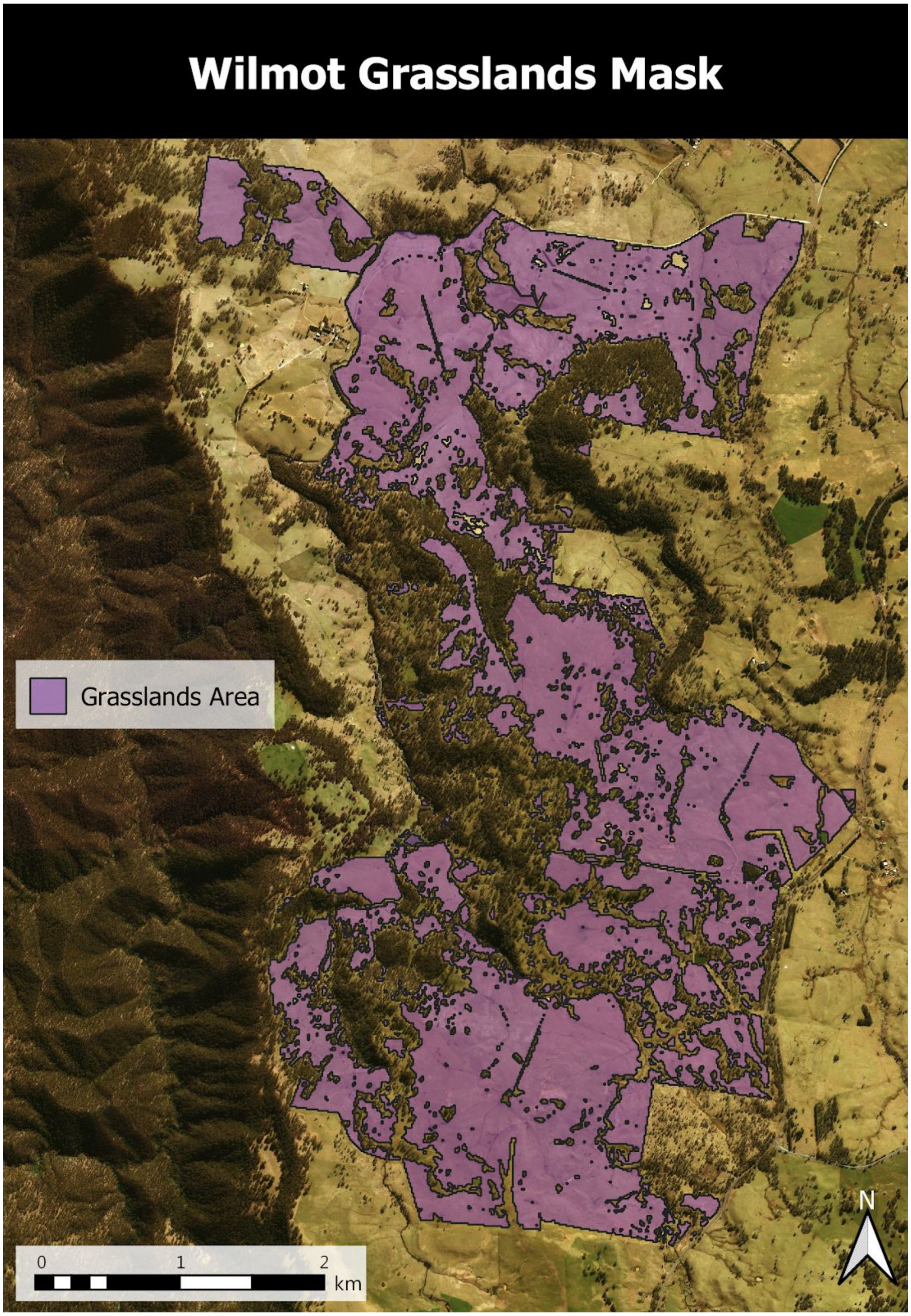


Figure 3. Masked area, avoiding trees, in order to account only for the grassland vegetation cover.

The size of each parcel was calculated using the QGIS field calculator. Results are shown in Table 1.

Table 1. Areas (ha) of the parcels within the project boundary. For each parcel, the net area of grass cover (i.e. without trees) is also shown.

PARCEL NAME	GRASS COVER AREA (Ha)	TOTAL PARCEL AREA (Ha)		PARCEL NAME	GRASS COVER AREA (Ha)	TOTAL PARCEL AREA (Ha)
Airstrip 1	11.7	16.2		Loading Ramp	0.5	0.7
Airstrip 2	8.5	16.0		Maida Vale House	4.5	7.1
Airstrip Lane	0.7	1.1		Maida Vale Road	3.3	7.7
Behind The Yards	4.8	6.7		Maida Vale Shed	25.5	26.0
Below The Yards	4.2	4.6		Main Water North	3.3	59.7
Big Hill	13.5	19.1		Main Water South Bottom	0.6	31.4
Billy's 1 North	22.3	28.4		Main Water South Top	2.3	36.2
Billy's 1 South	19.5	24.0		Majors Creek 1	35.4	44.9
Billy's 2 North	23.0	29.4		Majors Creek 2	25.2	34.1
Billy's 2 South	15.1	16.8		Majors Creek 3	24.5	33.3
Black Mountain East	10.5	29.2		Majors Creek West	17.4	26.8
Black Mountain West	3.7	30.5		Middle Junction East	8.0	18.5
Bottom Junction East	13.3	25.6		Middle Junction West	12.3	28.8
Bottom Junction West	18.6	28.1		Middle Miller	23.4	35.2
Bottom Miller.	18.0	33.3		MV Lane	33.1	41.4
Bush 1	0.3	14.9		Over River Bottom.	14.8	21.1
Bush 2	3.2	15.4		Over River Middle	12.6	19.2
Bush 3	0.5	6.1		Over River Top	18.1	29.6
Bush 4	0.9	30.5		Silage.	18.1	20.1
Crata Hut 1	13.7	32.6		Supplement	4.0	4.1
Crata Hut 2	9.6	18.5		Tank East	21.4	23.3
Crata Hut 3	3.1	8.4		Tank Lane	0.1	0.8
Grafton Road 1	18.4	21.3		Tank West	17.9	24.4
Grafton Road 2	25.0	26.3		Top Junction	18.2	29.2
Horse	7.1	9.7		Top Miller HP 2	11.1	16.8
Johns Valley 1	15.6	28.4		Top Miller HP1	12.7	23.1
Johns Valley 2	20.8	32.5		Top Miller...	20.3	35.5

Johns Valley 3	14.4	49.3		Trees 1	35.4	42.5
Johns Valley 4.	9.5	12.9		Trees 2	30.3	35.3
Johns Valley 5	16.5	22.7		Trees 3	29.7	35.8
JP's Bottom 1	8.7	9.6		Western Side 1	29.4	31.5
JP's Bottom 2	8.3	9.5		Western Side 2	28.6	37.9
JP's Bottom 3	8.4	9.1		Western Side 3.	9.9	36.1
JP's Bottom 4	7.5	9.4		Willows 1	3.2	3.2
JP's Middle East	8.4	12.6		Willows 2	5.8	6.0
JP's Middle West	10.4	12.4		Willows 3	11.1	11.2
JP's Top	8.1	18.8		Willows 4	4.7	5.3
Judys Hill.	17.1	26.2		Willows 5	6.2	6.3
Kangaroo Cove	0.3	5.3		Willows 6	6.4	6.9
Kendall Central	13.5	18.5		Willows 7	7.0	7.7
Kendall East.	18.8	20.8		Willows 8	6.1	7.4
Kendall West	14.5	16.7		Willows 9	2.8	2.9
Little Falls Gorge	3.1	15.6		Willows House.	4.7	5.7
Little Flat	10.9	11.2		Yards:Wilmot	0.1	0.2
				TOTAL	**1093.9**	**1795.2**

2.2 TEMPORAL BOUNDARIES

This assessment corresponds to the **2019 reporting date** for the Wilmot farm: May 27, 2019.

3. CALCULATING THE SOIL ORGANIC CARBON SEQUESTRATION

Soil organic carbon sequestration estimations were made according to the methodology provided in Section 3 of the Methodology Guidelines[3].

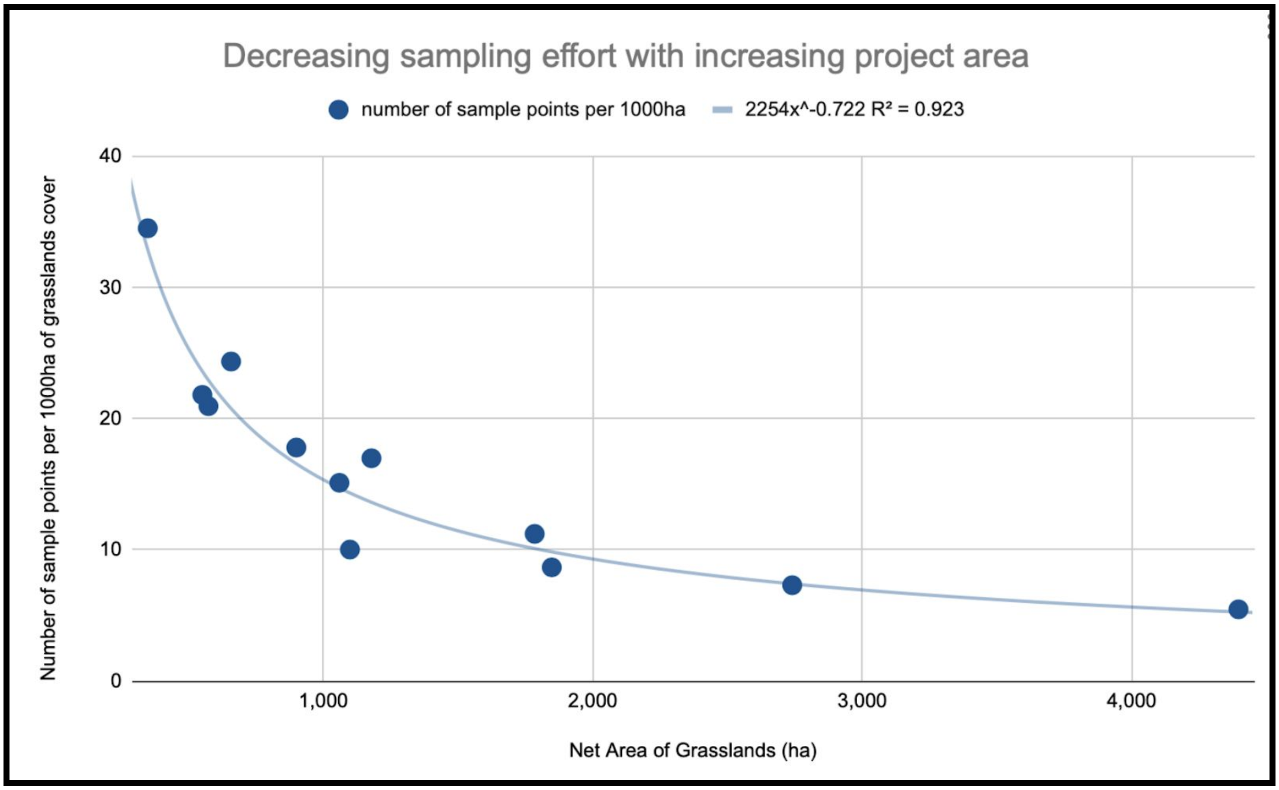
3.1. COLLECTION OF DATA

3.1.1. SAMPLE SIZE

MINIMUM SAMPLE SIZE ESTIMATION:

[3] Methodology for GHG and Co-Benefits in Grazing Systems

The minimum soil sample size for the Wilmot project was set according to the relationship between farm area and sample size as proposed in the Methodology Guidelines[4]. The relationship between the net area of grassland and number of sample points is shown below.



The number of soil samples every 1,000 ha (N_{1k}) was estimated as:

N_{1k} = 2254 * GrassArea$^{(-0.72)}$ (Eq. 1)

where the net grassland area for the project is in hectares.

Given the net grassland area within Wilmot is 1094 ha, the number of soil samples every 1,000ha is:

$N1k = 2254 * 1094^{(-0.72)}$ =14.4

The number of soil sampling points for the satellite calibration (N_{cal}) within the project area was then estimated as:

N_{cal}= (N_{1k} * GrassArea) / 1,000= $(14.4 * 1094)/1000$ = 15.77 (Eq. 2)

[4] Methodology for GHG and Co-Benefits in Grazing Systems

The total number of soil sampling points for the Wilmot farm was then increased by 30% to account for any additional data needed to validate model performance when calculating soil organic carbon stocks:

$N_{total}=N_{cal} + (0.3 * N_{cal}) = 15.77 + 4.73= \mathbf{20.5}$ (Eq. 3)

As shown above, the minimum number of Soil Organic Carbon (SOC) samples for The Wilmot Farm relative to the grassland area within the study site is **21 samples per sampling round**. This data is required to accurately calibrate and validate statistical models used to derive SOC stocks.

ACTUAL SAMPLE SIZE FOR THE REPORTING PERIOD 2018-2019:

For the 2019 reporting date, 10 sampling locations were chosen with 3 subsamples collected at each site. Subsamples were combined to build a composite sample.

As the total number of samples fell below the required minimum sample size estimation, ancillary data from a nearby farm called the Woodburn farm were used to increase the sample size used for model calibration*. Data from the Woodburn farm were suitable for use in calibration because this farm is located only 90km away and held under the same management practices by Impact Ag. Samples from this farm were collected following the same procedures described for Wilmot and extracted only 1 days later. 21 subsamples were collected at 7 locations on the Woodburn farm (3 subsamples per location), and combined into 7 composite samples bringing the total number of samples to 17 between the two farms.

**see Deviation from Methodology for more information regarding the deviation from the minimum number of samples estimated for the project area and the aggregation of data from another farm.*

3.1.2. STRATIFICATION

The landowner claims the paddock boundaries described in Figure 2 reflect all significant differences in paddock size (0.9 to 61.1 ha), soil type, management history, and vegetation cover. To ensure soil samples mirror variance found in the grasslands study area and to reduce sampling error, these paddocks were used as strata in a stratification sampling method to randomly select paddocks for soil sampling.

3.1.3. ASSIGNING SAMPLING LOCATIONS

- Sampled parcels were selected at random to reflect variation in strata described in section 3.1.2.

- Within each of the chosen parcels, soil sample locations were selected at random and marked using marker posts to identify sampling sites in subsequent sampling rounds.
- 12 cores separated by 5-10 m were extracted at each sample location and mixed to create a composite sample

3.1.4. EXTRACTING CORES

In compliance with Section 3.1 "Collection of Data" in the Methodology Guide[5], soil samples were extracted by using a spade to take a 1-inch wide slice from the top of a 15 cm deep hole.The slice was taken from one wall of the hole, following protocols to ensure the vertical integrity of the slice matched the desired depth. The process was repeated 10 to 12 times at each sample location, separating extractions by 5 to 10m. Multiple slices were combined to create composite samples for each site. Samples were bagged, cooled and carried to a laboratory for analysis within 48hs.

Samples were extracted at the Wilmot farm on 05/27/2019 and at the Woodburn farm on 05/28/2019.

For the bulk density sampling, a coring device was used to extract 32mm cores to a depth of 15cm at each sampling point.

3.2. SAMPLE ANALYSIS

3.2.1. PARAMETERS ANALYZED

The topsoil cores extracted at each sampling location were used to measure the following soil properties:

- Soil Organic CarbonPercentage
- Bulk density
- pH
- Macronutrients
    - Nitrate-Nitrogen
    - Ammonia-Nitrogen
    - Total Nitrogen
    - Phosphorus
    - Potassium
- Minor nutrients
    - CEC (cation exchange capacity)

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[5] Methodology for GHG and Co-Benefits in Grazing Systems

- Base saturations estimations as Percent CEC for:
    - Ca
    - Mg
    - K
    - Na
    - Al

3.2.2. METHODS

The Environmental Analysis Laboratory (EAL)[6], where all the samples were analyzed, is accredited by the National Association of Testing Authorities (NATA)[7] in accordance with ISO/IEC 17025-2005, for its technical competence in the field of Chemical Testing.

3.3. SPATIAL DISTRIBUTION OF SOC

3.3.1. SPATIAL LOCATION OF SAMPLES

- Sample locations were determined prior to any core extraction in a given stratum for each soil sampling round.
- The exact geolocation for the three subsamples within each parcel was chosen at random.
- The geographic point locations of assigned soil sampling points were recorded using a Trimble NAV-500 Guidance Controller, with sub-meter accuracy.

Sample locations for the Wilmot farm are shown in Figure 4:

[6] Environmental Analysis Laboratory (EAL), Southern Cross University, NSW, Australia
[7] National Association of Testing Authorities (NATA)

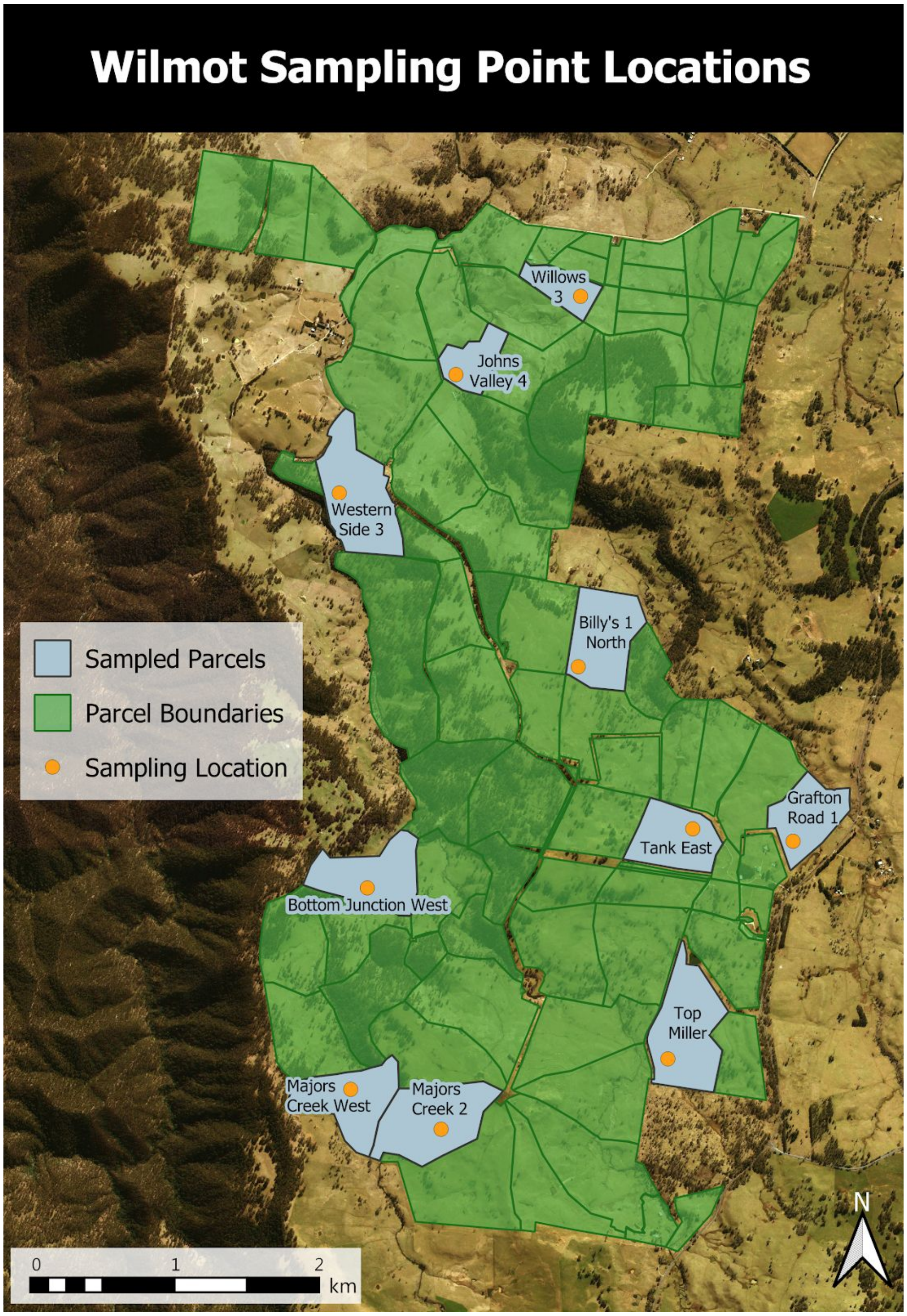

Figure 4. Sample locations and the corresponding parcel names at the Wilmot Farm.

3.4. SOC PERCENTAGES AT SAMPLING POINTS

Table 2 shows the percentage of SOC found in each sampling point.

Table 2. Percentage of SOC per sampling point.

FARM	LOCATION	%SOC 2019
WILMOT	Billy's Airstrip	5.32
	Bottom Junction	3.59
	Grafton Rd	4.75
	John Valley	2.21
	Majors Creek	5.06
	Majors West	5.3
	Tank	4.88
	Top Miller	5.8
	Western Side	3.09
	Willows 3	4.03
WOODBURN*	Sandy gate	1.67
	Top Knobs	5.07
	Wattle Tops	2.33
	Tree Guard	1.78
	Double Dutch	2.41
	Spring	1.91
	Pink	2.13

** See Deviation from Methodology for more information regarding ancillary data*

3.5. SPECTRAL VALUES AT SAMPLING POINTS

Sentinel-2 satellite imagery was downloaded within one month of the soil sampling dates. Images selected for the study were verified to be cloud free and atmospherically corrected using the European Space Agency Sen2Cor correction tool. If available, multiple images were downloaded and averaged to reduce the effect outlying spectral values could have on analysis.

In the case of Wilmot, two images without clouds were available from the following dates:

- 05/06/2019
- 05/21/2019

In the case of Woodburn, two images without clouds were available from the following dates:

- 05/25/2019
- 07/14/2019

The stacked images were averaged across the two dates for the Wilmot farm, and across the two dates for the Woodburn farm. In addition, an NDVI index was calculated for each image. Finally, the

QGIS Point Sampling tool was used to extract spectral values at sampling locations for each band and for the NDVI image.

3.6. CORRELATION BETWEEN SOC PERCENT AND SPECTRAL VALUES

Methodology Description:

Spectral data from the two farms were combined and plotted against soil organic carbon values as scatter plots. Of the 13 Sentinel-2 bands listed in Table 3[8], bands B2, B3, B4, B5, B6, B7, B8, B11 and B12 were selected for analysis. Linear and power regression models were used to fit each of the bands individually, and outliers calculated based on residual values were removed in accordance with standard statistical procedures. Models were scored using an R^2 value and SEE, and inspected visually to verify best fit. The highest scoring models were then applied to the corresponding band in the Sentinel-2 image to calculate percent soil organic carbon across the entire Wilmot farm.

Table 3. Sentinel-2 Bands and their Corresponding Resolution and Wavelengths

Band	Resolution	Central Wavelength	Description
B1	60 m	443 nm	Ultra blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Red Edge 1
B6	20 m	740 nm	Red Edge 2
B7	20 m	783 nm	Red Edge 3
B8	10 m	842 nm	Near Infrared (NIR)
B8A	20 m	865 nm	Red Edge 4
B9	60 m	940 nm	Water Vapor
B11	20 m	1375 nm	Short Wave Infrared 1 (SWIR 1)
B12	20 m	1610 nm	Short Wave Infrared 2 (SWIR 2)

[8] MSI Sentinel-2 Technical Guide

Results:

When assessed using linear and power regression models, Bands 4 and 12 from the Sentinel-2 images showed the highest correlation with soil organic carbon for the 2017 sampling points. Between the two, band 12 had a higher r^2 value and visually showed a better fit, so it was chosen as the predictive variable for soil organic carbon. The power regression model was then selected, showing a significantly better fit than the linear model according to the Normalized Standard Error of the Estimate (nSEE) values (3.98 compared to the linear regression nSEE of 15.93). The results from the statistical analysis and an ANOVA (analysis of variance) analysis are summarized below alongside coefficient values relating soil organic carbon percentages to Sentinel-2 Band 12. Figure 5 shows the visual relationship between Band 12 and the soil organic carbon percentage as a scatter plot.

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.955	.911	.904	.145

The independent variable is B12_2019.

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.589	1	2.589	123.269	.000
Residual	.252	12	.021		
Total	2.841	13			

The independent variable is B12_2019.

Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
ln(B12_2019)	-1.347	.121	-.955	-11.103	.000
(Constant)	71730.684	64563.976		1.111	.288

The dependent variable is ln(soc_percent_2019).

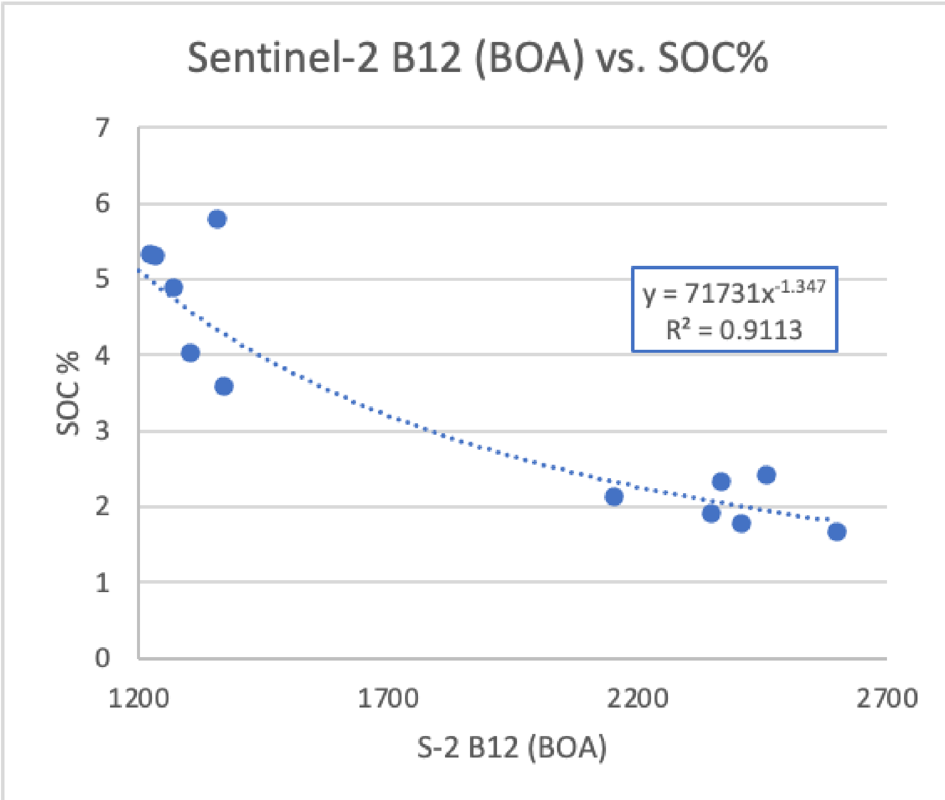

Figure 5. Scatter plot showing the 2017 power relationship between the sampled SOC percent and the reflectance values of Band 12 from Sentinel-2 at sampling points located in Wilmot and Woodburn farms.

Equation 4 relating Band 12 to soil organic carbon was applied to the averaged 2019 satellite image using the QGIS raster calculator to generate a soil organic carbon percentage map.

$$SOC\ (\%) = 71{,}731 * B12^{(-1.347)} \qquad \text{(Eq. 4)}$$

The resulting map was constrained to pixels within a range of 0-7% soil organic carbon in order to avoid possible shifts in the relationships outside of the tested range. Pixels with higher or lower values were set to the minimum and maximum values of 0 and 7 percent respectively to reduce over and underestimation of soil organic carbon stocks. Figure 6 shows the final soil organic carbon percentage for grasslands area on the Wilmot farm.

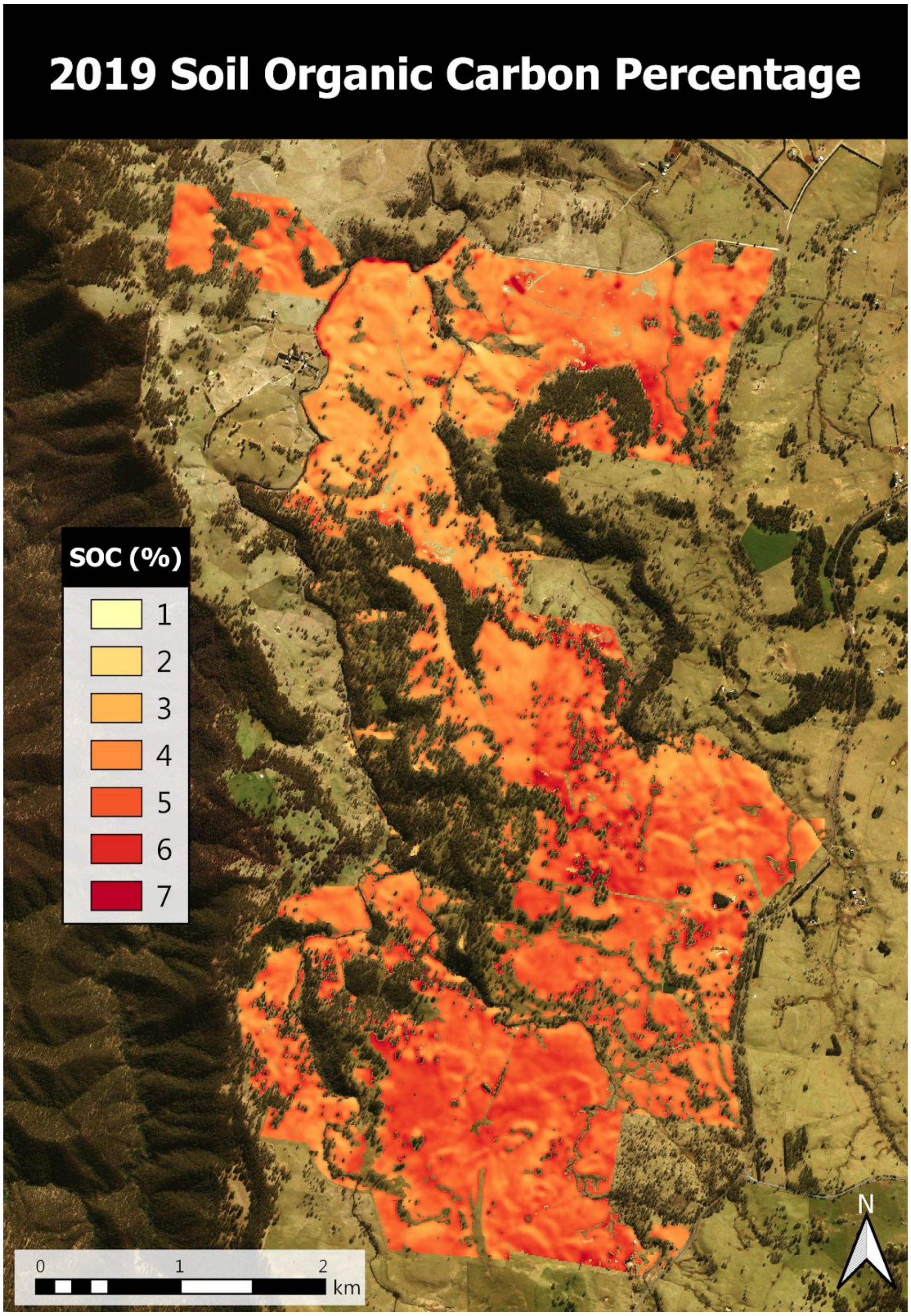

Figure 6. Variance in soil organic carbon percentage on the Wilmot farm during 2019.

3.7. SOC STOCKS CALCULATIONS

3.7.1. PERCENT SOC TO SOC STOCKS

To convert percent soil organic carbon to soil organic carbon stocks, a bulk density map showing soil variability is needed. Prior to the 2019 sampling round, bulk density measurements were not collected (see *Deviation from Methodology*) so another method to calculate bulk density was required. In reviewing scientific literature on Southern Australian soils, a statistically significant (p-value < 0.05) linear regression pedotransfer function (PTF) proposed by Merry[9] was found to relate percent soil organic carbon to bulk density (Equation 5).

Bulk Density (g/cm3) = 1.608 - 0.0872 * Percent SOC (Eq. 5)

The estimated bulk density values using the PTF were compared to the 2019 Wilmot bulk density values collected during the soil sampling survey (Figure 7), and an ANOVA (analysis of variance) analysis summarizes the relationship between the two (Figure 8). The uncertainty associated with using a pedotransfer function to estimate bulk density is expressed as:

$$\text{nSEE} = \frac{\textit{Standard Error of the Estimate}}{\textit{Average Bulk Density Observation}} = \frac{0.295}{1.4} * 100 = \mathbf{21\%}$$

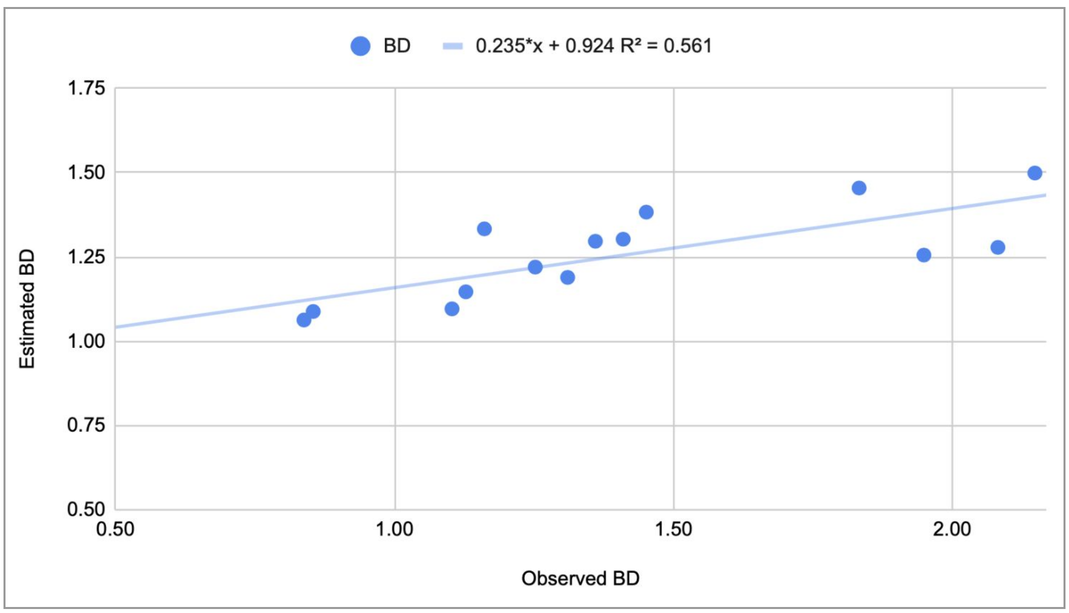

Figure 7. Scatter plot of the estimated bulk densities from the Merry PTF versus the observed bulk densities from the 2019 sampling round.

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.749[a]	.561	.524	.295058	.561	15.320	1	12	.002

a. Predictors: (Constant), BD_Merrysept19

Figure 8. Model summary for the estimated bulk densities from the Merry PTF versus the observed bulk densities from the 2019 sampling round.

[9] In: Spouncer, L.R., Skjemstad, J.O., Merry, R.H. (2000) Soil Carbon Information for Major Soils in IBRA regions - South Australia. CSIRO Land and Water Consultancy Report. Pp 22

The bulk density map for 2019 (Figure 9) was generated by applying the pedotransfer function to the 2017 soil organic carbon map calculated in Section 3.6.

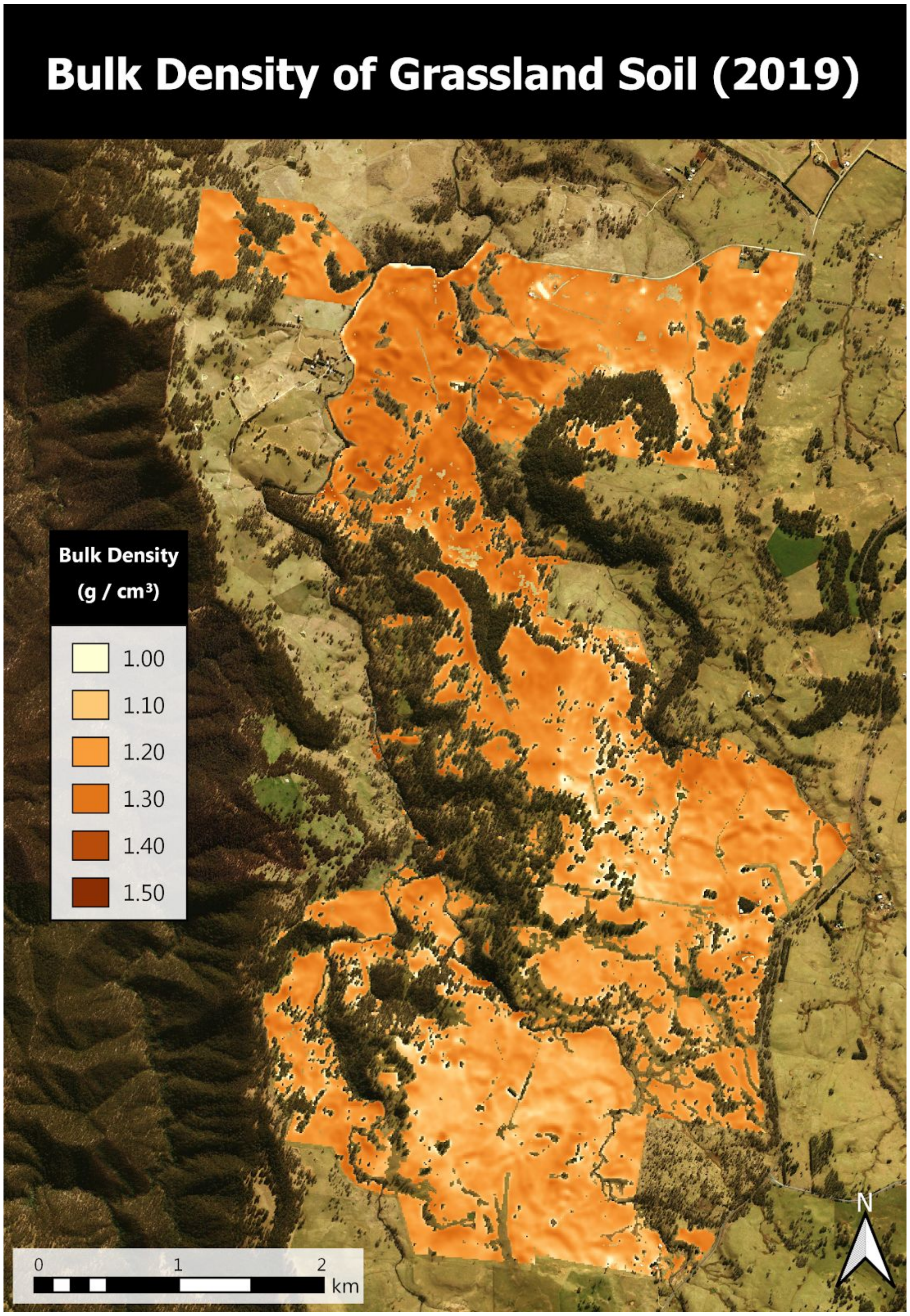

Figure 9. Variance in soil bulk density on the Wilmot farm during 2019.

Finally, soil organic carbon stocks were calculated by applying Equation 6 to the soil organic carbon percentage map generated in Section 3.6 and the bulk density values calculated above. A constant soil depth of 15 cm was used across the entirety of the Wilmot farm to calculate carbon found only within the depth range of extracted soil samples. The resulting raster represents the total amount of soil organic carbon stocks (metric ton/ha) found within each pixel.

$$\textbf{SOC stock(t/ha)} = \textbf{SOC\%} \times \textbf{BD (g/cm3)} \times \textbf{Soil Depth (cm)} \qquad \text{(Eq. 6)}$$

The QGIS zonal statistics tool was then used to estimate the total amount of soil organic carbon found within each of the Wilmot parcels (Figure 10). The soil organic carbon stocks for the whole project area was calculated by summing the results of each parcel. The resultant SOC stock for the Wilmot Farm in 2019 report is **90,348 metric tons of SOC.**

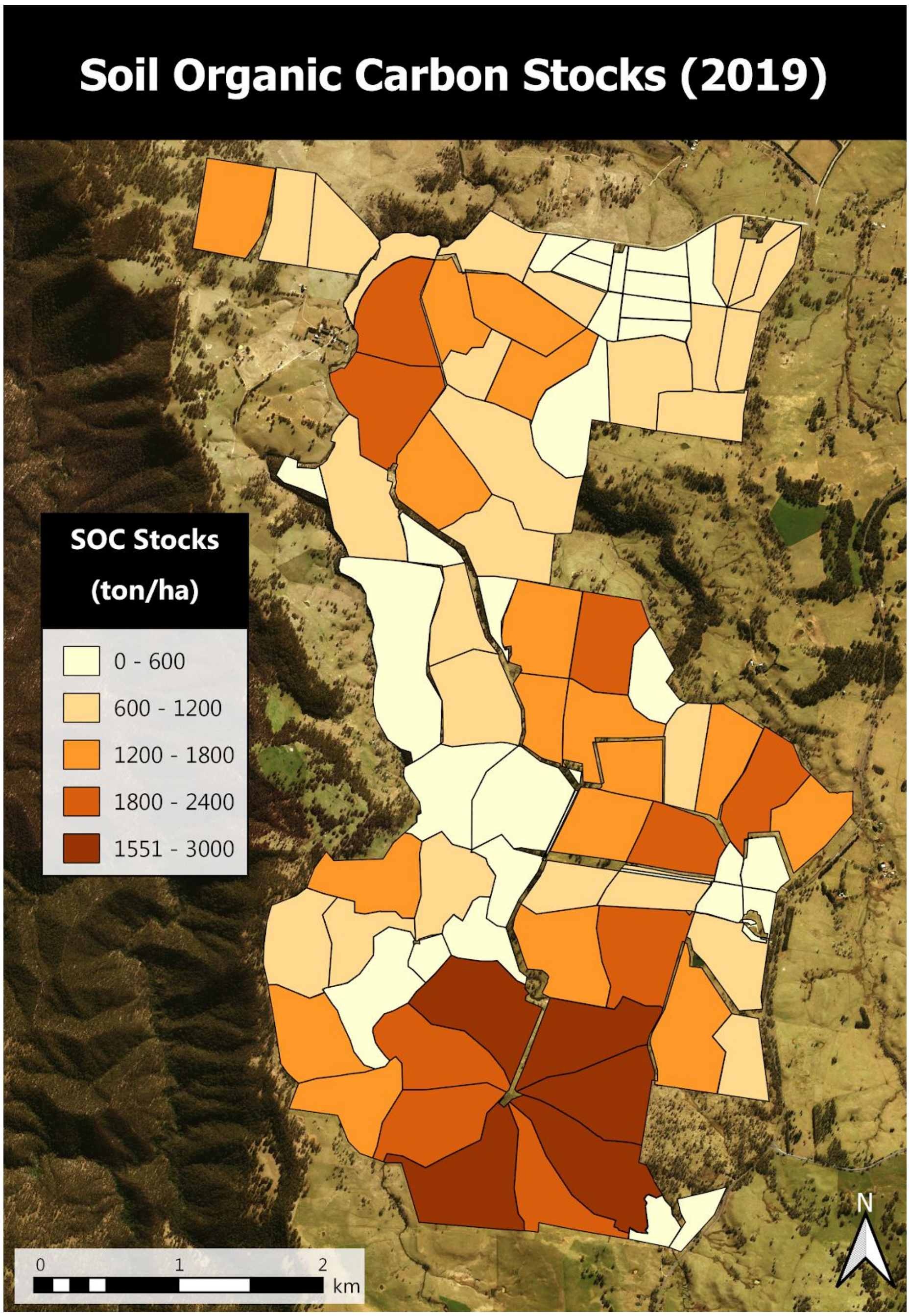

Figure 10. Total soil organic carbon stocks for each parcel on the Wilmot Farm during the 2019 period.

3.7.2. SOIL ORGANIC CARBON (SOC) STOCKS TO CO_2 EQUIVALENTS (CO_2e)

The conversion from SOC stocks to CO_2 equivalent stocks was calculated by multiplying the SOC stocks (in metric tons) by a conversion factor of 3.67:

$$\mathbf{CO_2e\ (metric\ ton)_{baseline} = SOC\ (metric\ ton) * 3.67} \qquad \text{(Eq. 7)}$$

Results:

The total CO_2 equivalents (CO_2e) estimated from the SOC stocks for the 2019 Wilmot report is **331,577 metric tons of CO_2e.**

3.8. CALCULATING THE GREENHOUSE GAS EMISSIONS

3.8.1. EMISSIONS FROM LIVESTOCK

The annual emissions from livestock are calculated according to Equation 8 following the Australian Carbon Credits Methodology Determination of 2018[10]:

$$E_{liv} = Q \times D \times EF_{liv}/1{,}000 \qquad \text{(Eq. 8)}$$

E_{liv} is the total emissions from livestock for a particular year for the project area, in metric tons of CO_2-e.

Q is the number of animals within the project area in that year, in livestock head.

D is the number of days in the reporting period that the livestock was within the project area.

EF_{liv} is the default emission factor for the livestock, according to its type, as set out in the Australian supplement[4]; in kilograms of CO_2e per livestock head per day.

Results:

The values from the Wilmot farm regarding *Q* and *D* are summarized in Table 4.

Table 4. Data for the determination of the GHG emissions from livestock in the project area for the 2019 period.

YEAR	N. of animals (Q)	N. of days on farm per head (D)	EF_{liv} (kg CO_2-e/head/day)
2019	1532	147	4.05

[10] Carbon Credits (Carbon Farming Initiative—Measurement of Soil Carbon Sequestration in Agricultural Systems) Methodology Determination 2018

The annual emissions were then estimated according to Equation 8:

- $E_{liv, 2019}$=1,532x147x 4.05/1000=912 tCO_2-e

The total GHG emissions from livestock for the reporting period were **912 tCO_2-e.**

3.9. CALCULATING THE CREDITABLE CARBON CHANGE

3.9.1. NET CO2-e STOCKS FROM THE PREVIOUS SAMPLED PERIOD

The previous period for which the Net CO_2 equivalent stocks were quantified for the project area, was the year 2018[11].

Results from 2018 for the Project Area were:

NET CO_2e $STOCKS_{2018}$= 301,976 tCO_2e

3.9.2. CALCULATING THE NET SOC STOCKS FOR THE 2019 PERIOD

NET CO_2-e $STOCKS_{2019}$= CO_2-e $(t)_{2019}$ - $E_{liv\text{-}2019}$=331,577 metric tons of CO_2-e - 912 tCO_2-e

NET CO_2e $STOCKS_{2019}$= 330,665 tCO_2e

3.9.3. NET 2018-2019 CO_2e ABATEMENT

NET CO_2-e $ABATEMENT_{2018\text{-}2019}$= NET CO_2-e $STOCKS_{2019}$ - NET CO_2-e $STOCKS_{2018}$

= **330,665** tCO_2-e - **301,976** tCO_2-e

NET CO_2-e $ABATEMENT_{2018\text{-}2019}$ = 28,689 tCO_2e

3.9.4. REPORT UNCERTAINTY

An estimation of uncertainty for the SOC percentages were calculated using the normalized Standard Error of the Estimate (SEE) from the soil organic carbon regression model in section 3.6. The results from the statistical analysis for the baseline data are shown below:

[11] Wilmot baseline-2018 crediting period - Report

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
.955	.911	.904	.145

The independent variable is B12_2019.

The Standard Error of the Estimate (SEE) is normalized by the mean value of the estimated SOC percentage as:

$$nSSE = \frac{Standard\ Error\ of\ the\ Estimate}{Average\ SOC\ observation} = \frac{0.145}{3.64} * 100 = 3.98\%$$

- For 2019, the nSEE for the SOC % prediction equals **3.98%.**
- The percent uncertainty of the bulk density estimation was 21%.

The final total uncertainty estimated for 2019 is:

$\mathbf{U_{2017}}$ **=** 3.98% + 21% =**24.98%**

Given that uncertainty is within the range 20%-30%, the Uncertainty Deduction (UD) that applies, according to the Methodology Guidelines[12], is 50% of the estimated Uncertainty:

Uncertainty Deduction (UD)=12.5%

3.9.5. CREDITABLE CARBON CHANGE BETWEEN 2017 AND 2019

According to the Methodology Guidelines[13], the Creditable Carbon Change for the period 2018-2019 shall be estimated as:

CREDITABLE CARBON CHANGE =(NET CO_2e ABATEMENT)×(1−*UncertaintyDeduction*)

Given that:

- NET CO_2e $\text{ABATEMENT}_{2018\text{-}2019}$ = 28,689 tCO_2e
- UD = 12.5%

Then:

CREDITABLE CARBON CHANGE =(28,689 tCO_2-e)×(1−0.125)= **25,103 tCO_2e**

[12] Methodology for GHG and Co-Benefits in Grazing Systems

[13] Methodology for GHG and Co-Benefits in Grazing Systems

4. CALCULATING THE SOIL HEALTH INDICATORS

4.1. pH

Methodology Description:

The standard method of measuring soil pH in all Australian states other than Queensland is to measure pH in calcium chloride. An air-dried soil sample is mixed with five times its weight of a dilute concentration (0.01M) of calcium chloride (CaCl2) and shaken for 1 hour before measuring pH using an electrode. Results are usually expressed as pH(CaCl2).

Soil pH in water: This is an adaptation of the calcium chloride method. Distilled water is used in place of 0.01M calcium chloride, and results are expressed as pH(w). This adaption was adopted as the pH measurement standard for this project.

Benchmarks:

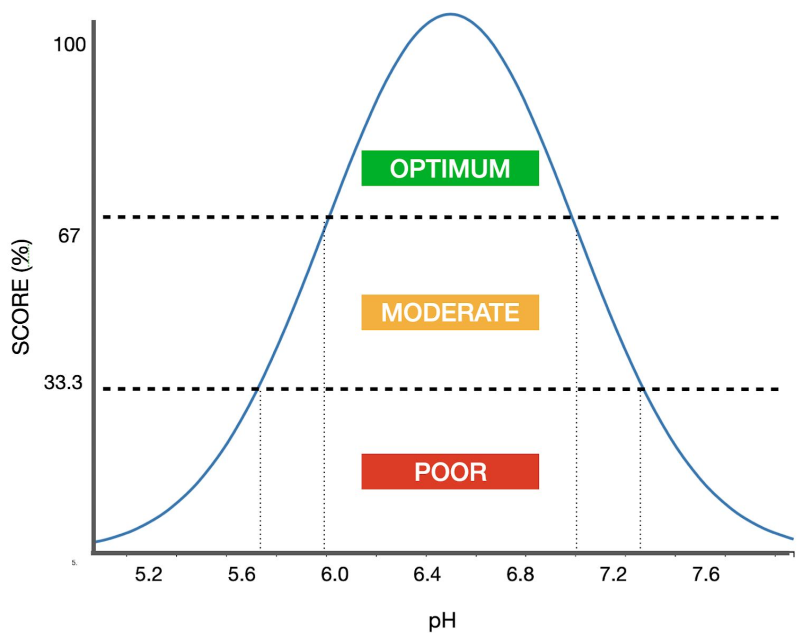

Figure 11. Soil pH following a Gaussian curve with optimal pH between 6.0 and 7.0

Soil pH follows an optimal (Gaussian) curve. Desired pH(w) levels for maximum nutrient availability are 6.0-7.0, according to New South Wales Agriculture[14]. In the absence of any type of land management, soil types found in Australian grasslands tend to revert to a lower pH.

Given the optimal range, fitted with a Gaussian curve and a standard deviation of 0.5 (Figure 11), the soil pH ranking for pastures in New South Wales is:

---

[14] New South Wales Agriculture

POOR: < 5.75 or > 7.25

MODERATE: > 5.75 and <6.0, or >7.0 and <7.25

OPTIMAL: 6.0 - 7.0

Results:

- Average pH values from 2019 soil samples: 5.66 (**POOR**)

4.2. MACRONUTRIENTS (NPK)

4.2.1. NITROGEN

Nitrate-nitrogen

Benchmarks:

- There are no real target levels, but agronomists generally prefer a level of 10 mg or more of Nitrate-nitrogen per 1kg of pasture soil (for both nitrate and ammonium[15]). The desired range for Nitrate-Nitrogen is between 10 and 50 mg/kg[16].

Results:

- Average Nitrate-Nitrogen from 2019 soil samples: 17.5 mg/kg (**OPTIMAL**)

Ammonia-nitrogen

Benchmarks:

- The desired range for Ammonia-Nitrogen is between 0 and 5 mg/kg[17].

Results:

- Average Ammonia-Nitrogen from 2019 soil samples: 7.3 mg/kg (**MODERATE**)

Total Nitrogen

Benchmarks:

---

[15] Result interpretation
[16] UNDERSTANDING YOUR STEP BY STEP Cath Botta
[17] UNDERSTANDING YOUR STEP BY STEP Cath Botta

- The Total Nitrogen benchmarks follow the ratings outlined in Table 5[18]

Table 5. Total nitrogen ranking system

Total N (%)

Rating (% by weight)	Description
<0.05	Very low
0.05 – 0.15	Low
0.15 – 0.25	Medium
0.25 – 0.50	High
>0.5	Very High

- POOR: <0.05 - 0.15 (very low and low values)
- MODERATE: 0.15-0.25 (medium values)
- OPTIMAL: 0.25-0.5< (high and very high values)

Results:

- Average Total Nitrogen from 2019 soil samples: 0.4 % (**OPTIMAL**)

The distribution of the Wilmot data for 2019 falls within the ranges illustrated below:

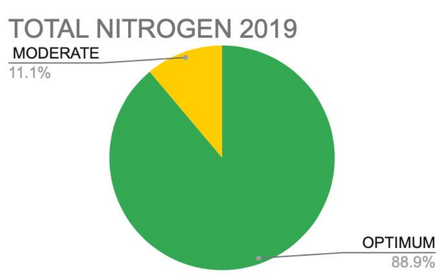

Figure 12: Total Nitrogen 2019 data

4.2.2. PHOSPHORUS

Methodology Description:

There are three main phosphorus tests used in Australia which have different minimum levels (or 'critical' values) for maximum yield.

[18] UNDERSTANDING YOUR STEP BY STEP Cath Botta

• The Bray test appears least affected by low pH and has a similar critical value across all soils (15ppm for pastures). The test is not suitable for soils with a pH (CaCl2) above 7.0.

• The Olsen test can be used on alkaline and acidic soils. Critical values are similar to those for the Bray test.

• The Colwell test is used extensively in New South Wales. Its critical value changes with soil type. Colwell P is a measure of immediately available phosphorus plus the phosphorus that is absorbed to the soil and released over the next few years.

Benchmarks:

Given the type of soils and the ecoregion where the Wilmot farm stands, the most suitable test is the Colwell test.

Colwell critical levels vary from 20 to 100 mg/kg depending on soil texture, type and crop type[19]. Reported values from the Colwell P test indicate a minimum of 25 mg/kg as the threshold for viable soils in pastures. The threshold considered here is the threshold value between poor and moderate categories. Colwell P> 45 mg/kg can be considered Optimal.

- POOR: < 36mg/kg
- MODERATE: 36-44mg/kg
- OPTIMAL: >44mg/kg

Results:

- Average Colwell-Phosphorus values from 2019 soil samples: 56.3 mg/kg (**OPTIMAL**)

The distribution of the Wilmot data for 2019 falls within the ranges illustrated below:

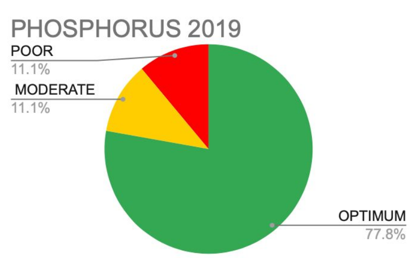

Figure 13: Phosphorus 2019 data

[19] Soil Test Interpretation Guide

4.2.3. POTASSIUM (K)

<u>Benchmarks:</u>

The critical values for surface soils are generally around 0.2-0.5 cmol(+)/kg or 80-250 mg/kg (Gourley 1999)[20]. Measured levels can be significantly lower on sandier soils.[21]

Considering that Wilmot has a HIGH stocking rate with long rest periods between grazing and loam soil types and based on the information cited above, the resultant potassium ranking is:

Poor: < 0.2 cmol/kg

Moderate: 0.2-0.28 cmol/kg

Optimal: 0.28-0.44 cmol/kg

<u>Results:</u>

- Average Exchangeable Potassium (cmol/kg) values from 2019 soil samples: 0.5 cmol/kg (**OPTIMAL**)

The distribution of the Wilmot data for 2019 falls within the ranges illustrated below:

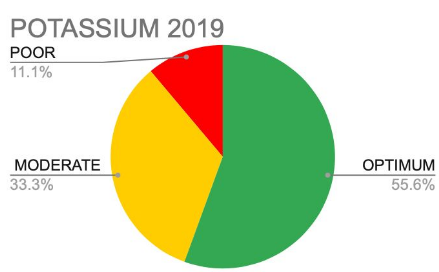

Figure 14: Potassium 2019 data

4.3. CEC (Cation Exchange Capacity)

<u>Benchmarks:</u>

[20] Gourley CJP (1999) Potassium. In 'Soil analysis: an interpretation manual'. (Eds KI Peverill, LA Sparrow, DJ Reuter) pp. 229–239. (CSIRO Publishing: Melbourne, Vic.)

[21] https://www.ccmaknowledgebase.vic.gov.au/brown_book/10_Nutrient.htm

The exchangeable cations give a measure of overall soil fertility. The cations—calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and aluminium (Al)—are added together to give the Cation Exchange Capacity (CEC). The higher the total, the more fertile the soil[22].

For New South Wales pastures, soils with a CEC below 3meq/100g (considered 'light' soils) have very low nutrient levels, whereas values of 25 or higher are considered Optimal[23].

Poor: <3meq/100g

Moderate: 4 - 24 meq/100g

Optimal: >25 meq/100g

Results:

Average CEC (meq/100g) values for 2019 Wilmot soil samples:: 11.5 (**MODERATE**)

Base Saturations of Ca, Mg, K, Na, Al as % of Cation Exchange Capacity (CEC)

4.3.1. CALCIUM

Benchmarks:

- The percentage range for optimal Calcium values falls between 65%–80%[17].

Results:

- Average Calcium as % CEC from 2019 soil samples: 75.2% (**OPTIMAL**) ; 100% of samples within the Optimal range.

4.3.2. MAGNESIUM

Benchmarks:

- The percentage range for optimal Magnesium values falls between 10%–15% (20% max).[17]

Results:

Average Magnesium CEC for 2019: 17.6% (**OPTIMAL**); 89% of samples within the Optimal range.

[22] What are the Optimal nutrient targets for pastures?
[23] What are the Optimal nutrient targets for pastures?

4.3.3. POTASSIUM

Benchmarks:

- For Potassium, 3%–8% of CEC are considered Optimal values[24]

Results:

- Average Potassium CEC for 2019: 4.1% (Optimal) ;78% of samples within the Optimal range.

4.3.4. SODIUM

Benchmarks:

- Desirable Sodium values as a percentage of CEC are below 6% for pastures in the same region[25]. Optimal Sodium values are between 0%–2% (max.) for the study area according to local producers.

Results:

- Average Sodium CEC for 2019: 1 % (**OPTIMAL**); 100% of samples within the Optimal range.

4.3.5. ALUMINIUM

Benchmarks:

- The desirable range for Aluminium as a percentage of CEC is between 0% (ideal) to 5% (max), and is considered to be optimal below 3% based on the local producers knowledge.

POOR: >3%

OPTIMAL: <3%

Results:

- Average Aluminium CEC for 2019: 1.4 % (**OPTIMAL**) ;89% of samples within the Optimal range, 11.1% above Optimal and below max.

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[24] What are the Optimal nutrient targets for pastures?
[25] What are the Optimal nutrient targets for pastures?

5. CALCULATING THE ECOSYSTEM HEALTH INDICATORS

5.1. ECOSYSTEM VIGOR

In accordance with section 5.1 in the Supplement[26] Ecosystem Vigor for the Wilmot Farm was assessed by comparing the average NDVI within the project area to the average NDVI of the surrounding landscape. A 10km radius set around the Wilmot farm was used to generate a polygon in QGIS for NDVI comparison. Equation 9 was applied to the Bands 4 and 8 from the averaged raster generated in Section 3.5.

$$NDVI = (B8 - B4) / (B4 + B8) \qquad \text{(Eq. 9)}$$

Impervious surfaces and tree canopy were masked out through visual inspection and raster calculations based on Band 4 from Sentinel-2 and Bing basemaps in QGIS. The average NDVI values were then estimated within the project area and within the surrounding buffer area separately using zonal statistics.

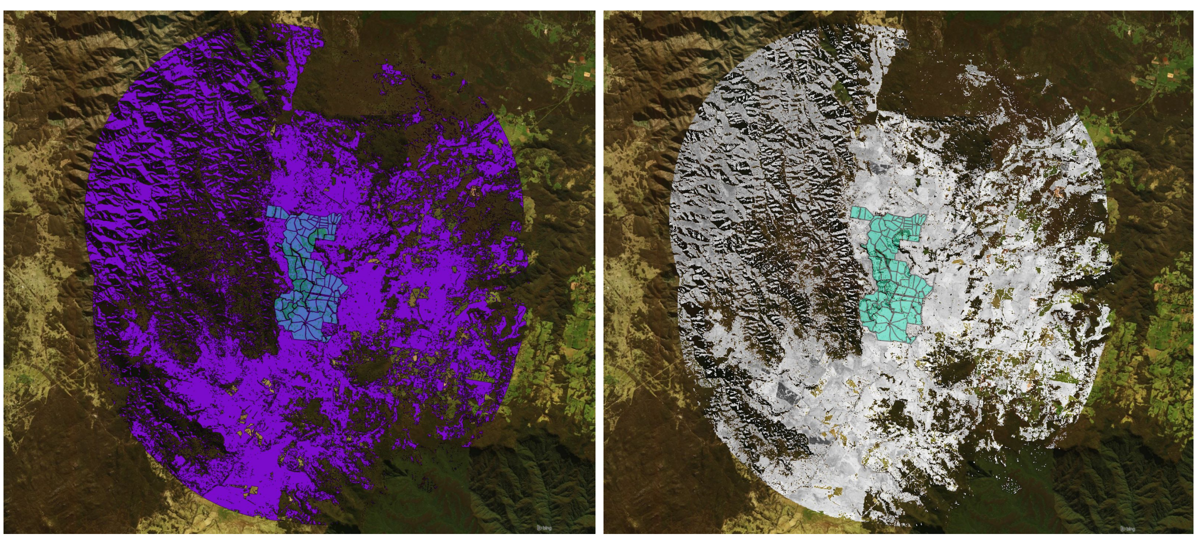

Figure 15: On the left, the Wilmot parcels in the center, surrounded by the 10km-wide radius buffer area (purple), after masking out the forested areas. On the right, the NDVI layer within the masked buffer area is shown in greyscale.

<u>Benchmarks</u>:

Benchmarks are calculated as the difference between the average NDVI value for the surrounding area and the average NDVI for the study site. Scoring ranges are considered as follows:

EXCELLENT: project average NDVI is >25% higher than the buffer NDVI.

[26] Methodology for GHG and Co-Benefits in Grazing Systems

GOOD: project average NDVI is 10-25% higher than the buffer NDVI.

FAIR: Project average NDVI is within an interval of +/- 10% the average buffer NDVI.

NEEDS IMPROVEMENT: Project average NDVI is more than 10% lower than the average buffer NDVI.

Results:

For 2019, the average NDVI for Wilmot Project Area was 0.64.

The average NDVI for the surrounding area (10km radius) was 0.36.

Scoring:

According to the results from 2019, given the value of Wilmot´s NDVI was 78% higher than the NDVI in the surrounding landscape, the Ecosystem Vigor for 2019 was ranked as: ***EXCELLENT***

Scores from previous sampling periods:

- For 2017 (Baseline), the vigor was ranked as ***FAIR***[27].
- For 2018, the vigor was ranked as ***EXCELLENT***[28].

5.2. ECOSYSTEM ORGANIZATION

5.2.1. TREE CANOPY COVER ESTIMATION

Local Benchmarks:

According to the resemblance the project area has to natural grasslands in New South Wales, the scoring ranges[29] for tree canopy cover are the following:

EXCELLENT: 50-55% tree cover, predominant native vegetation, natural structure has not been substantially altered.

GOOD: 30 to 50% tree cover; a significant proportion of native vegetation has been preserved or planted, but the original grassland structure has been altered.

FAIR: 15 to 30% tree cover; a small proportion of native vegetation has been preserved or planted, and the original grassland structure has been altered.

NEEDS IMPROVEMENT: Tree cover is below 15%. Grassland structure is predominantly altered by land use.

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[27] The Wilmot Cattle Project 2017- BASELINE Report
[28] The Wilmot Cattle Project Report 2018
[29] 13. Native vegetation | State of the Environment 2015

Quantification Methodology:

The tree canopy cover was determined in QGIS 2.18 based on Sentinel-2 imagery from the winter months of June and July 2017. Results were averaged across images.

Results:

The **tree % cover** in Wilmot farm for the reporting period 2017-2019 was **39% of the total area** (701 ha). Accordingly, the resemblance of the Wilmot grasslands to natural grasslands of the New South Wales area, in terms of tree canopy, is ranked as **GOOD.**

5.2.2. PROTECTION OF WETLANDS AND WATERCOURSES

There is currently no protection of watercourses in the Wilmot property. As a result, the Wilmot Project Area **NEEDS IMPROVEMENT** for watercourse protection.

5.3. ECOSYSTEM RESILIENCE

5.3.1. BARE SOIL ESTIMATION

Local Benchmarks:

According to the resemblance the project area has to natural grasslands in New South Wales, the scoring ranges[30] for bare soil are the following:

EXCELLENT: Project Area has a percentage cover of bare soil that is notably lower than the % bare soil cover in the surrounding zone. The difference is higher than 50%.

GOOD: Project Area has a percentage cover of bare soil that is lower to the % cover in the surrounding zone. The difference is smaller than 50% and higher than 20%.

FAIR: Project Area has a percentage cover of bare soil that is +/- 20% of the %bare soil cover in the surrounding zone.

NEEDS IMPROVEMENT: Project Area has a percentage cover of bare soil that is higher than 20% with respect to the surrounding zone.

Quantification Methodology:

[30] 13. Native vegetation | State of the Environment 2015

A Bare Soil Index (Equation 10) was calculated using Bands 2, 4, 8, and 11 from the averaged Sentinel-2 image generated in Section 3.5. Results from the calculation were used to compare the average BSI from within the farm boundaries to the average BSI value in a 10km radius surrounding the farm. The range of values accounting for bare soil in the area of interest were determined by visual inspection of historic images from 2017 in Google Earth.

$$BSI = [(B11 + B4) - (B8 + B2)] / [(B11 + B4) + (B8 + B2)] \quad \text{(Eq. 10)}$$

Results:

- The percentage area of bare soil estimated within the Wilmot Project Area was 0.73%.
- The percentage area of bare soil estimated in the 10km reference area was 7.33%.

As a result, the Wilmot Project Area had **ten times lower bare soil cover** as compared to the reference area, being the difference of 90%.

The level of resilience of the Wilmot Farm for 2019 was: **EXCELLENT**

Previous Years

- Year 2017 (Baseline): the level of resilience was rated as: **EXCELLENT**[31]
- Year 2018: the level of resilience was rated as: **GOOD**[32]

6. CALCULATING THE ANIMAL WELFARE

6.1. ANIMAL WELFARE RANKING

The Animal Welfare metric ranks within 3 possible categories (Poor, Fair, and Good) depending on the percent of accomplished items from the following list (more detailed information here). The calculation is only considered in relation to the total number of items that are applicable to the project.

1. Responsibilities
2. Access to feed and water
3. Risk management
4. Facilities

[31] The Wilmot Cattle Project 2017- BASELINE Report
[32] The Wilmot Cattle Project - 2018 Report

5. Animal handling
6. Castration / dehorning
7. Breeding
8. Calf raising systems
9. Dairy
10. Feedlots
11. Slaughtering

NEEDS IMPROVEMENT: <40% requirements are met.

FAIR: Between 40% and 70% requirements are met.

GOOD: >70% requirements are met.

EXCELLENT: 100% REQUIREMENTS MET

In the case of the Wilmot farm (See Animal Welfare Wilmot document for detailed review), the items that apply and their corresponding statements regarding compliance are listed below:

1. Responsibilities - fully addressed, clear responsibilities outlined in individual role descriptions and supported by appropriate company policies and training
2. Access to feed and water - fully addressed
3. Risk management - fully addressed, records of risk management kept via company policies and monthly managers reports
4. Facilities - fully addressed, all facilities constructed and maintained to allow humane treatment of animals
5. Animal handling - fully addressed, all staff trained in low stress stock handling
6. Castration / dehorning - fully addressed
7. Breeding - fully addressed
8. Calf raising systems - not used/not applicable
9. Dairy - not applicable
10. Feedlots - not used/not applicable

11. Slaughtering - not done/not applicable

As a result the final score is 7/7*100= **100% (EXCELLENT)**

7. SUMMARY OF RESULTS AND SCORING

I. **SOC STOCK$_{2019}$ = 90,348 metric tons of SOC**
II. **NET CO_2e STOCKS$_{2019}$= 330,665 tCO_2e**
III. **Credible Carbon Change$_{2018\text{-}2019}$ = 25,103 tCO_2e**
IV. CO-BENEFITS: The partial and final scores for Soil Health, Ecosystem Health and Animal Welfare for the Baseline period are shown in Table 5 below, based on the following scores extracted from the Methodology[33]:

Weights for Soil Health scoring :

- Poor: *0.33
- Moderate: *0.67
- Excellent Point: *1

Weights for Ecosystem Health scoring :

- Needs Improvement point: *0.25
- Fair point: *0.50
- Good point: *0.75
- Excellent Point: *1

TOTAL SCORE CALCULATION= Partial Weighted Points /Total points

Qualitative equivalencies:

- Total Score <0.40= Needs Improvement
- 0.40<Total Score <0.60=Fair
- 0.60<Total Score <0.80=Good
- Total Score> 0.80= Excellent

TABLE 5: SUMMARY SCORES FOR 2019

MAIN INDICATOR	PARTIAL INDICATOR	Rating (cross-check the corresponding rating)			**FINAL SCORE**
		Poor	Moderate	Optimal	

[33] Methodology for GHG and Co-Benefits in Grazing Systems

Soil Health	pH	X				**Qualitative Poor - Moderate - Optimal according to sum of weighted points**
	N				X	
	P				X	
	K				X	
	CEC				X	
Scores for Soil Health		**1*0.33=0.33**		**0**	**4*1=4**	**(4.25/5= 0.85 EXCELLENT**
MAIN INDICATOR	PARTIAL INDICATOR	NI	F	G	E	
Ecosystem Health overall score	Vigor				X	**Qualitative NI-F-G-E according to sum of weighted points**
	Organization			X		
	Resilience				X	
Scores for Ecosystem Health				**1*0.75=0.75**	**2*1=2**	**=2.75/3=0.92 EXCELLENT**
Score for Animal Welfare					**X**	**EXCELLENT**

* NI= Needs Improvement; F=Fair; G=Good; E=Excellent

TABLE 6: SUMMARY OF THE FINAL RESULTS FOR 2019 AND THE PREVIOUS PERIODS.

MAIN OUTCOME	2017 - Baseline	2018	2019
Total Carbon Change	-	13,140 tCO_2e	25,103 tCO_2e
Soil Health	EXCELLENT	EXCELLENT	EXCELLENT
Ecosystem Health	GOOD	EXCELLENT	EXCELLENT
Animal Welfare	EXCELLENT	EXCELLENT	EXCELLENT

8. DEVIATIONS FROM METHODOLOGY

The following methodology deviations were applied during this monitoring period:

8.1. ANCILLARY DATA

Deviation from Original Methodology:

Minimum Soil Sample Size Estimation for Satellite Calibration

- Section 3.1.12 of Methodology for GHG and Co-Benefits in Grazing Systems:

The sample size required to calibrate statistical models used to estimate soil organic carbon stocks must be large enough to account for spatial variability of SOC in the topsoil. The higher the variability, the larger the soil sample size should be. Section 3.1.1.2 of the Methodology for GHG and Co-Benefits in Grazing Systems defines the total number of sampling points as:

$$N_{samples} = 1.3 * (2{,}254 * GrassArea^{(-0.72)} / 1000) \qquad \text{(Eq. 1)}$$

According to Equation 1, a minimum of 21 samples need to be collected to accurately calibrate and test any sort of statistical model. The number of samples actually collected on the Wilmot farm for the three reported years are reported in Table 7.

Table 7. Total number of soil samples collected on the Wilmot farm 2017-2019.

Year	Date Sampled	Number of Samples	Deviation from Minimum Number of Samples
2017	06/01/2017	8	13
2018	06/22/2018	7	14
2019	05/27/2019	10	11

Solution and Deviation Impact:

As the total number of samples fell below the required minimum sample size estimation, ancillary data from a nearby farm called the Woodburn farm were used to increase the sample size used for model calibration. Data from the Woodburn farm were suitable for use in calibration because this farm is located only 90km away, falling within the same climatic region as the Wilmot farm. The Woodburn is held also under the same management practices as the Wilmot farm. Samples from this farm were collected following the same procedures described for Wilmot and extracted only 5 days later. 18 subsamples were collected at 6 locations on the Woodburn farm (3 subsamples per location), and combined into 6 composite samples bringing the total number of samples to 14 between the two farms.

Models generated with the Wilmot data were slightly less accurate than models generated using the combined dataset. Incorporating the Woodburn data, which generally had a lower range of percent soil organic carbon values, revealed Band 12 had a more significant relationship with SOC than Band 4 which was originally chosen using just the Wilmot data. The addition of the Woodburn data improved the size and reliability of the dataset, overall accuracy of models ultimately reducing the possibility of underestimating soil organic stocks.

The deviation does not negatively impact the conservativeness of the quantification of GHG emission reductions or removals.

8.2. BULK DENSITY

Deviation from Original Methodology: Bulk Density Analysis Using Pedotransfer Functions

Section 3.2 of Methodology for GHG and Co-Benefits in Grazing Systems:

The conversion of percent soil organic carbon to soil organic carbon stocks requires field-collected bulk density measurements and an estimation of soil depth (Equation 2). Prior to the 2019 sampling round, bulk density measurements were not collected so another method to calculate bulk density was required.

SOC stock(ton/ha) = SOC% × BD (g/cm3)× Soil Depth (cm) (Eq.6)

Solution and Deviation Impact:

In reviewing scientific literature on Southern Australian soils, a statistically significant (p-value < 0.05) linear regression pedotransfer function (PTF) proposed by Merry[34] was found to relate percent soil organic carbon to bulk density (Equation 2).

Bulk Density (g/cm3) = 1.608 - 0.0872 * Percent SOC (Eq. 5)

The estimated bulk density values using the PTF were compared to the 2019 Wilmot bulk density values collected during the soil sampling survey (Figure 16), and an ANOVA (analysis of variance) analysis summarizes the relationship between the two (Figure 17). The uncertainty associated with using a pedotransfer function to estimate bulk density is expressed as:

$$\text{nSSE} = \frac{\textit{Standard Error of the Estimate}}{\textit{Average Bulk Density Observation}} = \frac{0.295}{1.4} * 100 = \mathbf{21\%}$$

[34] In: Spouncer, L.R., Skjemstad, J.O., Merry, R.H. (2000) Soil Carbon Information for Major Soils in IBRA regions - South Australia. CSIRO Land and Water Consultancy Report. Pp 22

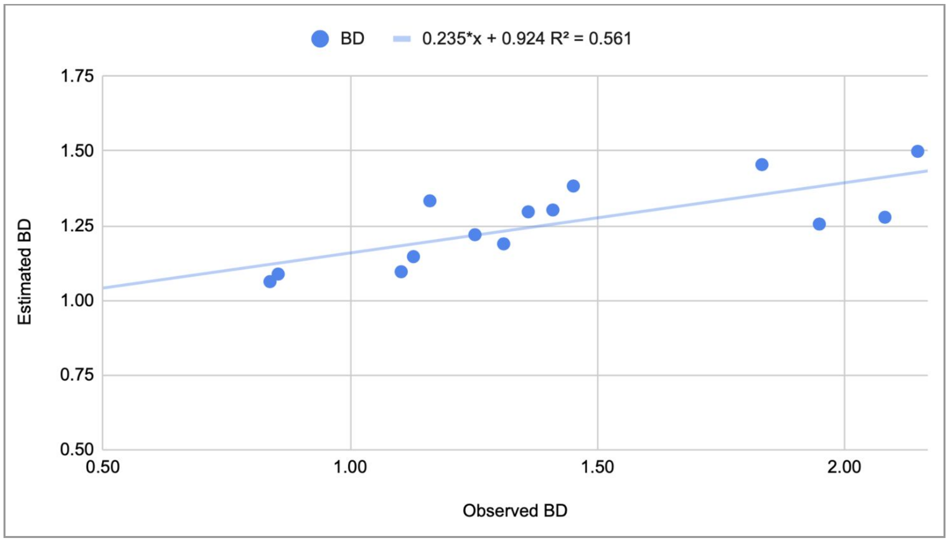

Figure 16. Scatter plot of the estimated bulk densities from the Merry PTF versus the observed bulk densities from the 2019 sampling round.

Model Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.749[a]	.561	.524	.295058	.561	15.320	1	12	.002

a. Predictors: (Constant), BD_Merrysept19

Figure 17. Model summary for the estimated bulk densities from the Merry PTF versus the observed bulk densities from the 2019 sampling round.

Equation 5 was then applied to the soil organic carbon map for the given sampling period to create a bulk density map for the Wilmot project area.

The uncertainty due to these bulk density measurements was 21% (see nSSE calculations above). According to Section 3.6.4 of the Methodology, the maximum uncertainty for any measurement within the project must fall below 50%. This uncertainty value was incorporated into the calculation of the Uncertainty Deduction.

Signature

Date: December 14, 2020

Christian Shearer
Chief Executive Officer
Regen Network Development, Inc.