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CULCAIRN SOLAR FARM

AGRICULTURAL IMPACT STATEMENT

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Submitted to:

Neoen
Level 10
227 Elizabeth Street
SYDNEY NSW 2000

Attention: Anne Frederic

Ph: 0456 006 545
Em: anne.frederic@neoen.com

Submitted by:

Riverina Agriconsultants
Agribusiness & Environmental Consultants
PO Box 1458
GRIFFITH NSW 2680

Ph: 02 6964 9911
Fx: 02 6964 5440
Em: admin@rivagri.com.au
Web: www.rivagri.com.au
ABN: 79 095 414 065

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1.0 EXECUTIVE SUMMARY

This Agricultural Impact Statement has been prepared to independently assess the impact on agricultural production of the proposed 350MW Culcairn Solar Farm located in the Greater Hume Local Government Area (LGA) in southern NSW. The development footprint of the proposed solar farm is about 1,084ha.

This report has assessed the:

- Existing land use to be about 75% annual cropping and 25% pastures and forage crops for livestock;
- Alternative land use options to be limited due to a range of constraints;
- Current gross annual farm gate value of production to be $1,580,000; and
- Current gross annual related economic activity to be $3,440,000.

The proposed post-development land use is pastures for sheep grazing in and around the solar panels. There is limited information available on pasture productivity under solar panels. This report has assessed the likely impact of the solar farm development to be a 25% reduction in pasture productivity.

This report has assessed the:

- Estimated post-development gross annual farm gate value of production to be $1,300,000;
- Estimated post-development gross related annual economic activity to be $2,830,000; and
- Estimated post-development reduction in local direct expenditure to be $450,000.

Hence the estimated impact of the proposed development a reduction in annual gross revenue of $280,000 (farm gate) and an annual reduction of $610,000 in related economic activity (pre and post-farm gate), assuming a 25% reduction in pasture productivity.

This assessment is limited to quantifying the impact of the development directly on agricultural production capacity. The impact outlined in this report will be mitigated by the rental payments remaining landowners will receive from the solar company, a portion of which will be reinvested in the farm business with related local economic activity benefits. The analysis in this report does not consider the economic benefits associated with the transition from production to solar farming, including fencing and civil contractors

2.0 INTRODUCTION

This Agricultural Impact Statement has been prepared for Neoen to independently assess the economic impact on agricultural production of the proposed Culcairn Solar Farm.

This report has assessed and quantified the economic impact of the proposed solar development on the agricultural output of the development area relative to:

- Current production systems; and
- Potentially higher value alternative production systems (if any).

2.1 Report Authors

This report was prepared by Michael Ryan, Principal Consultant of Riverina Agriconsultants, and Andrew Bomm, Principal Consultant of Progressive Agriculture, and was prepared following a site inspection of the subject land on 27 March, 2020.

3.0 LAND RESOURCE DESCRIPTION

3.1 Project Description

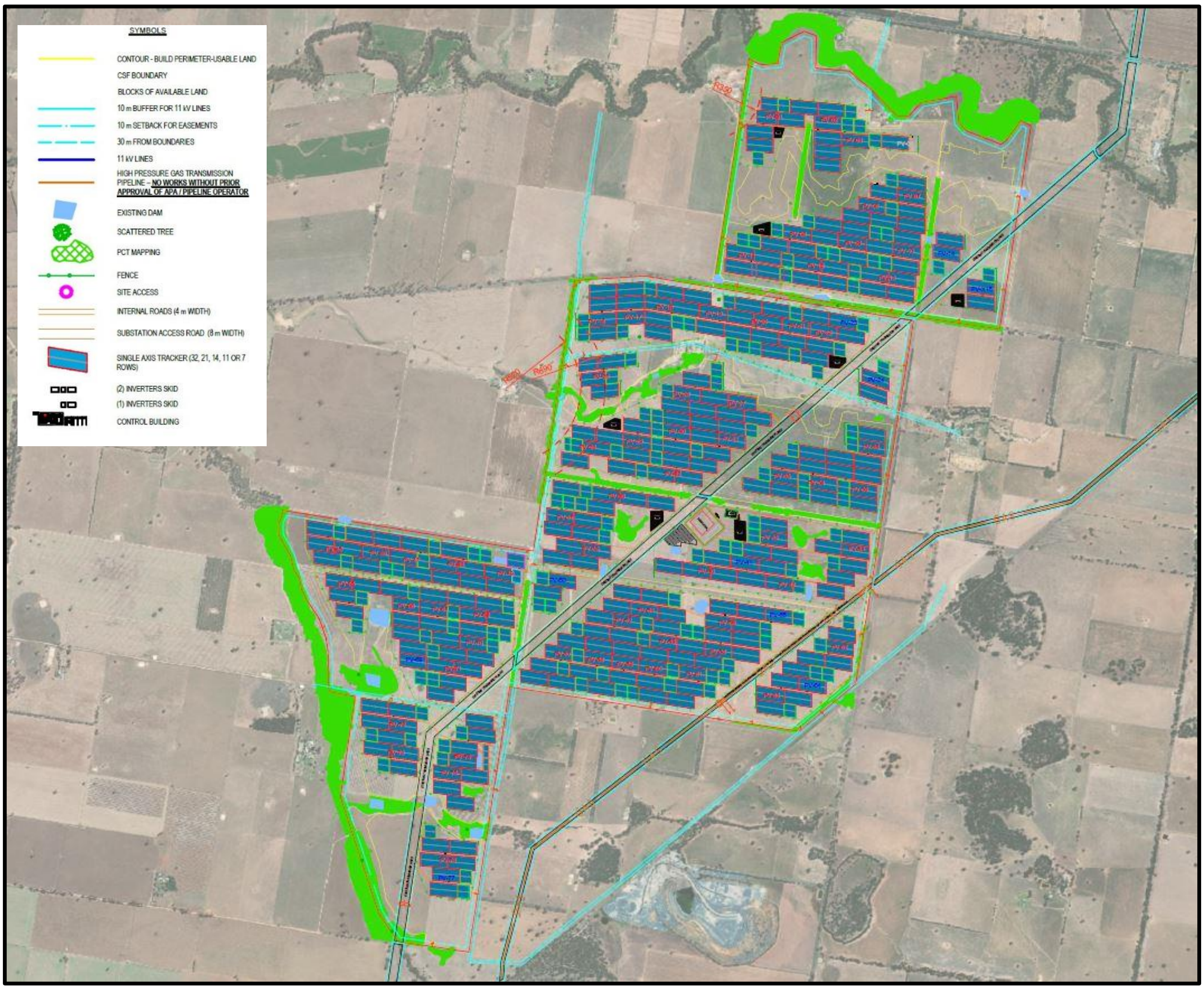
The proposed Culcairn Solar Farm is located in the Greater Hume LGA approximately 4km west of Culcairn, south of the Billabong Creek, spanning both sides of Cummings Road. According to NGH 2020:

> *"The development footprint would occupy around 1125 hectares (ha) of the 1351 ha subject land."*
>
> And
>
> *"The proposal would involve the construction of a ground-mounted photovoltaic (PV) solar array generating around 350 MW AC / .... of renewable energy and would connect into an existing 330 kV TransGrid transmission line that traverses the proposal. The power generated would be exported to the national electricity grid."*
>
> And
>
> *"The rural land within the region is used primarily for agriculture including cropping and grazing. The development area comprises several large paddocks, which have been deep ripped and largely cleared for pastures and grazing. Land and agricultural activities like those of the proposal area are widespread in the region. There is no evidence of horticulture or other intense farming activities within the proposal area."*
>
> And
>
> *"The land is classified as Class 4 under the Land and Soil Capability Assessment Scheme (OEH 2012) and is described as sloping land capable of sustaining cultivation on a rotational basis (Figure 6-8). The land is readily used for a range of crops and pastures. Class 4 land is considered to have moderate to severe limitations where pasture improvement relies on minimum tillage techniques and the productivity may be seasonally high but overall is low as a result of major environmental constraints."*
>
> And
>
> *"A reduction in the agricultural uses of the development site. Specifically, broad-acre dryland cropping would not be possible. This situation will affect land used principally for crop production."*
>
> And
>
> *"Other agricultural production, particularly sheep grazing, would continue albeit at a reduced capacity. Continuing grazing at a reduced rate would encourage grasses to continue growth, reduce the impact of soil compaction and maintain vegetation height below the panels and around the property."*
>
> And

"The property owner will be compensated by the Proponent/operator for hosting the solar farm through regular lease payments over the life of the solar farm. When compared with agricultural production, this payment has positive cashflow benefits and creates a diversity of income sources for the property owner. It is not seasonal, nor climate dependent. Lease payments would increase in line with CPI over the agreement period."

The solar farm area of 1,125ha as set out above has been modified (reduced) and is now understood to be 1,084ha. The revised site layout is provided as Figure 1.

Figure 1: Solar Farm Site Layout



Features that can be observed in Figure 1 include:

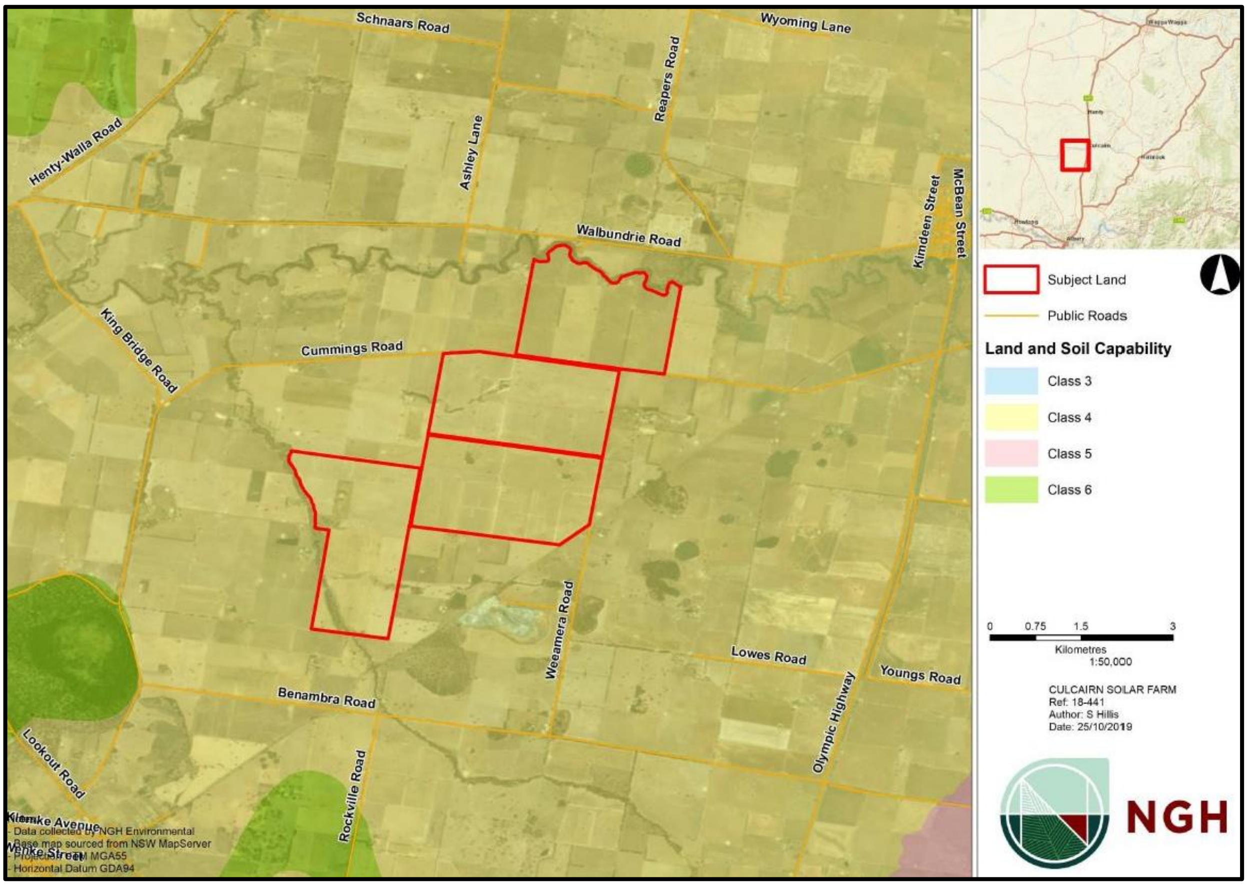
- The solar farm area running in a north-east to south-west direction;
- The Billabong Creek on the northern boundary of the solar farm area; and
- Cummings Road running east/west through the northern side of the solar farm area.

The area which houses the solar panels in Figure 1 is estimated to be 576ha. This area does not include the other site infrastructure such as internal roads, substation, battery facility and staff amenities which is estimated to be about 10% of the solar panel area, say 58ha. Rounded to the nearest 5ha the total area directly impacted by the proposed solar development is estimated to be 635ha of which 110ha is on the farm north of Cummings Road.

3.2 Land Resource Description

Figure 6-8 from NGH Environmental 2020 shows Land and Soil Capability for the proposed solar farm and surrounds and is provided as Figure 2 below:

Figure 2: Land and Soil Capability Mapping



Source: *NGH* Environmental (2020). Environmental Impact Statement, Culcairn Solar Farm Project Number:18-441

Features that can be observed in Figure 2 (above) include the proposed solar farm area marked with a red boundary, most of the area (and surrounds) is generally cleared for cropping and pastures and the majority of the land in the figure (including all of the solar farm area) is mapped as Class 4.

The report authors do not consider the solar farm area as '*having moderate to severe limitations*' and '*productivity may be seasonally high but overall is low*'. We note these descriptions arise from the Land and Soil Capability Assessment Scheme.[1] Discrepancies between mapped land capability and actual productivity often arise from interpreting broad-scape data at the scale of individual farms.

[1] Office of Environment & Heritage (2012)

However, the implications of whether land is correctly or incorrectly classified as Class 4 need not be overstated as it does not serve as a basis for quantifying agricultural impact. The assessment in this report is based instead on a comparison of the *actual* agricultural production capabilities of the land before and after development, not a comparison relative to a third-party classification of the landscape.

For the purpose of this report, all of the land proposed for the solar farm is considered to be productive land capable of the activities described in Section 4.0 and Section 5.0 of this report. The assessment within this Agricultural Impact Statement is based on how the solar farm area is being used, or could potentially be used, in a practical farming context.

McMahon (2019) described the soil type for the solar farm area as a Chromosol with the topsoil ranging from light clay to clay loam to fine sandy clay loam and the subsoil as ranging from light to medium clays to silty clay loams. McMahon (2019) states:

> *'Topsoil pH (1:5 soil/water) ranged from 5.4 – 5.9 and can be described as moderately acid.'*

According to the landowners the soils within the solar farm footprint are occasionally (say 1 in 10 years) spread with lime to increase soil pH and ameliorate the negative impacts of soil acidity on production. Table 2 in McMahon (2019) indicates four of the 12 soil samples analysed had a pH (1:5 water) of either 5.4 or 5.6 which is low. These soils would require topdressing with lime at for example 2.5tonnes/ha to ameliorate this low pH.

According to the landowners the northern farm (about 320ha) is currently used for pastures and forage crops, and the other two farms (total about 1,030ha) are used for annual winter crop production, with livestock periodically grazing crop stubbles. The two southern farms are prone to waterlogging and drains and raised beds have been installed in some areas to manage this constraint.

In order to ascertain the productivity of the proposed solar farm relative to the surrounding area, satellite imagery for 2016 to 2020 was obtained for the proposed solar farm area and a sample of farms in the vicinity. Biomass production was assessed using NDVI (Normalised Difference Vegetation Index). According to GISGeography:

> *"Normalized Difference Vegetation Index (NDVI) quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs).*
>
> *NDVI always ranges from -1 to +1. But there isn't a distinct boundary for each type of land cover.*
>
> *For example, when you have negative values, it's highly likely that it's water. On the other hand, if you have a NDVI value close to +1, there's a high possibility that it's dense green leaves.*
>
> *But when NDVI is close to zero, there isn't green leaves and it could even be an urbanized area.'*

Source: https://gisgeography.com/ndvi-normalized-difference-vegetation-index/

The NDVI imagery is included as Annexure 1, which comprises six images:

- The three farms in the solar farm area showing NDVI for 21 August, 2016 and a graph spanning March 2016 to November 2018;
- The three farms in the solar farm area showing NDVI for 26 August, 2019 and a graph spanning July 2017 to May 2020;
- The solar farm area (with a black boundary) and 12 other farms in the vicinity (with a blue boundary) showing NDVI for 21 August 2016;
- The solar farm area and the 12 other farms in the vicinity showing NDVI for 26 August 2019; and
- The solar farm area with a graph of NDVI for the solar farm area and the selected farms for the periods March 2016 to November 2018 and July 2017 to May 2020.

The two images of the solar farm area (only) show a large variation in NDVI in August 2016 and much less variation in NDVI in August 2019. The graph for each image shows total NDVI (as a point) for each date that a satellite image is available. There are significant drops in NDVI on occasion such as in February 2017 and September 2017. These are due to cloud cover obscuring some of the area, therefore such drops in NDVI should be ignored. Observations of these graphs include:

- Hope Farm (the northern farm) has higher biomass;
  - In all of 2016 and through to July 2017;
  - From November 2017 to September 2018;
  - From November 2018 to July 2019; and
  - From February 2020 to May 2020.
- The NDVI for the other two farms is similar at most dates.

This difference in NDVI suggests the northern farm produces more biomass. Some of this would be due to pasture growth outside the cropping season and some due to more productive land (better soil type) on the northern farm. Management may also play a role in the differences but less so than the fact that they are different systems (that is, pasture and cropping).

The images of the solar farm area and selected surrounding farms span the same period with the same NDVI date as for the solar farm area alone. These two images show lower biomass for the solar farm area compared to the surrounding farms in August 2016 and similar biomass in August 2019.

An observation of the graphs comparing the solar farm area to the surrounding farms is that the solar farm area has similar biomass to the surrounding farms except for:

- August to November 2016;
- April to September 2017;

- June to August 2018;
- April to August 2019; and
- March to May 2020.

Some care must be taken interpreting these images as the report authors do not know which of the selected farms are in crop or pasture at any given time. Notwithstanding the NDVI images indicate the solar farm area generally has lower biomass than the surrounding farms in the autumn, winter and spring.

If the NDVI analysis is adjusted to compare the northern farm only (of the solar area) to the surrounding farms the graphed NDVI trend reverses and the northern farm has higher biomass compared to the surrounding farms. This occurs over similar periods to the description above (of the northern farm compared to the other two farms in the solar area). The consistently higher biomass for the northern farm (in the solar area), when compared to the other two farms in the solar area and/or the selected surrounding farms, indicates this farm is generally more productive (notwithstanding the pasture system), most likely due to the presence of more fertile soil on the Billabong Creek floodplain.

On the basis of the NDVI analysis (set out above) it can be concluded that of the three farms in the solar farm area, the northern farm has a higher production potential than the other two farms. This conclusion has been supported by comments made by the landowners and the report authors' observations during a site inspection on 27 March, 2020. The northern farm which has been run as a grazing operation for over 10 years, is estimated to have a livestock carrying capacity of 15 DSE/ha. A DSE (Dry Sheep Equivalent) is defined by the NSW Department of Primary Industries as the feed requirements for a 50kg wether (adult male sheep) maintaining a constant weight. Such an animal has a DSE rating of 1.[2] The other two farms in the solar farm area are estimated to have a carrying capacity of 12.5 DSE/ha as they are considered to have slightly less productive potential for the reasons set out above.

[2] NSW Department of Primary Industries, Using DSEs and carrying capacities to compare sheep enterprises, sourced from https://www.dpi.nsw.gov.au/agriculture/budgets/livestock/sheep-gross-margins-october-2015/background/dse

4.0 EXISTING PRODUCTION ANALYSIS

Farming in the Culcairn district is predominantly a mixed broadacre livestock and annual winter cropping system. Livestock enterprises are most commonly sheep grazing for meat and wool, and cattle grazing for beef. Winter crops grown in the area are wheat, canola, hay/silage, barley, triticale, lupins and oats.

According to ABS (2018), as of 2015/16, 59% of the value of agricultural commodities produced in the Greater Hume LGA was derived from livestock, including beef cattle 35% and sheep (including wool) 19%. Cropping contributed 34% and hay 6%. 53% of the crop income was derived from wheat and 29% from canola.

The proposed solar farm area comprises three farms which align with the key agricultural enterprises set out above. A brief summary of each operation is provided as follows:

- The farm located on the north side of Cummings Road was purchased by the current owners in about 2009. The farm produces pastures and forage crops for grazing young bulls as part of a large stud bull enterprise. The landowners have indicated if the solar farm proceeds they will sell the land to Neoen and look to purchase a comparable sized farm to relocate their young bull depot. Hence the likely impact (if the solar farm proceeds) on this business is not a reduction in their capacity but rather a relocation of this part of the business, which will then displace a more typical land use in the area (annual cropping and livestock grazing);
- The farm in the centre of the solar farm has been owned by the same family for over 100 years. For the last three years this farm has been leased to an adjacent landowner who utilised the land for annual cropping and livestock (sheep) grazing of stubbles. The annual crops were produced for grain, hay and in some years the crop stubbles were baled. Prior to 2017 the landowners ran a continuous annual cropping program predominantly based on wheat and canola on a 2 to 1 rotation; and
- The southern farm was purchased by the current owners about 20 years ago. This farm produces annual crops, predominantly wheat and canola on a 2 to 1 rotation. Crop stubbles are grazed by cattle over the summer.

The two southern farms comprise about 75% of the total solar farm area and have been continually cropped with stubble grazing for a number of years. According to the landowners these two farms are constrained by waterlogging in the winter and frosts in the spring. The range of yields reported by the landowners from these areas range from 3 tonne/ha to 5 tonne/ha for cereals to 1.5 tonne/ha to 2.5 tonne/ha for canola. Soil acidity is an ongoing challenge with lime applications required about once every 10 years. The yields adopted for the analysis is this report are the mid-point of the above range, being 4 tonne/ha for wheat and 2 tonne/ha for canola, and assume any soil acidity issues are ameliorated by the application of lime.

As set out in Section 3.1 (above) the subject land is 1,351ha, which is estimated to be about 95% arable with the balance of the area infrastructure, waterways, native vegetation and tree plantations. On this basis the northern farm is estimated to be 300ha arable and the southern two farms are estimated to be 980ha arable. The assessment of existing productivity in this section of the report is based on 300ha of pasture and 980ha of crop with a rotation of 2 wheat to 1 canola.

Because the bull depot on the northern farm is operated in a different manner to more typical land use in the area, and because the expectation is that this bull depot will be relocated rather than displaced, the livestock enterprise adopted for the assessment of existing productivity is a commercial beef cattle breeding enterprise which is more representative of the wider area.

The value of agricultural production derived from the existing land use on the proposed solar farm area has been calculated using gross margins included as Annexure 2. The livestock gross margin adopted is a beef cattle breeding enterprise on 300ha of the solar farm area. This gross margin is based on the NSW Department of Primary Industries Beef Cattle Gross Margin Budget (for Butcher Vealers) dated April 2019. The crop gross margins are canola and wheat using a NSW Department of Primary Industries Gross Margin format having regard for current costs. Prices used are the average for the last five years according to ABARES[3] and areas used are 657ha of wheat (67% of 900ha) and 323ha of canola (33% of 980ha).

For each of the gross margins in Annexure 2, direct expenses that are/would be expected to be incurred in the Greater Hume LGA have been identified. On the basis that these inputs are those the report authors expect to have been purchased and/or produced in the LGA. These expenses are noted as a 'local expense' in Annexure 2. A summary of the gross margin analysis is provided in Table 1.

Table 1: Pre-development Analysis of Annual Gross Income and Direct Expenses

	Gross Income			Expenses			Local Expenses	
Enterprise	**$/DSE**	**$/Ha**	**Total $**	**$/DSE**	**$/Ha**	**Total $**	**$Ha**	**Total $**
Beef cattle breeding	60.39	905.78	271,733	28.81	432.16	129,648	363.68	109,105
Canola		1,068.00	344,964		454.90	445,806	425.00	416,500
Wheat		1,116.00	733,212		388.75	380,973	357.50	350,350
Stubble grazing	74.59		228,444	34.30		105,053		91,396
Total			**1,578,353**			**1,061,480**		**967,351**

Some comments on the data in Table 1 are provided below:

- The gross cattle income is based on the income in $/DSE (from the gross margin in Annexure 2) multiplied by the adopted stocking rate for the northern farm of 15 DSE/ha on 300ha. Cattle direct expenses are calculated as the cost in $/DSE multiplied by 15 DSE/ha on 300ha. Local expenses are 84% of total expenses (as set out in Annexure 2);

- The gross stubble grazing $74.59/DSE is the average of the adopted pre and post-development livestock enterprises being cattle breeding and merino wethers (refer to Section 6.8 below) included in Annexure 2 ($60.39/DSE for cattle and $88.80/DSE for sheep). The average of these two enterprises has been chosen to represent stubble grazing practices typical of the area. The total stubble grazing income is based on 980ha (being the crop area) of stubble providing 12.5 DSE/ha (980ha x 12.5 DSE/ha x 25% = 3,062.5 DSE for three months of the year. Stubble grazing direct expenses are calculated as the average cost per DSE (for the cattle and sheep enterprises) multiplied by 3,062.5 DSE. Local expenses are 87% of the total which is the average of the cattle and sheep enterprises in Annexure 2; and

- The gross crop income and direct expenses are based on the gross margins included in Annexure 2.

The total annual value of production (farm gate) from the proposed solar farm area is estimated to be $1,580,000 (as set out in Table 1 above, when rounded to the nearest $10,000).

[3] ABARES (2019)

The total annual direct expenses arising from the solar farm area (as set out in Table 1) are $1,060,000 and $970,000 in the Greater Hume LGA (when both are rounded to the nearest $10,000). These expenses are considered further in Section 6.8 of this report.

The related economic activity arising from the proposed solar farm area can be calculated using an economic multiplier. Upstream activities for the current landowners' enterprises include contractors, farm input and service providers. Downstream activities for the current landowners' enterprises includes distribution and processing (value adding). The current annual related economic activity for the proposed solar farm area can be calculated using the economic multiplier of 2.1788, as used by ABS, 2012 which equates to:

$1,580,000 x 2.1788 = $3,442,504

For the purpose of this assessment this figure has been rounded (to the nearest $10,000) to $3,440,000.

5.0 ALTERNATIVE LAND USES

In assessing the likely agricultural impact of the development, the report authors have assessed the impact relative to both current production systems used on the development footprint and any potential higher value uses that may be foregone as a consequence of development. In our view, there are no such potential uses that should be considered as part of this analysis.

As set out in Section 4.0 (above) 54% of the value of agricultural commodities produced in the Greater Hume LGA in 2015/16 was derived from cattle and sheep and 40% from cropping and hay. The balance (6%) comes from more intensive land uses such as pigs, poultry and horticulture.

Alternative animal-based options such as intensive livestock, for example pigs or poultry, may be technically feasible on these farms. However, proximity to nearby residences and the absence of a secure water source (required for intensive animal production) would most likely rule out these options as a land use opportunity in the solar farm area. Notwithstanding these limitations, intensive livestock production does not require large scale land development, so the proposed solar farm would not directly preclude these options being adopted by the current or adjacent landowners.

Annual rainfall for the locality is about 600mm and annual evaporation is about double (1,200mm). Given the moisture deficit of 600mm, irrigation is required to support perennial and/or high value crops. Alternative land uses that require irrigation water are therefore not feasible on the solar farm area due to the absence of a suitable water supply. Consequently, higher value broadacre cropping options and horticulture, including vegetables, fruit and nut trees, are not viable in the solar farm area.

One land use option for landholders in the Culcairn district is to receive stewardship payments for undertaking environmental conservation and stewardship practices. For instance, the *NSW Biodiversity Conservation Trust* has been offering landholders occupying land in the LGA between $49/ha and $98/ha in return for an agreed native vegetation management program. There may exist an opportunity for the current landholders to be paid for managing (under contract) timbered areas of the farms – areas not subject to the proposed solar development.

The productive agricultural impact of the proposed solar farm relative to the opportunity cost of foregoing high value small scale development is not considered relevant. Any technically or economically feasible development of this kind could still be undertaken on residual areas of the landholding. This principle can apply to other potential land uses such as native flower production or other cottage industry options that may return more economic output per hectare than current systems.

The current land use on the northern farm of a young bull depot is a high value land use. However, as set out in Section 4.0 (above) this enterprise will relocate rather than be displaced. No further assessment of this enterprise is warranted.

When considering alternative land uses for the farms of the proposed solar farm area, and whether foregoing these future opportunities may exacerbate the impact on agricultural output, the scope of these ‘alternatives’ is realistically only within the parameters of the current broadacre mixed livestock and cropping system. That is, altering the *mix* of livestock and cropping enterprises within the current system is the only realistic option.

If the production system was 1,280ha of cropping (wheat and canola on a 2 to 1 rotation) with stubble grazing, total annual income would be $1,710,000. This is $130,000more than the $1,580,000 set out in Section 4.0 (above). If the production system was 1,280ha of pastures running beef cattle and merino wether enterprises (refer to Annexure 1) on a 50:50 basis, total annual income would be $1,250,000, which is $330,000 less than the $1,580,000 set out in Section 4.0 (above). Note these figures are gross revenue and do not take into account costs or profitability.

This report's assessment of the proposed solar farm's impact on the annual value of agricultural production is predicated on a baseline that broadly reflects current production systems being used across the district. The adopted mix of livestock and crop production in this report is based on current land use with regard for agronomic constraints and appropriate risk management for these circumstances. Any alternative enterprises have not been quantified as they are not considered feasible or likely in the circumstances.

6.0 AGRIVOLTAICS

6.1 Definition

Agrivoltaics is the combination of solar energy and agricultural production systems, co-located on the same land.[4] The objective of agrivoltaic systems is twofold:

1. Maximising overall economic productivity from the land; and
2. Meeting community expectations by ensuring continuity of agricultural land usage is maintained post solar development.

Integrating an agricultural production system into a solar development can include animal grazing between panels or cropping under elevated arrays. Adopting agrivoltaic systems will generally be most beneficial where the agricultural productive capacity of the land developed for solar is high, and where there is community demand to maintain agricultural production on that land for socio-economic reasons. For example, where the community values retaining existing agriculture-related service industries.

Agrivoltaic systems may be expressed as 'agrovoltaics', 'agrophotovoltaics' or 'agrisolar' at various times. The terms are interchangeable, but for the purpose of this report we will use the term agrivoltaics, or agrivoltaic systems.

6.2 International Research

There has only been limited international research in this field, and most relates to crop production within solar arrays, rather than pasture for livestock grazing.

Academic Literature

Italian maize crop simulation

In 2018 researchers from Italy and The Netherlands simulated maize crop production using a 40 year climatic dataset from Northern Italy, comparing crop performance (using a radiation and shading model) under different PV array constructions. Key observations of the paper include:

- Reduction of solar radiation was more affected by panel density than whether panels were fixed or tracking arrays;
- Reducing solar radiation affects mean soil temperature (lower), evapotranspiration (lower), and soil water balance (higher);

[4] Guerin, T., (2019) p. 5

- Average grain yield was higher under the array than full light, with the advantage increasing under dry conditions; and
- The highest yields were achieved under full light, in conditions where rainfall satisfied crop water demand. In dry years crops under the PV array fared better.[5]

Michigan Technological University

In a 2015 paper titled 'The potential of agrivoltaic systems' researchers from Michigan Technological University summarised prior research and developed a crop simulation model to gauge the technical potential of scaling agrivoltaic systems. Key observations from the paper include:

- Lettuce crops grown beneath Photovoltaic (PV) arrays on stilts experienced no significant yield effects from shading;
- The lettuce plant can adapt to shading by increasing leaf area to compensate for reduced solar radiation, while wheat yields will be more affected as the plant cannot adapt to reduced light conditions;
- It is difficult to predict how different plants will behave under shading;
- Shading from PV panels reduces soil temperature and alleviates water evaporation during summer and dry climatic periods;
- Crop shade tolerance depends on the radiation interception efficiency of the leaves; and
- Information about shade tolerant crops is lacking, though trials on maize have not been promising.[6]

Field Trials

Oregon University Study

This 2018 study sought to measure the effects of a 2.4ha agrivoltaic solar farm on microbiology, soil and pasture production. The trial was conducted on the Oregon State University campus, with fixed mounted photovoltaic panels (PVP) 1.1m above ground and a distance between panels of 6m and panels inclined southward at 18° (see Figure 3).

The pasture below the panels and the control areas (areas with no solar panels) were in the same paddock being actively grazed by sheep. Observations within the treatment site were divided between full sun (no shade), partial sun (episodic shade) and fully covered (full shade).[7]

The study found soil moisture depleted more rapidly in the no shade area between the panels, than in the episodic or full shade areas, or the control area. Moisture depletion occurred faster in the no shade area than the control area with no panels. This difference to the control area was unexpected, and the study hypothesised it was associated with long wave radiation transfer affecting evapotranspiration, though it indicated further study of this issue was required.

[5] Amaducci, S., et al, (2018) p. 545, 553 and 555-556

[6] Harshavardhan, D et al, (2016) p. 300-301 and p. 307

[7] Adeh E., et al, (2018) p. 3, accessed on 10/01/20

The observation period started with a full moisture profile. At the end of this period soil moisture in the full shade zone was nearly twice the full sun zone, though mean soil moisture across all the solar panel affected zones was similar to the control.[8] The study noted the stark variability of soil moisture across zones, and that this:

> *"creates an undesirable variability across the field and hints that shade uniformity may be an important consideration for the design of future agrivoltaic systems."*[9]

From a water use efficiency perspective (moisture relative to biomass), the full shade area was three times more efficient than the control for the grasses present in the field being used.[10]

The study concluded that solar panels could have a beneficial effect, by reducing potential evapotranspiration in water limited areas, especially semi-arid pastures with wet winters, thus leaving water to be stored in the soil for longer and supporting pasture growth for extended periods.

The study found some evidence that plants with less root density and a high net photosynthetic rate may be best suited.

The authors stated that the economics of this system, including for different crop types, requires further study.[11] We note that day length, seasonal conditions and grass types researched in Oregon vary from the Culcairn site, and that as a consequence results would be expected to vary if the same trial methodology were used in the eastern Riverina. For instance, we would be cautious about extrapolating specific soil moisture differences between shading zones expressed in the study to the Culcairn site, given the very different rainfall quantities and patterns experienced between locations.

However, the analysis of a comparable grazing system should allow us to draw some inferences from this work. In particular, it appears that the findings of this study reflect certain observations made in discussions with Australian managers co-locating grazing stock with solar developments. In particular, the following key observations:

- Shading can improve soil moisture and maintain pasture growth for longer periods at certain times of the year; and
- Shade and soil moisture variability needs to be factored into the choice of pasture species mix and paddock rotations.

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[8] Adeh E, et al, (2018) pp. 9-11, accessed on 10/01/20

[9] Adeh E,et al, (2018) p. 11, accessed on 10/01/20

[10] Adeh E, et al, (2018) p. 14, accessed on 10/01/20

[11] Adeh E, et al, (2018) p. 16, accessed on 10/01/20

Figure 3 Oregon University Study Area

Photo courtesy of Oregon University

Fraunhofer Institute Study

In 2017 a small scale (194KW) agrivoltaic demonstration project was undertaken in southern Germany, focusing on yield effects across a range of crops.

In this project solar modules for electricity production were installed directly above crops. These panels covered an area of one-third hectare, at 5m above the ground to allow for crop operations beneath the panels. Winter wheat, potatoes, celeriac and clover grass were the first crops to be tested. The trial design ensured that the crops were exposed to uniform solar radiation. The crop yield of clover grass under the PV array was 5.3% less than the reference plot. The yield losses for potatoes, wheat and celeriac were between 1% to 18%. Researchers indicated further testing is required before drawing firm conclusions.[12]

Given the different solar configuration, climatic conditions, and cropping options demonstrated in this German trial, our view is that no inferences can be drawn that would be relevant to the Culcairn site being considered in this study.

[12] Fraunhofer Institute for Solar Energy Systems ISE, Press release 23/11/17 accessed 10/01/20

6.3 Australian Agrivoltaic Systems

When assessing options for co-locating agricultural production and solar panels, sheep grazing represents the only viable option and therefore the most useful basis for comparison when assessing productivity effects.

No formal trial data relating to agrivoltaic systems in Australian conditions is yet available to assist quantifying production outcomes. However, practical experiences from existing commercial systems, and useful recording of these experiences, provide a sound basis on which to assess the agricultural impact of solar development incorporating agrivoltaics systems.

Developer Neoen are already operating agrivoltaic systems at four sites in Victoria and NSW, as outlined below and in Section 6.5 (below).

Grazing Sheep

The adoption of agrivoltaics in Australia has, to date, involved incorporating pasture-based sheep grazing systems into solar production. Accordingly, this assessment of the likely impact of solar farm development on agricultural production is predicated on incorporating sheep grazing into solar farm developments.

The preference for sheep grazing reflects some clear realities with solar and agricultural production across the Australian landscape. Firstly, Australia has an abundance of land that may be suited to solar development (notwithstanding network capacity constraints), with solar development being undertaken at large scale on farms where broadacre production systems have been operating.

There are also practical challenges with incorporating other production systems into an Australian solar farm. Broadacre cropping is not a feasible option due to lack of access for cropping machinery. The alternative broadacre livestock option of running cattle is also problematic, as cattle are likely to damage solar infrastructure. Allowing goats to graze alongside solar panels would present an even greater risk to infrastructure.

Integrating smaller scale and/or more intensive farming enterprises appears unlikely for economic reasons. While some horticultural options (such as vegetables) within a solar development may be practically feasible, it would not make sense to diminish the productive capacity of a high value crop where alternative solar farm locations exist.

Trial Work

Agrivoltaics is a relatively new concept In Australia and globally. There has been limited formal trial work undertaken, either at small scale in a commercial agricultural setting, or in limited formal research trials. There appears to have been no formal trial work undertaken in Australia to either:

- Compare the viability of incorporating different production systems into solar developments; or
- Assess the costs and benefits of sheep grazing within a solar array.

There are clear impediments to co-locating most agricultural production systems with solar. As alternative options to sheep are at face value unfeasible, the absence of formal trial work to compare outcomes across varying production systems is understandable.

If community and government appetite builds for having agrivoltaics as a condition of solar approval, there would be a case to undertake research into the following issues:

- Quantifying the difference between the productive capacity of a pasture-based sheep grazing system, in a typical farm setting, and agrivoltaics;
- Understanding the most suitable pasture seed mix in an agrivoltaic environment characterised by highly modified shading patterns and soil moisture distribution; and
- The effect on pasture growth of varying solar panel configurations.

The Culcairn Solar Farm EIS (p. 88) notes that:

> *"The Proponent initiated discussions with CSIRO about a 3 year longitudinal 'agrisolar' research project exploring agrisolar co-benefits and ways to maximise productivity yields as well as soil quality, biodiversity, and the potential for carbon sequestration. The research opportunity was presented at the Clean Energy Council's Utility-scale PV Directorate meeting in October and an industry consortium is currently advancing the research project."*

In 2019, Neoen engaged specialist livestock consultant Phil Graham to prepare on sheep grazing on solar farms, based on his observations from visits to Neoen solar farms at Coleambally, Parkes and Dubbo. This project was initiated following advice from CSIRO, who were unable to undertake the work at the time. Information from that report is included below. In 2020 Neoen have been in discussion with regional research institutions to undertake work in these areas post-development.

With appropriate foresight and planning, trial work could conceivably occur on the site of a current or future commercial solar development, as part of a collaboration between government, researchers, developers, and land managers.

For now, without relevant Australian trial data on the effects of agrivoltaic systems on productive capacity, this report has been guided by local observations of systems in a commercial setting, and consideration of issues arising from international research work cited above.

Practical Observations

Sheep grazing provides a useful method for vegetation management in a low impact farming system and allows landholders to maintain agricultural production on the site of a solar development.

In quantifying the impact of agrivoltaic systems on agricultural productivity there are several constraints to be assessed. These include:

- Reduction of solar radiation caused by the shading effects of solar panels, with impacts in winter and spring on pasture growth;
- Reduced biomass due to the selection of alternative pasture species to assist with managing the risk of excessive grass height;

- Any incompatibility of the grazing requirements of landholders and graziers, utilising pasture on the solar development, with their broader farming enterprise; and
- Temporary loss of productive land because solar development infrastructure has occupied a proportion of farming land.

There has been relatively little documentation of agrivoltaics in the Australian farming context. However, *Downer Utilities Australia 2019* outlines observations about using sheep grazing for vegetation management at the Neoen solar farm at Numurkah. The key findings of the report include:

- Sheep grazing was a successful means by which to control vegetation among the panels, as an alternative to mechanical options;
- Damage and other negative impacts on the solar infrastructure or operations were not observed;
- Prior to construction, it is important to establish clearly defined roles and responsibilities of those responsible for grazing their sheep within the facility, including vegetation management parameters, fencing and other infrastructure, animal purchase and husbandry, and other terms of access;
- Proper planning in advance of construction is needed to establish a seed bank of an agreed pasture mix;
- Sowing a clover species before construction can reduce prevalence of invasive species and avoid high grasses (such as ryegrass) that pose fire risk; and
- Livestock fencing should be incorporated into design plans prior to construction, utilising 40ha – 50ha units with a water supply in each block.[13]

In his 2019 report to Neoen, observations made by specialist livestock consultant Phil Graham include:

- Sheep grazing can be a cheap and effective way of managing vegetation on solar farms;
- Differences between herbage levels in wet and dry seasons are substantial, requiring 4 – 6 times the number of stock to achieve pasture height targets;
- Flexibility to vary stock numbers in wet years is essential, and the stock owner should have land adjacent to the site so they can vary stock numbers as required;
- The largest effect on pasture production from solar development is the area removed from production by roads, buildings and associated infrastructure;
- Small rainfall events can be more beneficial as panels can distribute strip irrigation events to use moisture more effectively;
- Altered patterns of moisture availability distributed biomass differently but didn't reduce overall production;
- Animal performance could be improved by shelter from heat in summer and wet/cold weather during winter;

[13] Downer Utilities Australia (2019)

- The solar farm should be fenced in 40ha – 50ha watered blocks each with a water source to best manage pastures and control weeds;
- Establishing pasture before construction is optimal but may be challenging given the small sowing window, and depend on construction timing; and
- If land is being used for cropping, the landholder could under sow a pasture in the crop year before the lease commences.[14]

Discussion with livestock grazing consultants reinforced that sound planning before the construction phase is essential. Planning needs to have regard for fencing, watering points and pasture sowing because if commercial grazing is not implemented, this will limit productive capacity beyond the assumptions in this report. Neoen advise these matters are currently being discussed with landholders.

Understanding Shading Effects

Of the solar radiation reaching a solar development, a portion will be diverted by solar panels and the remainder will reach the ground. Whether the panels track from east-west or are fixed mounted will influence the disruption of light to pastures. The effect will be more pronounced in particular areas under fixed panels, and more dispersed with a tracking system, which is proposed for the Culcairn Solar Farm development.

Plant growth around and beneath the panels will only be affected if the shading effects restrict light to levels below the light saturation point of the plant, that is, the maximum amount of light a plant can use for photosynthesis.[15]

The implications of reduced solar radiation are difficult to quantify, particularly across different weather conditions and soil types, and are likely to be unevenly distributed across a growing season.

There is likely to be a negative effect from the solar panels at certain times of the year. Even in the context of pastures located under tracking panels, where the effects are dispersed and shade may only be intermittent, the additional shade pastures will experience during winter months is likely to inhibit photosynthesis and pasture growth during this period.

However, the interaction between solar radiation and soil moisture also has an effect on biomass. The shading effects of the panels can mitigate the effects of solar radiation on depleting soil moisture and limiting pasture growth during summer months.[16] The panels may also mitigate the effects of drying winds.

Panels are likely to reduce frost impacts and protect pastures longer coming out of spring and into summer, particularly where soil moisture is a limiting factor.

In net terms, the effect of reduced solar radiation is likely to be minimal, though the effect may vary across different climatic periods.

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[14] Graham, P. (2019)
[15] Guerin, T. (2019) p. 5
[16] Guerin, T.F., (2019) p. 6

6.4 Pasture Species Options

Investigations carried out whilst preparing this report indicated there is little known about the best species mix for solar farm pastures, as part-shading is uncommon in broadacre pasture systems, and little or no research has been undertaken. Shading may impact on pasture palatability and energy density, but there is no known research in this area to confirm this.

NSW Department of Primary Industries suggested pasture mixes for the Upper South West Slopes[17] (being the region nearest to the proposed solar farm) recommends for moderate rainfall areas (600mm+) phalaris, cocksfoot and sub clover with perennial ryegrass as optional.

Pastures species mix in the local region include perennial and annual grasses such as phalaris, fescue and rye grass. All of these grasses have the propensity to grow to 1 metre (or more) tall in the spring. This is an issue for solar farms as:

- Tall grass creates fire management issues;
- When these species mature and become unpalatable the only means of control is mechanical (slashing/mowing) which is costly and difficult to carry out in a solar array; and
- Tall vegetation (such as perennial grasses) growing underneath the solar panels interferes with drive shafts and other equipment.

Weeds will continue to create a height problem and will likely need to be managed manually at times.

Although biomass and productive capacity would be improved by a traditional species mix, the risk of having fast growing ungrazed pastures needs to be managed. The proponent has provided the authors with standard contractual terms for grazing contractors that stipulates a maximum 500mm grass height must be upheld.

Given the above average rainfall in 2016 and well below average rainfall in 2019, the number of stock required in 2016 seasonal conditions compared with 2019 would be in the order of 4 – 6 times more. In a commercial arrangement for grazing of the solar area (post-development) with a neighbouring landowner, there is a risk that the grazier will not be able to supply sheep to graze the solar site.

In this context, the most appropriate pasture species for the proposed solar farm are annual clover pastures comprising sub-clover (subterranean clover), balansa clover and gland clover. These pastures are well suited to the region and produce significant biomass without growing to a height that will interfere with the operation of the solar farm. Biomass production from a sub-clover only pasture may be less than a grass and clover pasture mix, however the differences are not material relative to the cost of managing tall grasses. Sub clover pastures will germinate in the autumn and hay off in the late spring and provide palatable dry feed over the summer period. Research work done on irrigated sub-clover pastures in the 1990s in the Murrumbidgee Irrigation Area showed sub-clover pastures could be continuously stocked at a set density by sheep 12 months of the year.

[17] NSW Department of Primary Industries - *Suggested Pasture Mixes for the Upper South West Slopes* sourced from https://www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/pasture-mix/upper-south-west-slopes

Upland cocksfoot, tall fescue and/or annual ryegrass would be suitable to plant at 6kg/ha – 8kg/ha with the sub-clover which would improve pasture production and provide increased competition for weed control, if the height of solar panels could be raised and/or spring grazing management practices can be put in place to manage pasture height. If grass heights are able to be managed to developer requirements during wet periods, annual ryegrass and/or *Resolute Tall Fescue* would be suitable for generating additional biomass.

NSW Department of Primary Industries[18] states:

> *"Ryegrass - Annual (Lolium rigidum)*
>
> *Annual self-regenerating aggressive winter-spring growing ryegrass. Suited to drier margin of ryegrass zone. Note that this species can be a weed in winter crops. Annual ryegrass toxicity, ergot and herbicide resistance can be a problem with this species.*
>
> *Usually sown at 15 kg/ha when sown alone or 5–10 kg/ha in a mixture."*

NSW Department of Primary Industries[19] states:

> *"Subterranean Sub Clover (Trifolium subterraneum)*
>
> *A self-regenerating annual. Grows mainly in autumn, winter and spring. Suited to moderately acid to neutral soils. Best suited legume for large areas of southern New South Wales. Resists grazing as seeds are buried.*
>
> *Ensure reliable seed set and improved persistence by using the most suitable variety for a particular district. Mixtures of varieties can be used to take advantage of extended seasons, for example, by including a slightly longer-season (later maturing) variety, and improve persistence by including a slightly shorter-season (early maturing) variety that has a higher proportion of hard seed. (The subterranean clover varieties are listed from late to early maturity). Sow in early to late autumn.*
>
> *4 – 10kg/ha. Inoculant Group C."*

NSW Department of Primary Industries[20] states:

> *"Balansa clover (Trifolium michelianum)*
>
> *A self-regenerating annual legume that grows mainly in spring. Suited to soils of pH ($CaCl_2$) 4.5-7.0. Tolerates waterlogging. Resists clover scorch and root rot.*

[18] NSW Department of Primary Industries – Ryegrass sourced from https://www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/species-varieties/ryegrass---annual

[19] NSW Department of Primary Industries - Subterranean Clover sourced from https://www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/species-varieties/subterranean-sub-clover

[20] NSW Department of Primary Industries – Balansa Clover sourced from https://www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/species-varieties/balansa-clover

Slow early growth but increases rapidly in late winter and spring as temperatures rise. Produces good quality hay. It has a high proportion of hard seeds. Sow in autumn (dryland) with good moisture or early autumn (irrigated).

2-5kg/ha. 0.5-10 kg/ha when used in mixtures, 5 kg/ha when used as a 1-year forage crop."

NSW Department of Primary Industries[21] states*:*

"Gland clover (Trifolium glanduliferum)

A self-regenerating, semi-erect annual legume, suitable to neutral to mildly acid soils. The major advantage of gland clover is its resistance to red legged earth mite and aphids. Resistant to scorch. Moderately tolerant of waterlogging. Growth period similar to early maturing sub clovers (e.g. Dalkeith). Useful in mixtures with other temperate legumes or lucerne. Produces high seed yields.

2-4 kg/ha. Inoculant Group C."

The final line in the NSW Department of Primary Industries quotes above is the sowing rate. For those areas not prone to waterlogging a mix of Prima gland clover, Paradana (or similar) balansa clover with Seaton Park and Coolamon sub-clover would be best suited. For those areas prone to waterlogging, gland and balansa clover with Yaninnicum sub-clover varieties such as Trikkala and Riverina would be best suited.

If grazing arrangements can provide for flexible access to livestock grazing, a fescue variety may improve productivity. According to www.notmanpasture.com.au:

"Resolute winter active tall fescue provides improved palatability over traditional phalaris based pastures. A proven performer it also delivers better persistence over perennial ryegrass pastures.

- *Ready to graze in 70-110 days*
- *Excellent winter growth and persistence*
- *Extremely palatable when grazed correctly*
- *Sowing rates should be 8–25kg/ha*
- *Avoid sowing in mid winter or late spring which may cause issues with establishment*
- *Minimum 500mm rainfall per annum unless irrigated*

https://notmanpasture.com.au/shop/pasture-grasses/tall-fescue/resolute-tall-fescue/

[21] NSW Department of Primary Industries – Gland Clover sourced from https://www.dpi.nsw.gov.au/agriculture/pastures-and-rangelands/species-varieties/gland-clover

Subject to the project commencement date, the report authors recommend the pastures are sown in autumn following a spring fallow the year prior. An alternative approach would be to undersow the pasture into a crop the year prior works commencing. The pastures should be sown in the autumn following a spring fallow the year prior. Sow 1.5kg/ha each of gland and balansa clover with 5kg/ha of sub-clover plus ryegrass and/or Resolute Fescue if plant height issues can be managed. Pastures should be sown with a starter fertiliser that includes nitrogen, phosphorous and sulphur. Pastures will perform best when top-dressed annually and are subject to ongoing weed management.

6.5 Examples of Commercial Operations

Neoen – Numurkah

Proponents of the Culcairn Solar Farm, Neoen, has a 128 MW solar farm in operation at Numurkah in northern Victoria, on a 515ha site. It generates 255 GWh of solar energy per annum, with agreements in place to supply the Melbourne tram network and the Laverton steelworks.[22]

One of the original landholders, Eddie Rovers, sold land to the developers and reached an agreement with the company to graze 750 of his sheep among the solar panels. In a filmed interview he indicates optimism about the benefits of shading and creating irrigated strips of pasture from dripping dew.[23]

Observations made about using sheep grazing for vegetation management at the Neoen solar farm at Numurkah are included as an appendix to the Culcairn solar farm EIS, the findings from which are summarised in Section 6.3 above.

Figure 4: Sheep grazing at Neoen Solar Farm at Numurkah

Image courtesy of ABC News, 5 September 2019

[22] Neoen, Media Release, 19 July 2019, 'Neoen's Numurkah Solar Farm begins full scale commercial operations for its Victorian customers', https://www.neoen.com/var/fichiers/190719-numurkah-full-scale-operations.pdf, accessed on 25/01/20

[23] Eddie Rovers, Direct comments, https://www.abc.net.au/7.30/renewable-energy-projects-helping-to-revitalise/11484992, accessed on 25/01/20

Neoen – Dubbo

Proponents of the Culcairn Solar Farm, Neoen, commenced commercial operations of their 55ha Dubbo solar farm in June 2018, which incorporates sheep grazing among the panels. The land had primarily been used for grazing prior to the development.

Dubbo farmer Tom Warren, who owns the land and grazes sheep at Neoen's solar farm, has made the following observations about co-locating sheep and solar:

- The productive capacity of pastures is around 80% of typical sheep grazing systems;
- Performance may potentially be better during drought due to shade and moisture retention protecting pastures;
- Dew run off from the panels creates irrigated green strips of pasture growth; and
- Merino wethers are best suited because of their temperament, using cell grazing rotation.[24]

Figure 5: Neoen Solar Farm at Dubbo

Image courtesy of Western Magazine, 29 October 2019

[24] Neoen Australia Dubbo Agriculture & Solar Video, https://www.youtube.com/watch?v=uO3k9EdZjmI, accessed 25/01/20

Wynergy

Wynergy is a solar farm construction company that claims to have developed a 'stock-proof' solar tracking system. The technology has not yet been implemented in a commercial setting.

Photon Energy

Netherlands-based company Photon Energy have indicated that they intend to graze sheep on several proposed developments across NSW. However, none of these projects have yet completed construction and commenced commercial operation.

Conclusion

The report authors are of the view that the emerging sheep grazing approach to agrivoltaic systems in Australia is the most suitable, where co-location is considered necessary or desirable.

From our investigations, alternative production systems, such as cropping or other livestock grazing, would not provide a conducive enterprise for co-locating agricultural and solar energy production. Cropping is not practically feasible and other livestock options such as cattle present unacceptable risk to infrastructure.

Sheep grazing is a common land use in the Greater Hume LGA and would be suitable for the land proposed for development.

If landholders are not required to introduce new enterprises to an existing farming system, the transition is practically feasible across the life of the development. Additional risks can present where:

- New and external tenancy arrangements need to be created; and
- The solar farm area is managed by graziers not operating on adjacent farms, requiring frequent stock transport in and out.

Neoen advise they are in discussions with adjacent landholders to operate the post-development grazing enterprise.

In discussions with industry participants with experience of agrivoltaic systems, there was a strong view that co-locating a solar farm with sheep grazing has the potential for little or no deleterious effects on agricultural production. However, estimates of reduced production should be considered in the context of various risk factors associated with agrivoltaic systems that can influence practical outcomes in a farming environment. As such these risk factors have been considered in the post-development productivity assessment in Section 6.8 (below).

6.6 Soil Health Impacts

Components of Soil Health

Soil health can be defined as the capacity of a soil to function, within natural or managed ecosystem boundaries, to sustain plant productivity, maintain water and air quality, support human well-being, and provide habitats for biodiversity.

Evaluation of soil health is a complex task, involving indicators of chemical, physical and biological (including microbial) components.[25] Key indicators of degraded soil health in agricultural production environments include:

- Depletion of organic matter in soils, with reduced organic carbon and beneficial soil microbes;
- Insufficient availability of key nutrients such as nitrogen, phosphorous and potassium;
- Acid or saline soils; and
- Poor physical structure causing erosion, diminished water holding capacity and preventing root growth.

Amelioration options include:

- Minimising soil disturbance and compaction to promote good soil structure;
- Maintaining ground cover to prevent erosion and increase soil organic carbon;
- Adding nutrients or planting nutrient fixing crops and pastures; and
- Applying lime to address pH constraints.

Nutrient Cycling in Cropping and Pasture Systems

Within an agricultural production system, a key determinant of soil health will be the balance between nutrients added or created through agronomic management and those taken out of soils in the production of biomass for agricultural production.

Cultivation for cropping will generally reduce the amount of soil organic matter, thereby reducing nutrient availability in soils. Nutrients (for example N, P, K) may be returned to the soil via application of fertiliser or by including legumes in the crop rotation, which biologically fixes atmospheric nitrogen in the soils. According to GRDC:

> *"Although crop rotations with grain legumes and ley pastures play an important role in maintaining and improving soil fertility, fertilisers remain the major source of nutrients to replace those removed by grain production. Fertiliser programs must supply a balance of the required nutrients in amounts needed to achieve a crop's yield potential. The higher yielding the crop, the greater the amount of nutrient removed."*[26]

[25] Rivedi P, et al (2016)

[26] GRDC Grownotes, (2016)

Crop production can have negative implications for soil health if soils are frequently cultivated. Maintaining a permanent ground cover of pasture can reduce surface runoff and soil erosion, relative to a tillage-based cropping system.

However, most winter cereal cropping systems in the Culcairn district have adopted zero or minimal tillage practices to conserve moisture and organic material in the soil, including the retention and incorporation of crop stubbles into the soil. This widespread practice change over the past ten years has reduced the extent to which pasture-based systems provide soil health advantages over continuous cropping.

Despite this beneficial practice change, there is likely to be some improvement in soil health by ceasing cropping on the southern two farms and transitioning land use to improved pastures. The natural fertility of cropped agricultural soils is declining over time. Wheat and canola rotations deplete soil nutrient availability and generally require application of inputs to replace nutrient uptake through crop plant growth.

The extent to which pasture-based production systems at this location will be better for soil health depends on previous management interventions to improve nutrient cycling and soil organic matter in a cropping system and landholders undertaking best practice management in an agrivoltaic pasture-based system.

Application of nutrients, lime and gypsum will need to continue on the development site to overcome soil constraints. Due to the physical impediments from a PV array, landholders will need to modify application delivery systems from those used on typical pastures. If cost or accessibility limits best practice management, this could limit the soil health benefits of moving to a pasture-based system.

The developer has undertaken agrivoltaic soil management at other agrivoltaic sites and has experience with addressing trafficability issues.

Effects of Shading

There are likely to be soil health trade-offs associated with the effects of shading from PV arrays.

Within a farming environment incorporating solar panels, the aggregate volume of water reaching the soil will be the same as would be the case in its absence. However, the distribution of that moisture across the paddock may be more uneven as a consequence of the panels deflecting rainfall and dew. Increased retention of soil moisture in areas subject to additional shading may have a positive effect on soil carbon, though this would need to be demonstrated through periodic soil testing at the site.

Contrastingly, a 2005 New Zealand study found that increasing shade decreases the legume content of pastures relative to other species in the mix, resulting in reduced nitrogen cycling.[27]

Quantifying the overall effect is complex and beyond the scope of this report. However, it is unlikely that additional shading will have a significant effect (positive or negative) on soil health at the site, in comparison with the significance of the effects of agronomic practices implemented in a pasture-based farming system.

[27] Dodd, M. B. et al (2005) p. 536

Compaction

Soil compaction under machinery traffic can be deleterious to soil health. Compacted soils are more prone to erosion, reduced water holding capacity and root growth. Heavy machinery such as headers, tractors and chaser bins can be particularly damaging to soil structure. Controlled-traffic farming minimises the paddock area compacted under heavy wheel tracks. According to GRDC Australian research indicates that the yield benefit from introducing controlled-traffic farming generally ranges from two to 16 per cent across the whole farm.[28]

In moving from cropping to livestock production under a PV array, the soil effects of altered soil compacting practices are uncertain. While agrivoltaics eliminates very heavy cropping machinery traversing the soils, the number of tracks created by farming activities within the PV array are likely to increase, albeit at a lesser weight to compact soils.

Conclusion

A transition to permanent pasture ground cover at the proposed location over the development period is likely to see some overall improvement to soil health. However, estimating any quantifiable benefits is not possible within the scope of this report, being subject to complex biological trade-offs and variables relating to future management practice.

6.7 Impact on Value of Production – Proposed Development

Issues for Consideration

To assess the effect of an agrivoltaic system on overall agricultural productivity, the following issues need to be considered:

- Proportion of productive area displaced by solar infrastructure;
- Effect of shading on pasture growth;
- Soil moisture retention and distribution;
- Effect of panels on moisture (including dew) capture and distribution;
- Suitable pasture species mix for the agrivoltaics environment;
- Limitations on fertiliser application;
- Paddock design for effective mustering and pasture management;
- Stock water access, quality and distribution;
- Flexibility to vary stocking density for pasture management;

[28] Fisher, P et al (2020)

- Weed control;
- Bushfire risk management; and
- Dust suppression practices.

Proposed Agrivoltaic Systems at Culcairn Site

Full details of the proposed solar development are included in the EIS prepared on behalf of the proponent. For the purpose of the agricultural focus of this report, the key elements of the proposed solar development are:

- Solar panels and associated energy and logistics infrastructure occupying 1,084ha of the 1,351ha subject land as depicted in Figure 1; and
- Photovoltaic solar panels (2m x 1m) mounted on single axis trackers at approximately 4m maximum panel height above ground at maximum tilt, with approximately 5m – 10m row spacing.

As indicated in Section 4.0 of this report, approximately 75% of the development footprint is cropped annually, while the remainder is used for grazing livestock.

This is a function of the mix of enterprises favoured by the landowners for profit and management reasons.

As set out in Section 4.0 (above); the cropping potential of the land subject to development is up to 95% of the total development footprint and cropping enterprises across the LGA comprised 40% of the total value of agricultural production in 2015/16.

NGH, 2020 makes several comments about intended agrivoltaic system adoption. It states that one of the agricultural impacts of the development would be a loss of cropping production:

> *"A reduction in the agricultural uses of the development site. Specifically, broad-acre dryland cropping would not be possible. This situation will affect land used principally for crop production. However, this opportunity to rest the land would provide a multitude of benefits including returning soil organisms, soil carbon, soil moisture and soil structure to the areas previously cropped and grazed. Diversity in groundcover and perennial species of grasses would be encouraged to increase soil stability, increase organic material and reduce evaporation losses.[29]"*

It also notes the option of sheep grazing:

> *"Other agricultural production, particularly sheep grazing, would continue albeit at a reduced capacity. Continuing grazing at a reduced rate would encourage grasses to continue growth, reduce the impact of soil compaction and maintain vegetation height below the panels and around the property."[30]*

[29] NGH, (2020), *p. 182*
[30] NGH, (2020), *p. 182*

In response to stakeholder concerns to the potential loss of agricultural production, the proponent indicated in the EIS that strategies could include:

> *"Provide opportunities for adjacent landowners to utilise land under solar panels for sheep grazing. Communicate with neighbours regarding other opportunities for maximising land use on solar farms (as per advice from local agronomists, farmers and Landcare)."*[31]

The two landholders retaining ownership of the land (post-development) indicated that post-development the pastures would run Merino wethers between the solar panels. This may be undertaken by external parties under a contractual grazing arrangement. The parties are unable to be contracted until development approval processes have occurred.

Operational questions such as pasture species mix, paddock layout, stock water access points and fertiliser application have been considered but not yet resolved. One of the landholders has developed preliminary plans for a rotational grazing layout to manage stocking rates and has shared this with the proponent's design team. Neoen advise this will be incorporated in the project's design, prior to construction commencing.

The proposed sale of the northern farm to the developer would necessitate a separate commercial grazing agreement.

Observations

On the basis of our assessment of current industry practice and the characteristics of the proposed solar farm area, and taking into account that the proposed agrivoltaic system to be implemented has yet to be determined, we make the following observations:

- The paddock area available for stocking would be reduced by approximately 10%. This accounts for solar panel array, battery and inverter stations, a substation, buildings, access roads, fencing, additional fire breaks, etc;
- Shading from the solar panels will likely reduce overall pasture growth in the winter and early spring, however it will assist to support extended pasture growth in summer and autumn. This may have some complementary benefits for adjacent graziers utilising the solar site for feed;
- The unevenness of soil moisture retention and distribution will not greatly affect available soil moisture overall but will encourage altered patterns of pasture growth. This includes possible dew capture to 'irrigate' pasture rows below the panels;
- A pasture species mix needs to be selected that will be best suited to meeting pasture height parameters, will best respond to periodic shading and will provide competition for avoiding invasive weed infestations. Recommendations for pasture species for agrivoltaics are provided in Section 6.4 (above);
- Planning and implementing ground preparation, timing, and the pasture seed mix *prior* to construction will achieve the best outcome, as undertaking sowing post-construction will limit pasture establishment potential;

[31] NGH, (2020), *p. 88*

- Fertiliser applications will be able to be maintained, albeit using smaller scale equipment, potentially with a similar approach to that taken in a viticultural or orchard setting. Aerial applications may not be feasible if damage to panels is perceived as a risk by the solar company. This should be investigated by the proponent;

- The proponent continuing previous practice (at other sites) of stocking solar farms with Merino wethers (or weaner ewes) is preferable to other breed options due to their temperament and non-wool shedding nature. This option should minimise potential for sheep damaging the panels and other infrastructure;

- Manual weed control is still likely to be required, including the use of smaller and more labour intensive spray rigs capable of operating between panel arrays;

- Careful planning and design work will be required to ensure paddock size and layout is conducive to both the construction and management of solar infrastructure, and the rotational grazing, watering and mustering requirements of the sheep enterprise. Each design solution will need to be negotiated and developed to meet the individual circumstances of the site, the intended development, and the preferences of the farm manager;

- Sound contractual grazing agreements are needed to ensure there is flexibility to vary stocking density within the solar paddocks to avoid pasture growth escaping grazing capacity, and loss of ground cover resulting in dust creation during dry periods. Neoen have provided the authors with a standard grazing services contract to be provided to graziers that stipulates a maximum grass height of 500mm and no over grazing be adhered to;

- A clear agreement between the solar company and grazier will be required in advance of construction planning being finalised, to ensure pasture sowing, paddock layout, vegetation management and other key issues are understood and implemented *prior* to construction, after which decisions to alter arrangements become more difficult; and

- Well maintained pastures increase soil organic matter over time. If pastures are topdressed, weeds controlled, not overgrazed and lime is applied periodically (as indicated by soil testing) the pastures are likely to remain productive for the life of the project and soil organic matter will increase.

The report authors estimate that an agrivoltaic system at this location would reduce the productive sheep carrying capacity of the area impacted by the development of 635ha (refer to Section 3.0 above) by 25%.

This estimate is based on assumptions drawn from the current information available on agrivoltaic systems, including insights from the available scientific literature, interviews with landholders that have adopted or are considering this system, and agronomists. These assumptions are conservative, as they potentially overestimate the reduction in agricultural output from the development. The key assumptions are:

- 10% of the land will be displaced from agricultural productivity due to the construction of physical infrastructure. This equates to a loss of productive area of 58ha at the proposed solar farm;

- A reduction in solar radiation across the site has the potential to limit pasture growth overall, though the exact quantity by which this will occur is difficult to determine without formal trial work being conducted. The effect on productivity may well be minor. It is worth noting that the current key limiting factor to pasture growth is rainfall;

- The different patterns and timing of pasture growth compared with typical grazing paddocks may create useful synergies for parties agisting stock on the site. However, contractual terms with the developer covering pasture management to specific parameters, may offset broader farming system benefits;
- There are risks that:
  - The pasture species mix ultimately selected is not well suited to the agrivoltaics environment, or there is sub-optimal sowing practice and/or timing;
  - Fertiliser regimes and weed management are not conducted to the same beneficial extent as in other paddocks due to difficulty accessing the site and cost; and
  - An optimal rotational grazing layout cannot be negotiated and implemented, hindering efficient mustering, pasture management and stock watering.

6.8 With or Without Assessment

As set out in Section 4.0 (above) the current annual farm gate value of production arising from the proposed solar farm areas is estimated to be $1,580,000. The landowners have indicated a plan to run merino wethers on the proposed solar farm area post-development. As set out in Sections 6.5 and Section 6.7 (above) this enterprise appears to be the best option as a productive post-development land use.

Included in Annexure 2 is a copy of a NSW DPI gross margin for a merino wether enterprise (dated October 2018) which best represents the intended post-development enterprise. The gross revenue from this gross margin is $88.80/DSE. The pasture productivity post-development is calculated as follows:

- Northern farm of 300ha with a solar development of 110ha (including panels and infrastructure). Hence post-development carrying capacity is:

  190ha (300ha – 110ha refer to Section 3.0 above) x 15 DSE/ha + 110ha x 15 DSE/ha x 75% = 4,087.5 DSE

- Southern two farms of 980ha with a solar development of 525ha. Hence post-development carrying capacity is:

  455ha (980ha – 525ha) x 12.5 DSE/ha + 525ha x 12.5 DSE/ha x 75% = 10,609.4 DSE

  Which totals 14,697 DSE (4087.5+10,609.4)

  which for the purposes of this assessment has been rounded to 14,670 DSE.

The post-development annual gross revenue can be calculated as: 14,670 DSE x $88.80 DSE = $1,302,696

which is $1,300,000 when rounded to the nearest $10,000.

The post-development annual related economic activity can be calculated using an economic multiplier of 2.1788 (refer to Section 4.0 above) as follows:

$1,300,000 x 2.1788 = 2,832,440

which is $2,830,000 when rounded to the nearest $10,000,

The annual reduced value of production arising from the proposed solar development assuming reduced pasture productivity of 25% is set out in Table 2. Annual related economic activity impacts of the farm gate reduction in gross revenue based on an economic multiplier of 2.1788 (as set out in Section 4.0 of this report) is also provided in Table 2.

Table 2: Gross Revenue Analysis (25% reduction in productivity)

Gross Revenue (pa)		Post-development Impact (pa)	
Pre-Development	**Post-Development**	**Farm Gate**	**Related Economic Activity**
$1,580,000	$1,300,000	$280,000	$610,064

The assessment in Table 2 indicates the most likely outcome of the proposed solar farm is a reduction in annual farm gate gross revenue of $280,000 and a reduction in annual related economic activity of $610,000 (rounded from $610,064).

Related economic activity from the existing landowners' enterprises includes upstream activities such as contractors, farm input and service providers. The key downstream activities include processing and distribution. Impacts of the proposed solar farm will include less reliance on contractors, input and service providers and less produce to be transported to off-take locations. There are limited (if any) processing facilities within the Greater Hume LGA. Some but not all of the related economic activity impacts will be felt within the Greater Hume LGA.

The assessment in Table 2 (above) does not consider rental income derived from the proposed solar farm as this report relates to agricultural impacts only.

As set out in Section 4.0 (above), the pre-development direct expenses are estimated to be $1,060,000 and $970,000 in the Greater Hume LGA (when both are rounded to the nearest $10,000). The post-development expenses are set out in Annexure 2 and estimated to be $39.80/DSE of which 90% is expected to be spent with businesses in the Greater Hume LGA. Post-development direct expenses can be calculated as follows this equates to:

14,670 DSE x $39.80/DSE = $583,866

Which is $580,000 when rounded to the nearest $10,000. Of this amount, 90% is expected to be spent with businesses in the Greater Hume LGA (refer to Annexure 2which equates to:

$580,000 x 90% = $522,000

Which is $520,000 when rounded to the nearest $10,000.

Therefore, the estimated impact of the proposed solar farm on local annual direct expenditure is:

$970,000 - $520,000 = $450,000

7.0 SOCIAL IMPACTS

7.1 Employment Pre and Post-Development

According to the landowners, the solar farm area currently provides employment for two full time equivalent (FTE) employees, plus some casual employment at peak times. The proposed post-development sheep grazing enterprise is estimated to require 1.5 FTE employees.

According to NGH 2020[32] there will be five to ten FTE operational staff and up to six service contractors employed for the life of the project, and up to 500 employees for the 8 to 12 month peak of construction (estimated at 350 FTE jobs). Maintenance contracts for panel cleaning, fence repair, road grading, etc. would also be required and would likely be met by local contractors. However, the scope of this assessment is limited to quantifying the direct upstream and downstream impacts attributable to any reduction of agricultural production capacity.

7.2 Secondary Support Business Impacts

There are a range of upstream and downstream employment roles associated with agricultural production in the Culcairn district. These include:

- Agronomy services;
- Input providers (chemical, fertilisers, etc);
- Machinery sales and mechanical support;
- Grain and livestock transport;
- Production marketing; and
- Shearing, fencing, harvest and other contractors.

As indicated in Section 6.7 and Section 6.8 (above), the reduced carrying capacity of the proposed solar farm area post-development is estimated to be 25% with a reduced annual gross revenue of approximately $280,000 per annum based on the existing enterprise mix. Assuming a two-year period of disruption to agricultural output during the land preparation and construction period, the first two years of the project will generate reduced agricultural revenue of $2,600,000. Over the 30 year life of the project, the estimated reduced farm gate revenue is $11,000,000 (in 2020 dollar values). Applying an economic multiplier of 2.1788 (as set out in Section 4.0 above), the related economic activity reduction over 30 years (in 2020 dollar values) is $23,970,000 (when rounded to the nearest $10,000). These estimates do not consider the construction period expenditure such as on fences and roads.

[32] NGH, (2020) ref: p. xix, p. 47, p. 94

The post-development sheep enterprise will generate upstream and downstream benefits as is the case now for the existing enterprises, albeit at a reduced (up to 25%) level of productivity. All current and potential cropping activities on the land will cease post-development. Such changes in land use are typical of what happens across the broader farming region with cropping land being converted to livestock production and vice versa with seasons, market and other forces dictating ongoing transitions between enterprises at the farm level.

The landowners will be receiving rental payments from the solar company, which is another source of business revenue, albeit from a non-agricultural land use enterprise.

Although rental income from solar farming does not attract the same agricultural service industry expenditure, a significant portion of the revenue could be expected to be re-invested in supporting the productive capacity of the businesses' remaining agricultural enterprises. For example, purchasing more land, investing in infrastructure upgrades on-farm, more efficient machinery, or soil health improvements, with resulting related economic activity benefits.

Finally, in a transition from regular production to solar farming, some service industries will benefit. For instance, fencing and civil contractors are likely to experience higher demand for that site than would have been the case, while agronomic consultants and spray and spreading contractors may only experience marginal downturn in requirement for their services, if at all. Businesses related to servicing grain production on the site would be the most affected.

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Annexure 1

NDVI Imagery

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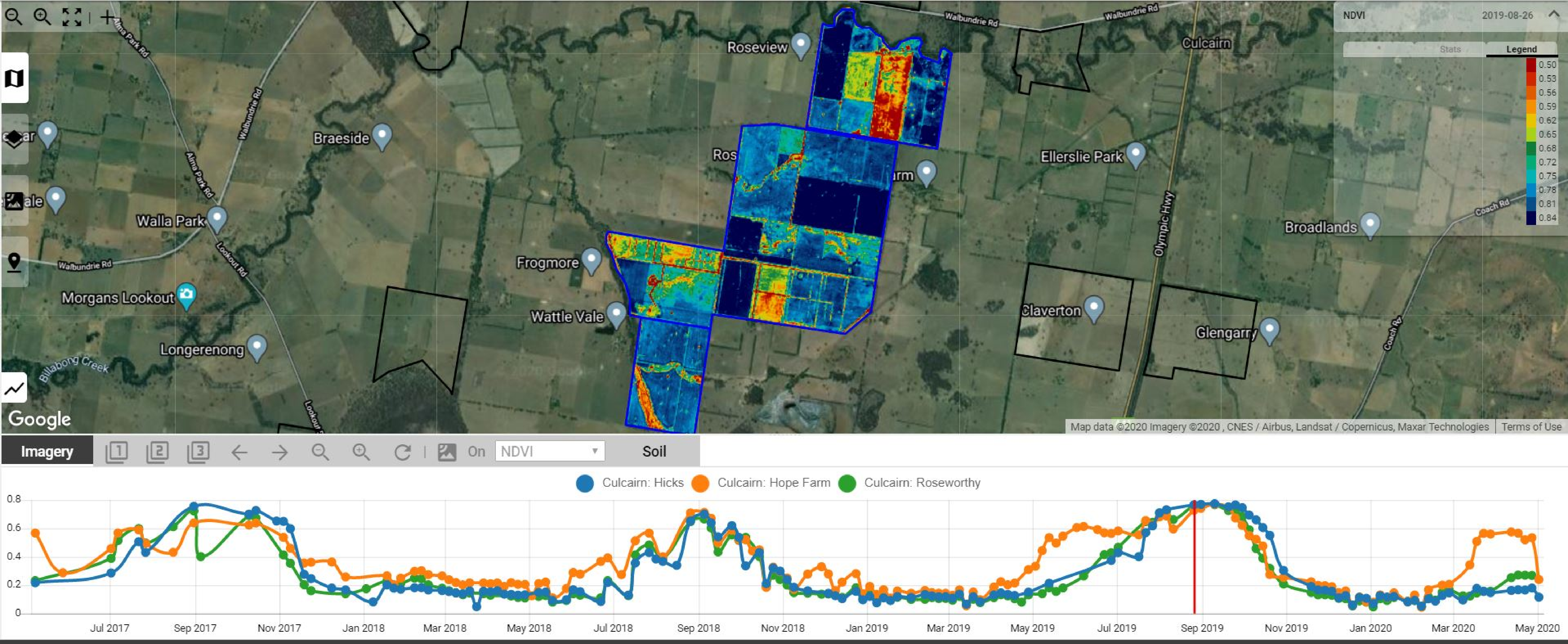

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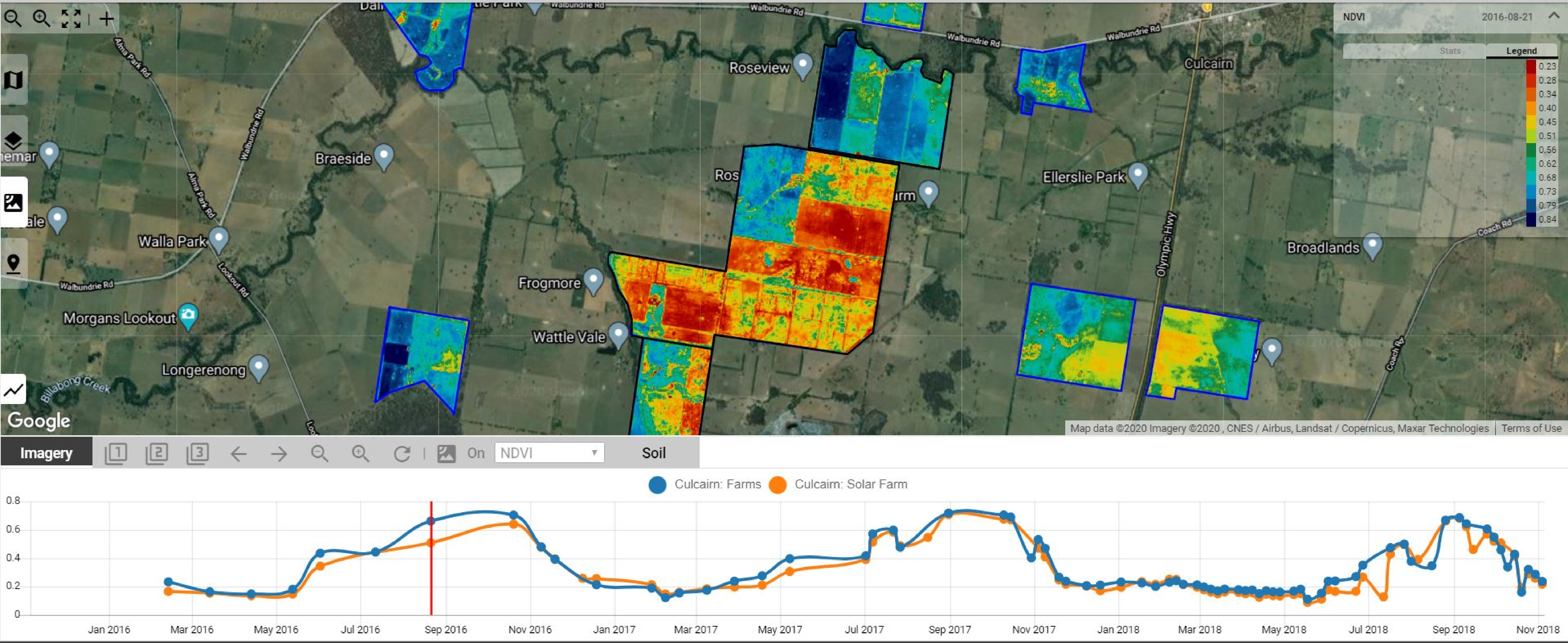

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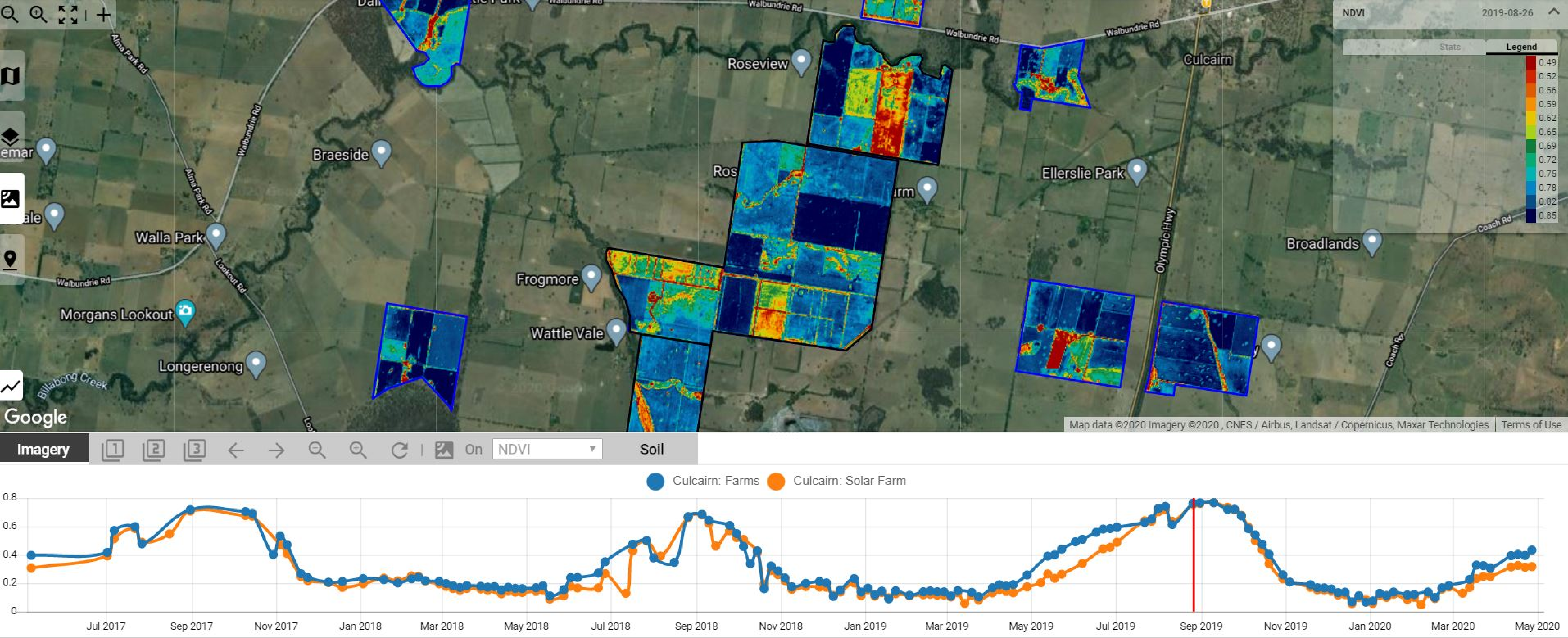

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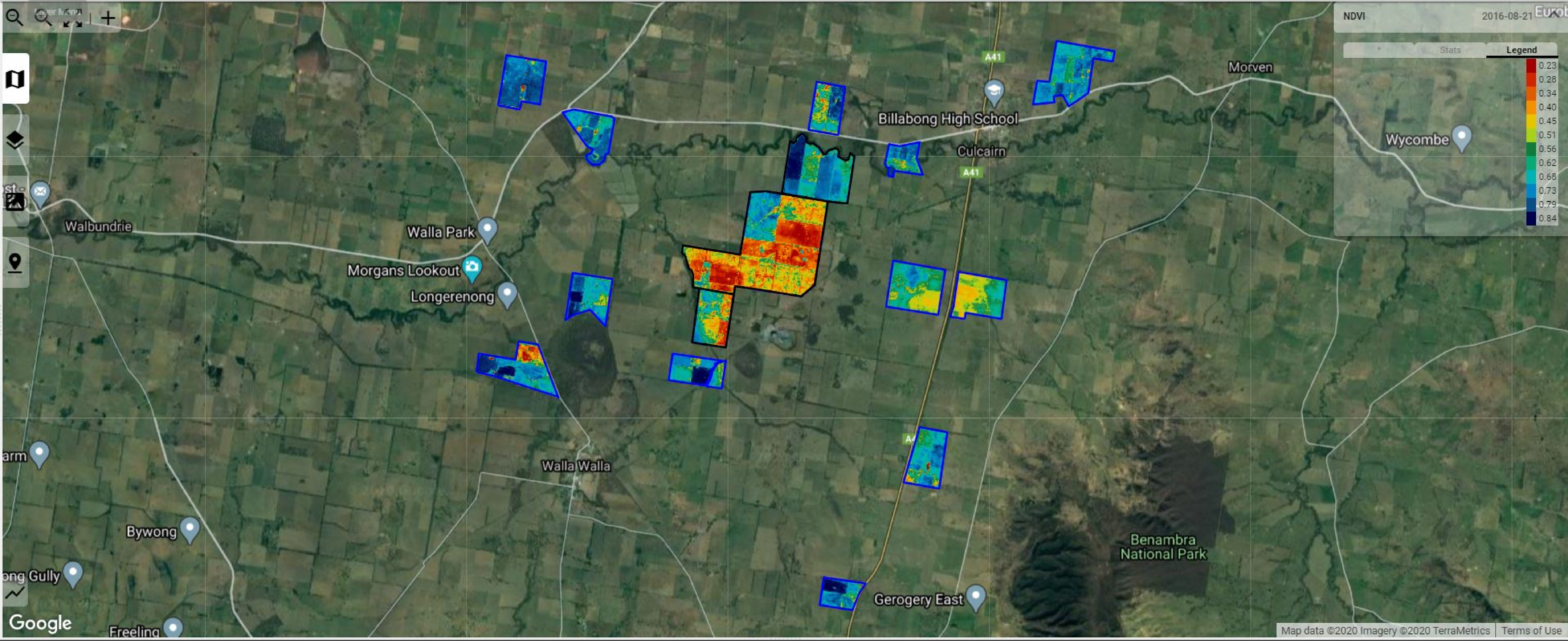
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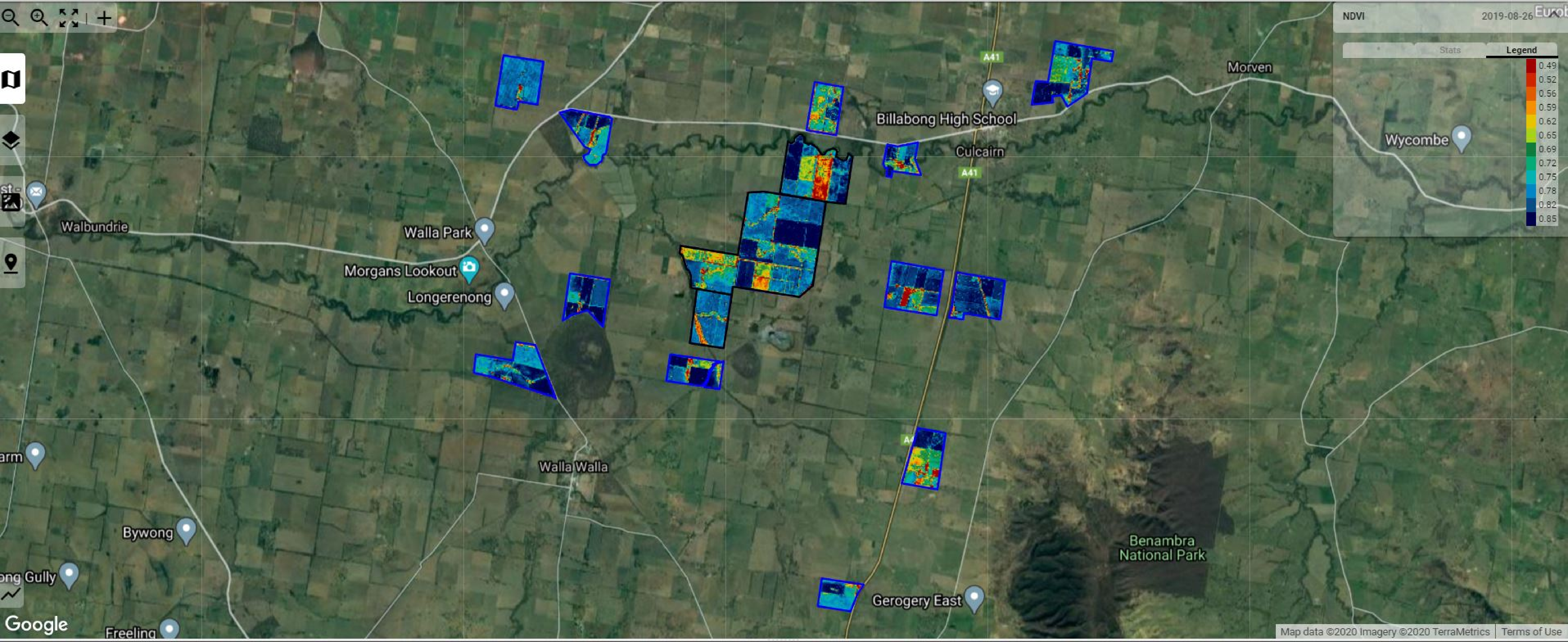

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Annexure 2

Gross Margins

BEEF CATTLE GROSS MARGIN BUDGET

Farm enterprise Budget Series: April 2019

Enterprise: **Butcher vealers**

Enterprise Unit: **100 cows**

Pasture: **Improved pasture**

INCOME:				**Standard Budget**	**Your Budget**
	32	steer vealers @	$880 /hd	$28,160	
	13	store steers @	$771 /hd	$10,021	
	32	heifer vealers @	$825 /hd	$26,400	
	13	store heifers @	$695 /hd	$9,033	
	1	CFA Bull @	$1,800 /hd	$1,800	
	9	CFA cows @	$1,124 /hd	$10,114	
	9	Other culls @	$1,124 /hd	$10,114	
		A. Total Income:		**$95,641**	

VARIABLE COSTS:

Replacements	1	Bull @	$3,500 /hd	$3,500	
	18	Replacement heifers @	$700 /hd	$12,600	
Livestock and vet costs: see section titled beef health costs for details.				$1,405	
Fodder crops / hay / grain				$0	
Drought feeding costs.				$0	
Pasture maintenence (improved pasture costs for 209 ha per 100 cows)				$20,900	
Livestock selling cost (see assumptions on next page)				$7,231	
		B. Total Variable Costs:		**$45,636**	

	GM including pasture cost	GM excluding pasture cost	
GROSS MARGIN (A-B)	**$50,005**	**$70,905**	
GROSS MARGIN/COW	**$500.05**	**$709.05**	
GROSS MARGIN/DSE*	**$29.98**	**$42.51**	
GROSS MARGIN/HA	**$239.26**	**$339.26**	

Change in gross margin ($/cow) for change in price &/or the weight of sale stock

(Note: Table assumes that the price and weight of other stock changes in the same proportion as steers. As an example if steer sale price falls to 540c/kg and steer weight to 140 kg, gross margin would fall to $369 per cow. This assumes that price and weight of all other sale stock falls by the same percentage.

Liveweight (kg's) of Stock sold		**Steer sale price cents/kg dressed** 530	540	550	560	570
	Steer wt.					
-40 kgs	**120**	242	255	268	281	294
-20 kgs	**140**	354	369	384	399	414
0	**160**	466	483	**500**	517	534
+20 kgs	**180**	579	597	616	635	653
+40 kgs	**200**	691	711	732	753	773

GM $ per Cow

An increase of 5% in weaning percentage increases gross margin per cow by $38.17

Assumptions **Butcher vealers**

Enterprise unit is 100 cows weighing on average 540 kg
Weaning rate: 90% (higher than other enterprises because replacements purchased PTIC)

Sales

70% steers sold at 9 months	160 kg	@550c/kg	dressed weight
30% store steers sold at 10 months	270 kg	@286c/kg	live weight
70% heifers sold at 8 months	150 kg	@550c/kg	dressed weight
30% store heifers sold at 9 months	250 kg	@278c/kg	live weight
18 replacement heifers purchased pregnancy tested in calf @ $800/head			
Cull cows cast for age at 10 years	280 kg	@401c/kg	dressed weight
100% of empty cows culled at weaning	"	"	"
4% cows culled for other reasons	"	"	"
Bulls run at 3% & sold after 4 years use	450 kg	@400c/kg	

Selling costs include: Commission 4%; MLA levy $5hd; freight to abattoirs @ 10c/kg dw for stock sold on dressed basis. freight to saleyards @ $12.00/hd + yard dues @ $8/hd for lw sales. NLIS tags @ $3.60 for all progeny sold.

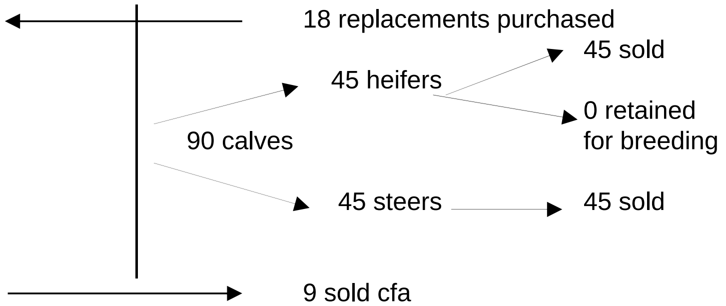
Cows: age at first calf : 24 months

Mortality rate of adult stock: 2%

The average feed requirement of a cow + followers is rated at 2.29 LSU or15.84 dse's*. This is an averag figure and will vary during the year. Note that dse rating is lower than some other enterprises because replacement heifers are purchased.

Age structure

Age	Number
2	17
3	16
4	14
5	13
6	12
7	10
8	9
9	9
Total joined	**100**
10	9



Marketing Information:
The majority are sold as vealers to local trade categories with the balance sold into the feeder market. MSA vealer protocols will influence management. For example vealers must be processed within 24 hours of separation from dams.

Production Information:
Cows for this enterprise will most likely be crossbreds put to a terminal sire or good milking pure bred lines. Female offspring usually sold with males. Early-mid maturity essential.
Good quality replacements are purchased pregnancy tested greater than 5 months in calf to calve in line with the rest of the herd. Early calving (June/July) desirable for this enterprise in northern areas. Selection of efficient dams with good milking ability and lighter liveweights can improve stocking rates and profitability.
Note that herd structure table assumes a high culling rate in early years due to the culling of cows that are tested as empty (100% culling assumed on pregnancy test results), poor performers and off types. However, as replacements are purchased PTIC** numbers required are less than the self replacing enterprises.

** PTIC = Pregnancy tested in calf.

Cattle Gross Margins (NSW DPI April 2019)

Enterprise	Butcher Vealers		
Enterprise Unit		100	Cows
Pasture	Improved Pasture		

INCOME				
No	Type	$/Hd	Total $	
32	steer vealers @	880	28,160	
13	store steers @	771	10,023	
32	heifer vealers @	825	26,400	
13	store heifers @	695	9,035	
1	CFA Bull @	1,800	1,800	
9	CFA cows @	1,124	10,116	
9	Other culls @	1,124	10,116	
	A. Total Income:		95,650	
VARIABLE COSTS:				Local Expense
1	Bull @	3,500	3,500	Yes
18	Replacement heifers @	700	12,600	Yes
	Livestock and vet costs:		1,405	Yes
	Fodder crops		-	Yes
	Hay & Grain or silage		-	Yes
	Drought feeding costs		-	Yes
	Pasture maintenence (improved pasture costs for 209 ha per 100 cows)		20,900	Yes
	Livestock selling cost		7,231	No
	B. Total Variable Costs:		45,636	84%
	GROSS MARGIN (A-B)		50,014	
	GROSS MARGIN/COW		500.14	
	GROSS MARGIN/DSE*		31.57	
	GROSS MARGIN/HA		239.30	
	DSE/Cow		15.8	
	Area Ha		209	
	Total DSE		1,584	

Crop Gross Margins

Crop	Canola			
INCOME:				
	T/Ha	$/T		
	2.0	534.00	1,068.00	
A. TOTAL INCOME $/ha:			1,068.00	
VARIABLE COSTS:				Local Expense
Cultivation			-	Yes
Sowing			60.00	Yes
Fertiliser & application			160.00	Yes
Herbicide & application			70.00	Yes
Insecticide & application			15.00	Yes
Windrowing			30.00	Yes
Harvesting			50.00	Yes
Levies			13.88	No
Crop Insurance			16.02	No
Cartage			40.00	Yes
B. TOTAL VARIABLE COSTS $/ha:			454.90	425.00
				93%
C. GROSS MARGIN (A-B) $/ha:			613.10	

Crop	Wheat			
INCOME:				
	T/Ha	$/T		
	4.0	279.00	1,116.00	
A. TOTAL INCOME $/ha:			1,116.00	
VARIABLE COSTS:				Local Expense
Cultivation			-	Yes
Sowing			50.00	Yes
Fertiliser & application			150.00	Yes
Herbicide & application			60.00	Yes
Insecticide & application			7.50	Yes
Windrowing			-	Yes
Harvesting			50.00	Yes
Levies			14.51	No
Crop Insurance			16.74	No
Cartage			40.00	Yes
B. TOTAL VARIABLE COSTS $/ha:			388.75	357.50
				92%
C. GROSS MARGIN (A-B) $/ha:			727.25	

MERINO WETHERS (20 micron)

Farm Enterprise Budget Series - Oct 2018 (average wool and sheep price 1 Apr to 30 Sep)

Flock size: 1000 wethers
Wether body weight: 59 kgs
DSE rating: 1.18 DSEs/wether

					Standard Budget $	Your Budget $
INCOME						
Wool	**number**	**class**	**kg /hd**	**$/kg**		
Shear	1000	wethers	6.06	$13.32	$80,784	
	174	wethers 4 month	1.26	$5.96	$1,310	
Crutch	990	wethers	0.40	$8.61	$3,411	
Sheep Sales	**number**	**class**	**$ /hd**			
	156	CFA wethers	$124.05	(26.0 kg cwt)	$19,308	
Fodder	**tonnes**	**type**	**value per tonne**			
Graz/fodder crop	0 t	0	$0 /t		$0	
			A. Total Income:		**$104,812**	
VARIABLE COSTS						
Replacements	**number**	**class**	**cost ($)/hd**			
	174	wethers	$85.00	(4 months)	$14,790	
Cartage	174	wethers	$2.00		$348	
Wool Harvesting & Selling Costs				**reps**		
Shearing	1174	wethers	$7.15	1	$8,397	
Crutching	990	wethers	$1.58	1	$1,566	
Wool tax			2.00%		$1,710	
Commission, warehouse, testing charges			$40.50/ bale		$1,498	
Wool - cartage	37	bales	$10.00		$370	
- packs	37	packs	$13.50		$500	
Sheep Health						
Broadspectrum	826	wethers	$1.51	2	$2,495	
	174	weaners	$0.71	2	$247	
Narrowspectrum	1000	wethers	$0.32	1	$320	
Lice control	1174	wethers	$1.13	1	$1,327	
Fly control (long acting)	1000	wethers	$1.80	1	$1,801	
Vaccination- 6 in 1	1000	wethers	$0.30	1	$300	
Livestock Selling Costs						
Livestock cartage	156	CFA wethers	$2.00		$311	
Commission on sheep sales			4.95%		$956	
Levies (Yard dues, MLA Transaction levy and LLS rates)					$402	
Pasture maintenance	118 ha	@	$37 /ha		$4,372	
Fodder						
		Supplementary feed @ $320 /t				
Wethers	826	3.5 kg/hd/week	$0.32 /kg	4 weeks	$3,659	
Wether weaners	174	2.8 kg/hd/week	$0.32 /kg	10 weeks	$1,559	
	Total feed	16,308 kg	@	$320	**$5,218**	
Graz/fodder crop	0 ha	@	$0 /ha		$0	
			B. Total Variable Costs:		**$46,928**	

	excl. fodder	incl. fodder	
GROSS MARGIN (A-B)	**$63,102.71**	**$57,884.23**	
GROSS MARGIN /WETHER	**$63.10**	**$57.88**	
GROSS MARGIN /DSE	**$53.48**	**$49.05**	
GROSS MARGIN /HA	**$534.77**	**$490.54**	

This budget should be used as a GUIDE ONLY and should be changed by the grower to take account of movements in commodity and input prices, changes in seasonal conditions and individual farm characteristics. Estimated prices are GST exclusive.

ASSUMPTIONS MERINO WETHERS (20 micron)

1. Flock Parameters

Cull age	6.5 years	Adult mortality	2%
Replacement age	1.5 years	Body weight	59 kg
Productive life	5.0 years	DSE rating	1.2
Stocking rate/ha	10 dse's		

Sheep and wool prices thanks to MLA market reporting, AuctionsPlus and AWEX. Wool cuts based on wether trial data

Pasture maintenance = 90kg/ha single super @ $3450t + $6.00/ha application

2. Flock Structure

Sheep numbers are modified to reflect mortality throughout the year.

Age	No. of wethers
0.5	174
1.5	172
2.5	169
3.5	165
4.5	162
5.5	159
6.5	0
Total	**1000**

174 **replacements bought**

156 **CFA's sold**

3. Wool Prices

Merino Wether	Micron	AWEX Type	Clean price	Yield	Greasy price	Specifications (all 35n/ktex)	Proportion of Clip
- Fleece GTM	20	MF5B.	$22.12	65%	$14.42	1%VMB, 90mm	80%
- Skirtings/bellies	19	MP5B.	$17.87	56%	$9.97	4.8%VMB, 80mm	15%
- Cardings	20	MZ2B.	$11.07	52%	$5.75	2.9%VMB.	5%
					$13.32		used in budget

4. Sensitivity Tables - Changes in Gross Margin $/DSE (includes fodder)

Wool Cut kg/hd	Wether Greasy Wool Price $/Kg greasy				
	$7.99	$10.66	**$13.32**	$15.98	$18.65
3.64 kg	$6.82	$14.87	$22.92	$30.97	$39.02
4.85 kg	$14.55	$25.28	$36.02	$46.75	$57.49
6.06 kg	$22.22	$35.64	**$49.05**	$62.47	$75.89
7.28 kg	$29.89	$45.99	$62.09	$78.20	$94.30
8.49 kg	$37.56	$56.35	$75.13	$93.92	$112.70

Wool Cut kg/hd	Wether weaners Wool Price $/Kg greasy				
	$3.57	$4.77	**$5.96**	$7.15	$8.34
0.76 kg	$48.36	$48.49	$48.62	$48.75	$48.88
1.01 kg	$48.49	$48.66	$48.84	$49.01	$49.18
1.26 kg	$48.62	$48.84	**$49.05**	$49.27	$49.49
1.52 kg	$48.75	$49.01	$49.27	$49.53	$49.79
1.77 kg	$48.83	$49.13	$49.44	$49.74	$50.04

CFA wethers $/hd	Replacement wethers $/Hd				
	$51.00	$68.00	**$85.00**	$102.00	$119.00
$74.43	$47.85	$45.34	$42.83	$40.33	$37.82
$99.24	$50.96	$48.45	$45.94	$43.44	$40.93
$124.05	$54.07	$51.56	**$49.05**	$46.55	$44.04
$148.86	$57.18	$54.67	$52.16	$49.66	$47.15
$173.67	$60.29	$57.78	$55.28	$52.77	$50.26

Note: The above sensitivity tables vary price and quantities by +/- 20% and +/- 40%.

M.Weth. Wean. kg/Hd/wk	Feeding Adult Wethers kg/Hd/week				
	1.73 kg	2.60 kg	**3.46 kg**	4.33 kg	5.19 kg
1.4 kg	$51.27	$50.49	$49.72	$48.94	$48.16
2.1 kg	$50.94	$50.16	$49.38	$48.61	$47.83
2.8 kg	$50.61	$49.83	**$49.05**	$48.28	$47.50
3.5 kg	$50.27	$49.50	$48.72	$47.95	$47.17
4.2 kg	$49.94	$49.17	$48.39	$47.62	$46.84

Adult Wethers kg/hd/wk	Grain price $/Tonne				
	$160.00	$240.00	**$320.00**	$400.00	$480.00
1.7 kg	$52.04	$51.32	$50.61	$49.89	$49.17
2.6 kg	$51.65	$50.74	$49.83	$48.92	$48.01
3.5 kg	$51.27	$50.16	**$49.05**	$47.95	$46.84
4.3 kg	$50.88	$49.58	$48.28	$46.98	$45.68
5.2 kg	$50.49	$49.00	$47.50	$46.01	$44.52

Note: The feeding sensitivity tables vary quantities/cost by +/- 25% and +/- 50%.

Sheep Gross Margins (NSW DPI October 2018)

Merino Wethers (20 Micron)

Flock size	1000	wethers					
Wether body weight	59	Kg					
DSE rating	1.18	DSE/Wether					
						$	
INCOME							
Wool	number	class	kg/ha	$/kg			
Shear	1000	wethers	6.06	$13.32		80,719.20	
	174	wethers 4 mon	1.26	$5.96		1,306.67	
Crutch	990	wethers	0.4	$8.61		3,409.56	
Sheep	Sales	number	class	$/ha			
	156	CFA wethers	$124.05	$1.00	(26 kg cwt)	19,351.80	
Fodder	tonnes	type	value	per	tonne		
Graz/fodder crop	0	t	0	$0	/t	-	
A.	Total	Income:		**Total Income**		**104,787.23**	
VARIABLE	COSTS						Local
Replacements	number	class	cost ($)/hd				Expense
	174	wethers	$85.00	(4 months)		14,790.00	Yes
Cartage	174	wethers	$2.00			348.00	Yes
Wool	Harvesting	&	Selling	Costs	reps		
Shearing	1174	wethers	$7.15	1		8,394.10	Yes
Crutching	990	wethers	$1.58	1		1,564.20	Yes
Wool	tax	2.00%				1,708.71	No
Commission, warehouse, testing charges				$40.50	bale	1,498.50	No
Wool - cartage	37	bales	$10.00			370.00	Yes
- packs	37	packs	$13.50			499.50	Yes
Sheep	Health						
Broadspectrum	826	wethers	$1.51	2		2,494.52	Yes
	174	weaners	$0.71	2		247.08	Yes
Narrowspectrum	1000	wethers	$0.32	1		320.00	Yes
Lice control	1174	wethers	$1.13	1		1,326.62	Yes
Fly control (long acting)	1000	wethers	1.80	1		1,800.00	Yes
Vaccination- 6 in 1	1000	wethers	0.30	1		300.00	Yes
Livestock	Selling	Costs					
Livestock cartage	156	CFA wethers	$2.00	1.00		312.00	No
Commission on sheep sales			4.95%			957.91	No
Levies (Yard dues, MLA Transaction levy and LLS rates)						402.00	No
Pasture maintenance	118	ha @	$37	/ha		4366	Yes
Fodder							
Supplementary feed @			$320	/t			
Wethers	826	3.5	kg/hd/week	0.32	$/Kg	3,700.48	Yes
Wether weaners	174	2.8	kg/hd/week	0.32	$/Kg	1,559.04	Yes
Graz/fodder crop	0	ha @	$0	/ha			
				Total Variable Costs		**46,958.66**	**42,079.54**
							90%
					excl fodder	incl fodder	
	GROSS	MARGIN	(A-B)		63,088.09	57,828.57	
	GROSS	MARGIN	/WETHER		63.09	57.83	
	GROSS	MARGIN	/DSE		53.46	49.01	
	GROSS	MARGIN	/HA		534.64	490.07	
	excl						

DSE/Hd	1.18
DSE/Ha	10
Ha	100
Total DSE	1,180