PROJECT SUMMARY REPORT

PROJECT 2008/104 & 2008/105

BENCHMARKING NUTRIENTS ON EGG FARMS IN THE CONDAMINE CATCHMENT USING ELECTRO-MAGNETIC INDUCTION TECHNOLOGY

PREPARED FOR:

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EXECUTIVE SUMMARY

Sustainable nutrient management in the egg industry has been recognised as an area of priority for improved management, particularly for free range farms. Hens excrete a large proportion of the nutrients that they ingest (as manure), which can create a risk to the environment depending on how these nutrients are managed. These nutrients can build up to levels well beyond what is required for pasture or crop growth, and can present an environmental risk if the nutrients move off the site with water.

One issue with managing manure nutrients is the variability in nutrient levels that can result in free range or manure application areas. Having an improved understanding of this would help farmers devise new management strategies to improve nutrient management and reduce the risk of nutrient losses.

This project utilised a readily available technology (electro-magnetic induction, or EM) for the purpose of mapping manure nutrient distribution. This is a relatively novel application, and no other published studies have been found that use this approach for mapping nutrient distribution on poultry farms. Few studies are available that investigate nutrient distribution on free range farms worldwide, making this project a significant advancement to knowledge on the topic.

The project benchmarked nutrient levels on egg farms across the Condamine Catchment in South-East Queensland, covering around 95% of the egg producers in this region. Nutrient surveys using EM technology and soil sampling were conducted on 14 free range farms, 7 manure application paddocks on the area surrounding two older style caged egg farms.

Results from soil testing across the free range farms showed that in general nutrient levels were high for nitrate (measured as nitrate-N) and phosphorus (measured as Colwell P). Levels tended to be higher than those recommended for manure reuse areas in other industries (i.e. Skerman 2000). Nutrient distribution in free range areas showed a fairly consistent pattern of elevated nitrate and phosphorus close to the sheds (within approx. 20m). Some older farms had very high nutrient levels even at some distance from the sheds (up to 50m) though it was not clear if this was also driven by inherent soil fertility. In this way, free range egg farming is similar to some other 'open lot' production systems such as beef and dairy lot-feeding.

EM surveying on manure application areas was very useful for identifying elevated nutrient levels and promoting practice change. Only one paddock in the current project displayed consistently high nutrient levels, however many such areas may exist across the catchment as a result of intensive livestock farming practices. EM is a useful way of giving farmers confidence to make management changes, by providing a more robust assessment of nutrient levels. EM surveying was useful for determining inherent variability in soil properties that will influence yield and sustainable nutrient usage. This is highly valuable for all farmers who are moving towards a precision agriculture approach to farming.

The project found that most manure application areas investigated had nutrient levels ideal for cropping and were not of concern from an environmental perspective. Previous research has shown that on paddocks with differing soil types, split applications of manure would be highly worthwhile and would improve the sustainability of the practice.

The EM surveys identified excessive nutrient ‘hotspots’ in some paddocks where manure had been stored prior to spreading. It is recommended that improved management of manure stockpiling is promoted to farmers.

An objective of the project was to help egg farmers to identify areas where improved environmental management was required and to promote practice change. The general interest in the project suggest that the project was successful in achieving this goal. This was demonstrated in the success of a workshop held with farmers after the nutrient surveys had been completed. The nutrient maps were found to be particularly useful for demonstrating the distribution of nutrients.

The workshop identified that while many options were available for improving nutrient management, there were still impediments to practice change. Some of these impediments include:

- The capital or labour costs associated with improved management, and
- Uncertainty of the benefits of improved management.

It is also apparent that better information is required to structure improved environmental management. In particular:

- Guidelines need to be developed to ensure that suitable management changes are made to mitigate the risks of nutrient losses. This will require research to quantify the benefits of various practice changes.
- Design guidelines are also required to improve the infrastructure required for environmental management at new developments.
- Demonstration of benefits is required to help farmers feel confident their added effort will lead to improved environmental management.

Some practice change options that could be promoted on the basis of this project include:

- Construction of runoff diversion banks around free range areas to divert clean runoff from crossing the site.
- Construction of compacted pads around free range sheds (out to approx. 20m).
- Construction of designated manure storage areas with compacted pads and runoff control.
- EM surveying of manure application areas where high rates of manure have been applied in the past.

Other management practices that will improve nutrient management could be demonstrated using EM surveying ‘before and after’ the management change was implemented. These options could be followed up by Condamine Alliance depending on the availability of funding.

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1 INTRODUCTION

1.1 Background

Sustainable nutrient management in the egg industry has been recognised as an area of priority for improved management, particularly for free range farms. Hens excrete a large proportion of the nutrients that they ingest as manure, some of which is deposited in the free range area. These nutrients can build up to levels well beyond what is required for pasture or crop growth, and can present an environmental risk if the nutrients move off the site with water.

There is also increased interest in improving the efficiency of using manure as a fertiliser for crop production, and here also there is a need to benchmark performance and establish best management practices for nutrient management.

One issue with managing manure nutrients is the variability in nutrient levels that can result in free range or manure application areas. Having an improved understanding of this would help farmers devise new management strategies to improve nutrient management and reduce the risk of nutrient losses.

A big gain has been made to the understanding of nutrient variability across fields through the use of a precision agriculture tool; Electromagnetic Induction (EM) soil surveying. This tool, together with strategic soil sampling, can be used to create detailed maps of nutrient distribution across fields, informing land managers on where to apply nutrients and where to reduce application rates. This will enable more efficient use of manure than has been possible in the past.

Technical information and previous case studies explaining and demonstrating EM technology for mapping nutrients in a range of intensive livestock industries are available from Condamine Alliance or FSA Consulting (Wiedemann et al. 2008a, Wiedemann et al. 2009).

1.2 Egg Industry Nutrient Management

Egg farms generate large volumes of nutrients from excreted manure. This manure is deposited in the shed and (for free range farms) across the area in which the birds range. It is important from the perspective of sustainable nutrient reuse on free range farms to know how much manure is deposited in the outdoor run area around the sheds. Likewise, on caged egg farms where manure is spread on cultivation or pasture areas it is important to know the soil nutrient loading rate on these areas.

Free range egg farmers generally clean manure from sheds after the end of a cycle of birds at approximately 80 weeks and take this manure off-site or to cultivation areas for use as a fertiliser. However, manure that is deposited outdoors on free range farms cannot be so easily managed. Preliminary nutrient surveys (Wiedemann et al. 2009) suggest that nutrient levels can be highly variable across free range areas. This is not surprising considering the behaviour of the birds and the obvious deposition of manure around the sheds and nearby trees.

Poultry manure contains high levels of nutrients compared to many other animal manures, and levels for properties of interest are shown in Table 1. The 'fresh' manure samples have been collected from caged birds with daily manure removal. The free range and barn litter represents an analysis typical of the material that would be removed from a free range shed. This material is usually a mix of manure and sawdust, it is generally drier and has lower nitrogen levels than manure from caged birds.

TABLE 1 – CHARACTERISTICS OF LAYER MANURE AND FREE RANGE POULTRY LITTER

Parameter	Units	Cage Manure[1]	Free Range and Barn litter[2]
Moisture	%	64.2	20.8
pH - Water		6.2	6.9
Electrical Conductivity	dS/m	14.1	9.5
Organic Carbon	%	38.0	32.3
Nitrogen	%	5.9	2.7
Phosphorus	%	2.0	1.6
Potassium	%	2.1	1.5
Calcium	%	10.2	10.6
Sulphur	%	0.5	0.5

Source: Wiedemann et al. (2008b). [1]Average of 5 samples – daily manure removal and no drying. [2]Average of 7 samples collected at the end of 70-80 week cycles.

There are still substantial gaps in the knowledge of manure and nutrient excretion from egg production hens, particularly in free range areas. Typical mass balance methods that have been employed in other industries (i.e. pork and feedlot beef) have not been developed for egg production hens at this stage, making planning and management of nutrient loading more difficult.

Considering this, the most reliable option to assess nutrient management is to take a retrospective assessment of soil nutrient levels in critical areas, such as free range areas close to the sheds and in manure application areas.

1.3 Environmental Issues of Concern

Nutrients from egg farms are potentially an environmental concern because of the risk they pose to water quality, either groundwater or surface water. The nutrients of particular concern are nitrogen (mainly in the form of nitrate) and phosphorus. These nutrients interact with soil and water differently. Nitrate is highly mobile and rapidly moves through the soil profile with water. If high loads of nitrate are present in the soil (in excess of plant requirements), and high amounts of water leach through the soil profile this nitrate is likely to be lost to groundwater. Nitrate can also be lost in surface runoff and contribute to eutrophication of waterways.

Phosphorus is less soluble than nitrate and binds very strongly to soil, reducing the risk of leaching. In most cases, phosphorus will not move more than 20-30cm down the soil profile. However, phosphorus may be lost with surface runoff or soil erosion and be carried to nearby waterways.

Considering this, the primary risks associated with egg farming are losses of nutrients (particularly phosphorus) with runoff or erosion, and losses of nutrients (particularly nitrate) with leaching.

It is very difficult to assess the actual nutrient losses from a site. It is also difficult to assess if these nutrients contribute to environmental harm. Most egg producers in the Condamine Catchment operate in low rainfall, dryland farming regions and are a long distance from the nearest waterway. It could be argued that the risk of nutrients moving from these sites to sensitive receptors (creeks and rivers) is low. However, at this stage the degree of nutrient loading on egg farms is not well understood, and this project was initiated to address this.

1.4 Project Objectives

The project aimed to assess nutrient levels on free range farms in the Condamine Catchment (95% of producers in the catchment), to help improve manure reuse and help mitigate risks to water quality.

The project aimed to establish a benchmark for nutrient levels on egg farms in the catchment through objective measurements (soil sampling) and to estimate variability in nutrient levels through the use of EM surveying. The benchmark data are to be used for:

- Identifying and assessing potential environmental risks from high nutrient levels,
- Identifying and developing risk mitigation and improved management solutions,
- Improving egg producers' knowledge and skills in the management of nutrients, and
- Informing the continuous improvement of current recommended practices for nutrient management and relevant components of the Queensland Egg Industry Environmental Management System.

2 METHODOLOGY

2.1 Farms Surveyed

A total of 23 sites were surveyed as part of the project. Of these, the majority (14) were free range farms. The remaining sites were paddocks used for manure application (7 areas) and older caged egg farms (2 areas). Details for the farms surveyed are provided in Table 2.

TABLE 2 – DETAILS FOR FARMS SURVEYED

FARM NAME	***Type***
S&A PARRY	Free range
N Kratzmann	Free range
McLean Farms	Manure application areas
DA Hall	Multiple sites
Darling Downs Eggs	Manure application area
A Hintz	Manure application area
Shamrock Park	Free range
W Kessler	Free range
Wingrave Farm	Free range
R&L Parry	Free range
T Inwood (Brooklea)	Manure application area
W Brosan (Ellaville)	Free range
Country Range Farming (CRF)	Multiple sites
W MacDonald	Free range
Knotsbury	Free range

2.1.1 Free Range Farms

The sustainability of free range farms was assessed primarily through observing soil nutrient levels and variability. However, in order to make a more complete assessment, observations of management practices that may alter nutrient levels / distribution were also collected. Variable factors influencing nutrient levels and distribution included:

- Hen numbers per shed (this increases the stocking density immediately around the shed).
- Size of range area and the presence of restrictions on bird movements (i.e. fenced range areas, fenced exclusion areas).
- Farm age.

Farms generally ranged in size from 500 birds to 2500 birds per shed. The range areas associated with these sheds varied from < 0.2 ha to about 2 ha. In some cases the birds had access to a larger area than this, but the birds were consistently observed to spend most time within a relatively small distance from the sheds, hence the surveys rarely extended more than 150m from the shed.

At the time of sampling, most farms had pasture in range areas in preference to crops, though birds did have access to crop areas at three sites (Kessler's and the CRF farms Widdlecombe and Rocky View). Range areas were fenced to restrict bird movements at two sites (CRF Valley View and S&A Parry). Other sites may have had general livestock fences, but these did not restrict the movement of the hens to any significant degree.

Farms ranged in age from close to 100 years of poultry farming to less than 2 years of operation. As expected, this had a significant impact on the level of nutrients found.

Photographs are shown below for three free range areas surveyed as part of the project.

PHOTOGRAPH 1 – FENCED FREE RANGE AREA

PHOTOGRAPH 2 – OPEN FREE RANGE AREA

PHOTOGRAPH 3 – FREE RANGE AREA LOCATED IN CULTIVATED FARMLAND

2.1.2 Manure Application Areas

All paddocks surveyed where used for crop production using manure as the primary fertiliser. Most paddocks were black Vertisols, typical of the Darling Downs, and were planted annually with either summer or winter cereals. In most cases manure had been used on the paddocks for several years without regular soil testing and consequently the sustainability of application rates was not clear.

Sustainability for manure reuse on cropping land is largely determined by the concentration of critical nutrients in the soil. Sustainability can be assessed firstly by measurement of soil nutrients and secondly by a review of the balance of nutrient inputs/outputs from the paddock.

If elevated levels of phosphorus and nitrate-N are observed (i.e. well above the required level for cropping), then the sustainability of manure application could be called into question.

At all properties additional information about manure application rates, paddock history and average crop yields were collected in order to gain a better understanding of the sustainability of practices.

Photographs are shown below for two typical manure application areas surveyed as part of the project.

PHOTOGRAPH 4 – MANURE APPLICATION AREA – PASTURE LAND

PHOTOGRAPH 5 – MANURE APPLICATION AREA – FALLOW CROP LAND

2.1.3 Caged Egg Sheds

The project focussed on free range farms and manure application areas. However for comparison two older caged egg production facilities were surveyed to observe nutrient levels immediately surrounding the sheds. These older style sheds may contribute to nutrient loading on the land surrounding the sheds via nutrient leaching (from manure in the sheds) or from manure stockpiles located near the sheds.

The two sites surveyed gave a good comparison of performance compared to the free range farms.

The photograph below shows a typical older style caged shed. The area surrounding this shed was surveyed as part of the project.

PHOTOGRAPH 6 – SURVEY AREA SURROUNDING AN OLDER STYLE CAGED HEN SHED

2.2 Survey Method

The EM surveys followed the method outlined in Wiedemann et al. (2008a) and will not be repeated in detail here. Survey transect width varied depending on the size of the sites from 1m to 20m spacing. Spacing depended on the size of the sites, which ranged from about 0.2 ha for the smallest free range sites to over 40 ha for one manure application area.

The survey data (apparent soil conductivity or EC_a readings) were geo-referenced using a hand-held GPS unit, with data points at 1-3m spacing depending on the size of the site. An example of an EC_a map is shown in Figure 1.

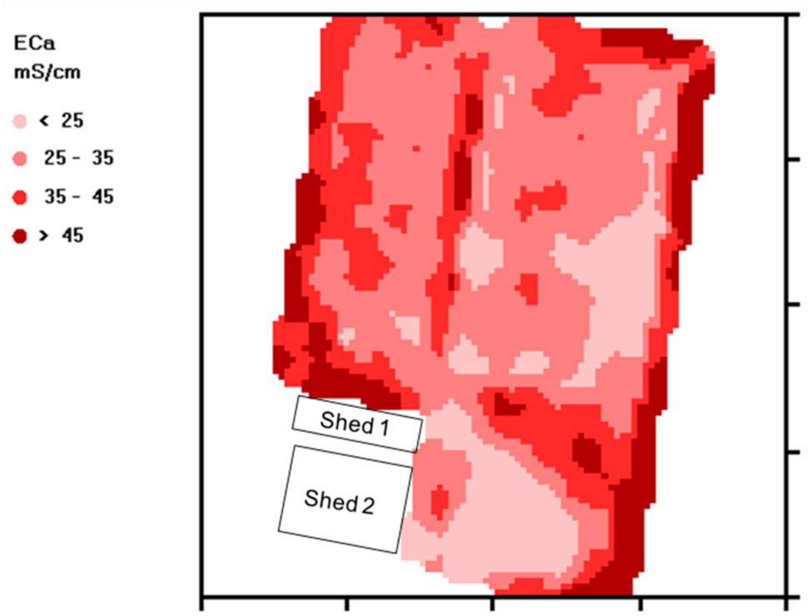

FIGURE 1 – EXAMPLE APPARENT SOIL CONDUCTIVITY (EC_A) DISTRIBUTION

Apparent soil conductivity data were used to locate six soil sampling points (using the ESAP program – Lesch et al. 2000) to assess the variability in soil properties across the site. These sampling points are statistically selected by the program to best cover the range in apparent conductivity observed.

Six soil sampling sites were selected at each farm to capture the main variability in soil conductivity across the survey area. An example of the survey map with selected soil points generated in the field from the survey is shown in Figure 2.

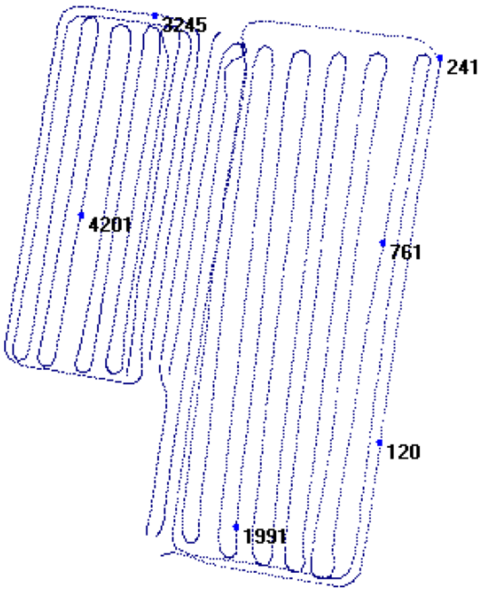

FIGURE 2 – EXAMPLE SURVEY TRANSECT SHOWING SOIL SAMPLING POINTS

Based on the experimental design, soil samples were collected using a hand auger or hydraulic soil corer. Samples were collected from 0-30cm from 2 sub-samples taken 50 cm apart and bulked. Sample sites were located using a hand-held GPS (accuracy of +/- 5 m). At some sites soil conditions prevented sampling to 30cm and in these cases samples were collected at either 0-20cm or 0-15cm. These have been noted were applicable.

The soil samples were submitted to SGS Agritech Toowoomba (a NATA accredited laboratory) for analysis. After laboratory analysis, data were statistically analysed to compare soil parameters at the six sample points with the distribution of conductivity across the survey area. The ESAP-Calibrate program (Lesch et al. 2000) was used to determine basic soil sample statistics and statistical relationships between EC_a and soil parameters of interest. From the statistical results, soil properties with moderate to high R^2 values were mapped for each farm. Results for individual farms were presented in reports for each site.

3 RESULTS AND DISCUSSION

3.1 Soil Nutrient Levels on Free Range Sites

Soil nutrient levels were assessed by taking soil samples across 14 free range areas in the catchment. At each site, six soil samples were collected following the method outlined, giving a total of 84 soil samples.

Aggregated results are presented in Table 3. The very large range in the data and large standard deviation highlight the variability in nutrient levels observed. It should be taken into account that the sampling strategy was designed to capture variability in nutrient levels, which may skew results towards higher levels compared to a random sampling design. Data were also skewed by the presence of several very old farms (80-100 years of continuous poultry farming) which displayed the highest nutrient levels. The range in Colwell phosphorus levels is shown in Figure 3.

TABLE 3 – SUMMARY RESULTS FOR SOIL SAMPLES COLLECTED AT 14 FREE RANGE SITES IN THE CONDAMINE CATCHMENT

Parameter	Mean	Median	Min	Max	St. Dev
pH	6.6	6.5	4.9	8.3	0.6
Nitrate N	95.2	34.5	0	529	135.3
Colwell P	308.3	141.5	1	1856	390.0
EC	0.3	0.2	0.05	1.54	0.3
Chloride	75.8	37.5	4	437	93.3
CEC	32.7	33.8	4.3	67.8	17.1
ESP	2.4	1.4	0.2	14.9	3.0
Organic Matter	3.9	3.3	0.8	8.8	2.2

n = 84

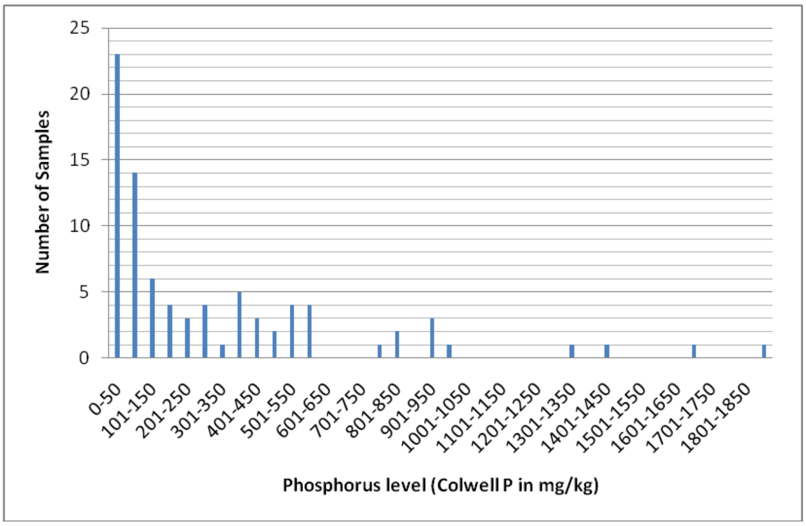

FIGURE 3 – COLWELL PHOSPHORUS LEVELS FOR SAMPLES COLLECTED AT FREE RANGE SITES

Aggregated mean values were calculated for each site (from 6 soil samples), and varied greatly for the soil parameters of interest. The range in mean values and standard deviation is shown in Table 4. Note that one site was omitted because it was not considered representative.

TABLE 4 – VARIANCE IN MEANS FOR SOIL PARAMETERS AGGREGATED ACROSS 14 FREE RANGE SITES IN THE CONDAMINE CATCHMENT

Parameter	Range in Means		St. Dev of Means	Mean R^2
	Min	Max		
Nitrate N	4.7	208.8	66.3	0.77
Colwell P	17.5	853.7	293.9	0.66
EC	0.1	0.5	0.2	0.77
Organic Matter	1.5	7.2	1.7	0.66

n = 13

The results show a considerable variance in nutrient levels between free range farms across the catchment. This is likely to be the result of differences in farm age and stocking density. The farm with the consistently lowest mean nutrient levels had been operational for only two years, while the highest mean nutrient levels were associated with farms that had been operational for close to 100 years.

Nitrate-N and phosphorus levels ranged from low levels to excessively high levels. There are no specified guidelines for nutrient levels in free range areas, however Skerman (2000) does suggest maximum levels of Colwell-P for feedlot manure application areas, which could be considered appropriate for free range areas where no mitigation methods are in place for controlling nutrient losses. The levels suggested by Skerman (2000) are soil type specific, and vary from 35 – 85 mg/kg as the acceptable limit. From the mean Colwell P levels shown in Table 3 it is clear that most farms have areas that exceed these limits.

Thresholds for nitrate-N are provided by Skerman (2000) for soil samples collected from the bottom of the root zone (generally 60-100cm). Considering the samples for this project were collected from the surface soil (0-30cm), there is no appropriate threshold value. However, surface nitrate levels are considered to elevate the risk of leaching where they are > 3 times the requirements for a pasture or crop (i.e. over about 100 mg/kg). Areas with elevated nitrate were often found to be devoid of pasture at the time of surveying because of the prevailing drought and high stocking densities. This will further increase the risk of nutrient loss as there are few plants present to draw moisture and nitrate after rainfall.

From the mean nitrate-N levels in Table 3 it can be seen that there is a heightened risk of nitrate leaching from the free range farms surveyed. It should be noted however that the large range in mean nitrate levels (Table 4) show that this does not apply to all farms.

3.2 Soil Nutrient Levels on Manure Application Areas

Soil nutrient levels were assessed by taking soil samples across 7 manure application areas in the catchment. At each site, six soil samples were collected following the method outlined, giving a total of 42 soil samples.
Aggregated results are shown in Table 5. The very large range in the data and large standard deviation highlight the variability in nutrient levels observed. It should be taken into account that the sampling strategy was designed to capture variability in nutrient levels, which may skew results towards the highest levels. On several paddocks, extremely high nutrient values were observed in small areas where manure was stockpiled prior to spreading.

TABLE 5 – SUMMARY RESULTS FOR SOIL SAMPLES COLLECTED AT 7 MANURE APPLICATION AREAS IN THE CONDAMINE CATCHMENT

Parameter	Mean	Median	Min	Max	St. Dev
pH	7.9	8.0	6.4	8.9	0.7
Nitrate N	35.3	25.5	1.0	461.0	70.4
Colwell P	51.6	37.5	2.0	385.0	63.0
EC	0.2	0.2	0.1	1.0	0.2
Chloride	58.7	35.5	5.0	475.0	76.2
CEC	55.7	63.9	13.2	83.4	18.1
ESP	2.5	2.0	0.4	7.5	1.9
Organic Matter	2.8	2.7	1.8	5.1	0.7

n = 42

Aggregated mean values were calculated for each site (from 6 soil samples). The range in mean values and standard deviation is shown in Table 6.

TABLE 6 – VARIANCE IN MEANS FOR SOIL PARAMETERS AGGREGATED ACROSS MANURE APPLICATION AREAS IN THE CONDAMINE CATCHMENT

Parameter	Range in Means		St. Dev of Means	Mean R^2
	Min	Max		
Nitrate N	2.0	81.7	28.5	0.70
Colwell P	18.7	146.3	47.9	0.70
EC	0.11	0.30	0.08	0.85
CEC	19.2	69.8	19.4	0.75
Organic Matter	2.2	3.3	0.4	0.44

n = 6.

The results show a considerable degree of variance in nutrient levels between manure application areas across the catchment. This may relate to underlying soil properties (as can be seen by the large range in CEC) and by differences in manure application rates over time.

In general, nutrient levels were found to be in the range suitable for cereal cropping and below the critical environmental thresholds. This suggests that most of these manure application areas are being managed sustainably. One exception was a paddock that had been used for manure reuse over a long period of time, which had led to a build up in soil nutrients well beyond what is required for cropping. Nutrient levels on this site exceeded the environmental thresholds set by Skerman (2000) for surface phosphorus.

3.3 Soil Nutrient Levels on Caged Egg Sites

Soil nutrient levels were assessed by taking soil samples across land surrounding two older style caged egg sheds in the catchment. At each site, six soil samples were collected following the method outlined, giving a total of 12 soil samples. Soil results for these sites are shown in Table 7.

TABLE 7 – SUMMARY RESULTS FOR SOIL SAMPLES COLLECTED FROM LAND SURROUNDING TWO OLDER STYLE CAGED EGG FARMS IN THE CONDAMINE CATCHMENT

Parameter	Mean	Median	Min	Max	St. Dev
pH	6.9	6.8	6.3	7.6	0.4
Nitrate N	11.8	5.0	3.0	59.0	16.6
Colwell P	409.7	265.0	47.0	1211.0	353.9
EC	0.2	0.2	0.1	0.3	0.1
Chloride	33.5	22.5	7.0	84.0	26.7
CEC	47.2	50.8	17.8	65.4	13.3
ESP	0.7	0.5	0.4	2.2	0.5
Organic Matter	7.7	8.8	5.0	8.8	1.5

Aggregated mean values were calculated for each site (from 6 soil samples). The range in mean values and standard deviation is shown in Table 8.

TABLE 8 – VARIANCE IN MEANS FOR SOIL PARAMETERS AGGREGATED FOR TWO SURVEY SITES OF LAND SURROUNDING OLDER STYLE CAGED EGG FARMS IN THE CONDAMINE CATCHMENT

Parameter	Range in Means		St. Dev of Means	Mean R^2
	Min	Max		
Nitrate N	4.2	19.5	10.8	0.70
Colwell P	310.3	509.0	140.5	0.86
EC	0.16	0.22	0.04	0.53
CEC	46.2	48.3	1.48	0.77
Organic Matter	7.0	8.3	0.9	0.06

n = 2

3.4 Nutrient Distribution on Free Range Sites

Of the 14 free range sites surveyed as part of the project, four farms are presented here as case studies to demonstrate the results. Nutrient distribution was surprisingly consistent from one farm to the next, though the magnitude of the EC_a and soil values ranged widely.

3.4.1 Case Study Farm 1

Farm 1 is a free range area surrounding a shed housing 2,500 birds. The birds are able to range around the shed and into the adjoining cultivated paddock. The survey covered a small part of the range area immediately down slope of the shed, covering an area of 0.3 ha.

Figure 4 shows the apparent soil conductivity (EC_a) of the survey area, together with the location of the shed and other features.

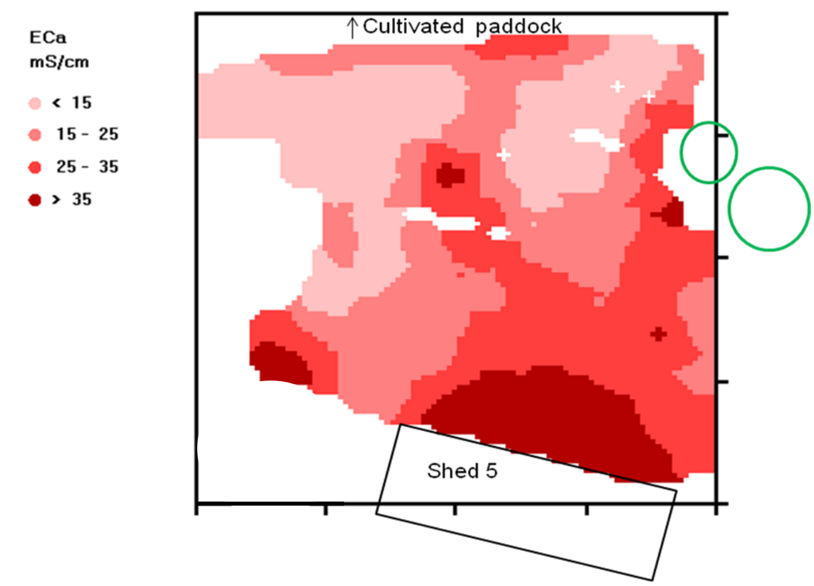

FIGURE 4 – APPARENT SOIL CONDUCTIVITY (EC_A) OF THE SURVEY AREA (FARM 1)

Based on the EC_a map and soil samples collected at the site, selected soil parameters were mapped (Figure 5 and Figure 6).

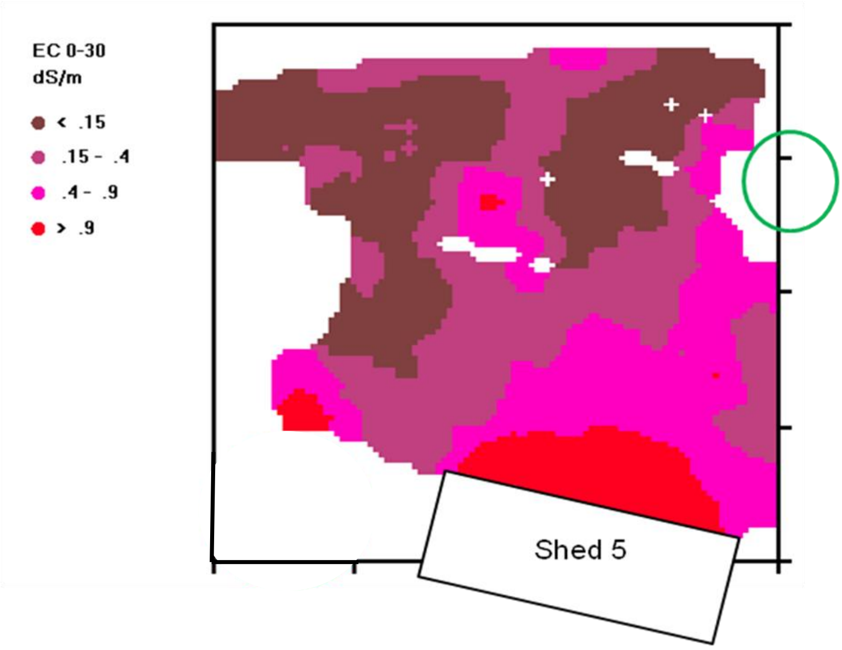

FIGURE 5 – PREDICTED ELECTRICAL CONDUCTIVITY DISTRIBUTION (FARM 1)

Variation in soil conductivity showed a strong regression relationship with EC_a (R^2 = 0.92). Considering the location of the shed, and from observations on site, the elevated EC levels appear to correspond to areas of high manure deposition (i.e. close to the shed) and to topography. The site slopes to the north (top of the image) suggesting that salts and nutrients may be leaching downhill.

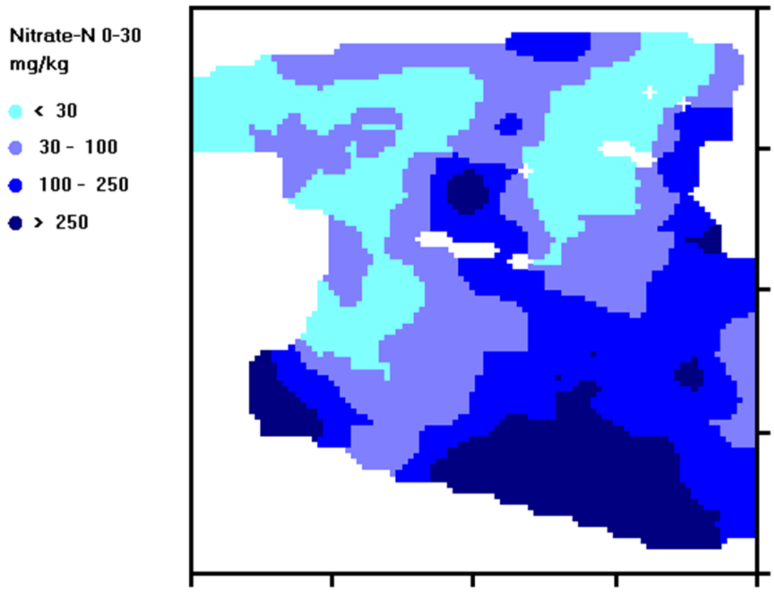

FIGURE 6 – PREDICTED NITRATE-N DISTRIBUTION (FARM 1)

Variation in soil conductivity was showed a strong regression relationship with EC_a at this site (R^2 = 0.94). Figure 6 shows that levels of nitrate-N were highest immediately around the poultry shed. Downhill from the shed there are two bands of higher nitrate-N which correspond to slight depressions. Distribution of nitrate-N across survey area appears to be variability in manure deposition. Nutrients may also be moving down slope with water.

Overall, the results for this site indicate that nutrients are not evenly distributed in the free-range area at this site. Nutrients may be moving down slope, and may extend beyond the survey area.

3.4.2 Case Study Farm 2

Case study farm 2 was a site surrounding two free range sheds, covering an area of approximately 1.2 ha. The sheds had been used for egg production for approximately 12 years and housed 2,500 (shed 1) and 1,500 hens (shed 2).

A map of the apparent soil conductivity (EC_a) across the survey area is shown in Figure 7.

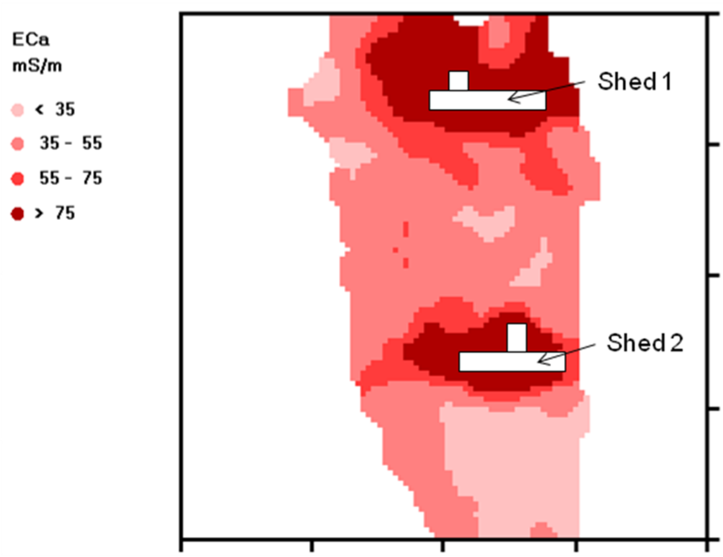

FIGURE 7 – MAP OF THE APPARENT SOIL CONDUCTIVITY (EC_A) OF THE SURVEY AREA (FARM 2)

Based on the EC_a map and soil samples collected at the site, selected soil parameters were mapped (Figure 8 to Figure 10).

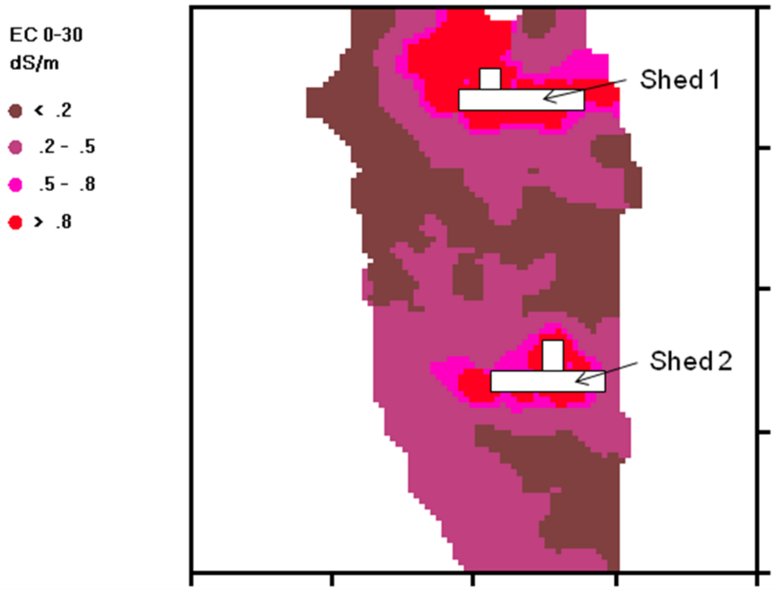

FIGURE 8 – PREDICTED ELECTRICAL CONDUCTIVITY DISTRIBUTION (FARM 2)

Variation in soil conductivity (EC) across the survey site showed a strong regression relationship with EC_a (R^2 = 0.93). The corresponding EC map (Figure 8) shows elevated conductivity levels surrounding both sheds 1 and 2.

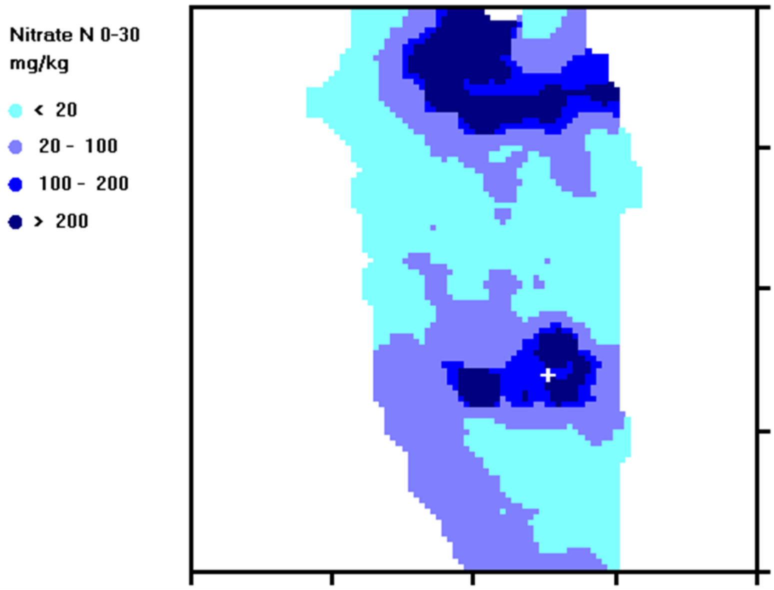

FIGURE 9 – PREDICTED NITRATE-N DISTRIBUTION (FARM 2)

Variation in nitrate N showed a moderate regression relationship with EC_a (R^2 = 0.67). The nitrate N map (Figure 9), has a similar pattern of distribution to the EC map (Figure 8) with elevated levels (>100 mg/kg) found around both sheds.

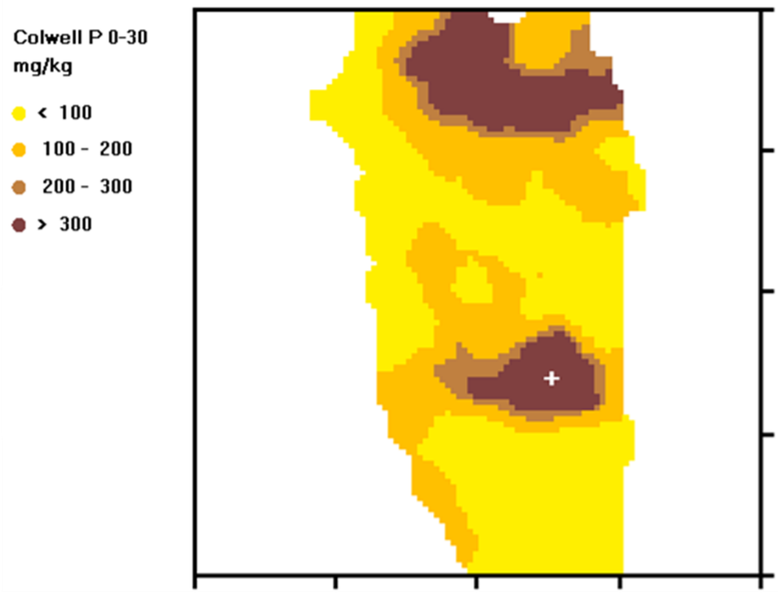

FIGURE 10 – PREDICTED COLWELL P DISTRIBUTION (FARM 2)

Colwell P showed a moderate regression relationship with EC_a (R^2 = 0.77), and displayed a similar pattern to EC and nitrate-N, with higher levels around the sheds (Figure 10). Elevated phosphorus levels were observed right across the site, however it could not be ascertained if this was the result of poultry farming, or if soil nutrient levels were naturally high.

The results from case study farm 2 identified a moderate relationship between nutrient distribution and the EM survey. Maps of nitrate and phosphorus at the site clearly identified elevated levels close to the sheds, though these were restricted to a relatively small area.

As with other sites, there was little ground cover in the free range area surrounding the sheds because of prevailing drought conditions and the high stocking rates. This increases the risk of nutrient losses from leaching and runoff.

3.4.3 Case Study Farm 3

Case study farm 3 is a free range area located between three sheds, each housing approximately 5,000 birds. The area between these sheds is cultivated and sown with summer and winter cereals which the birds graze. These crops are also harvested for grain.
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A map of the apparent soil conductivity (EC_a) across the survey area is shown in Figure 11.

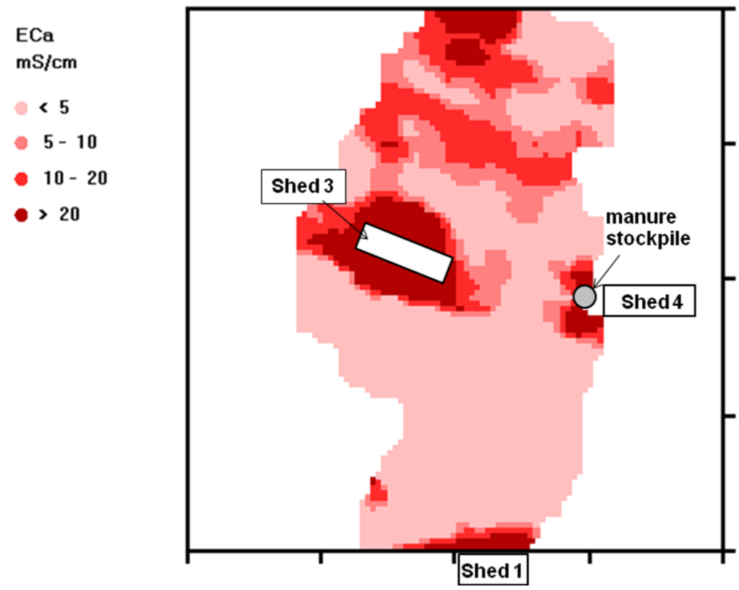

FIGURE 11 – APPARENT SOIL CONDUCTIVITY (EC_A) OF THE SURVEY AREA (FARM 3)

Based on the EC_a map and soil samples collected at the site, selected soil parameters were mapped (Figure 12 to Figure 14).

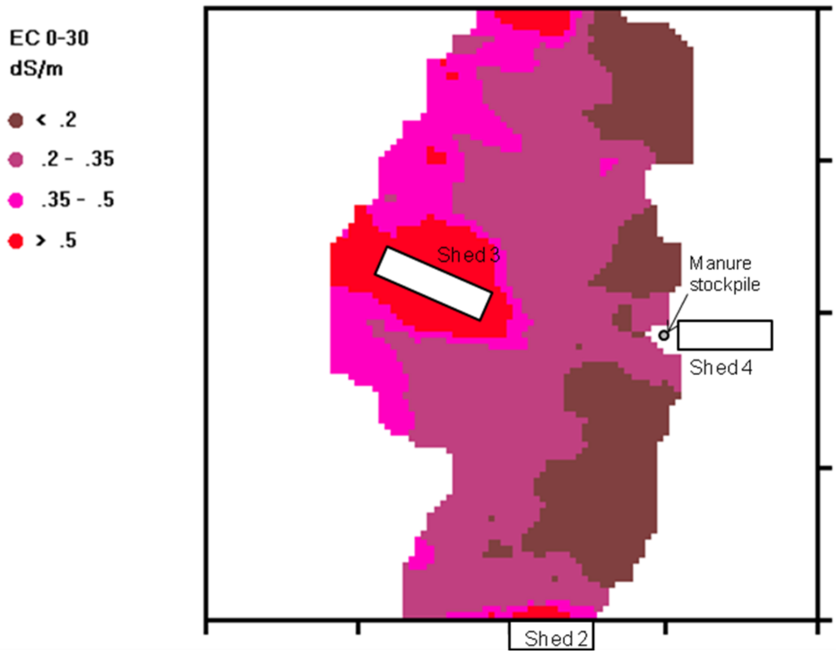

FIGURE 12 – PREDICTED ELECTRICAL CONDUCTIVITY DISTRIBUTION (FARM 3)

Variation in EC showed a strong regression relationship with EC_a (R^2 = 0.96) at this site. The corresponding EC map (Figure 16) shows a distinct pattern of higher levels of EC close to sheds 2 and 3, and decreasing EC levels as the distance from the sheds increases. Elevated EC levels in the north western corner are probably due to a manure stockpile which is located there.

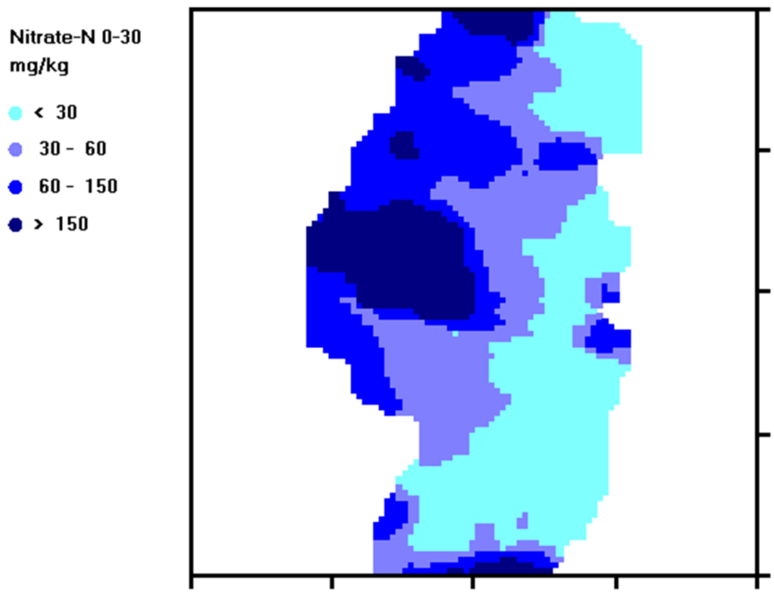

FIGURE 13 – PREDICTED NITRATE-N DISTRIBUTION (FARM 3)

The variation in nitrate N showed a strong regression relationship with EC_a ($R^2 = 0.92$) at this site. Elevated levels of nitrate-N corresponded to the location of the poultry sheds. Elevated levels were also observed in the north western corner of the survey area where manure is stockpiled.

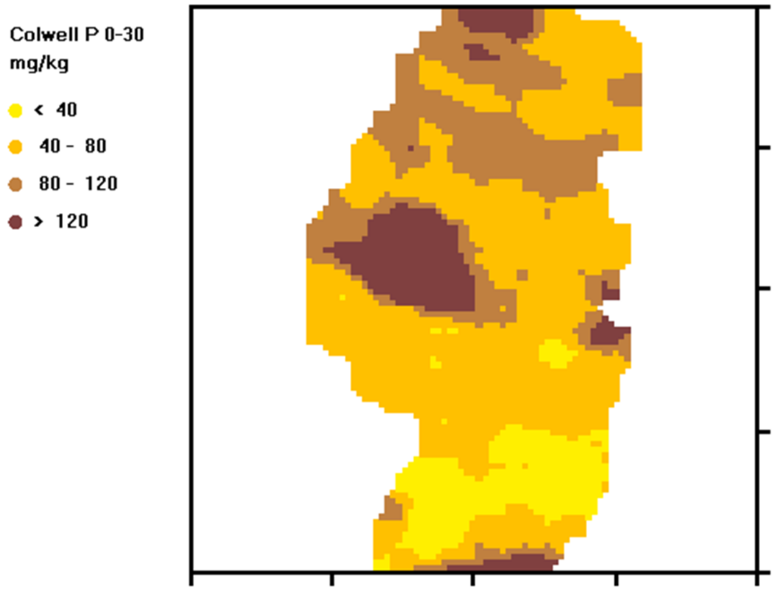

FIGURE 14 – PREDICTED COLWELL P DISTRIBUTION (FARM 3)

Phosphorus (measured as Colwell-P, or plant available P) showed a strong regression relationship with EC_a ($R^2 = 0.98$) at this site. Elevated levels of phosphorus occurred around the sheds and near the manure stockpile area.

EM survey results from this site identified a strong relationship between nutrient distribution and the EM survey. Similar distribution patterns were observed for EC, nitrate-N and Colwell P, with all showing elevated levels close to sheds 2 and 3 and in areas where manure is stockpiled (next to shed 4 and in the north-west corner of the paddock). Considering the pattern of distribution, it appears that nutrient distribution is closely related to the poultry farming activity on the site.

3.4.1 Case Study Farm 4

Case study farm 4 is a free range area for a shed housing 1,800 birds. The range area was one of the few completely fenced range areas surveyed, and encompassed an area of around 0.3 ha.

Figure 15 shows the apparent soil conductivity (EC_a) distribution of the survey area, together with the location of the shed and other features.

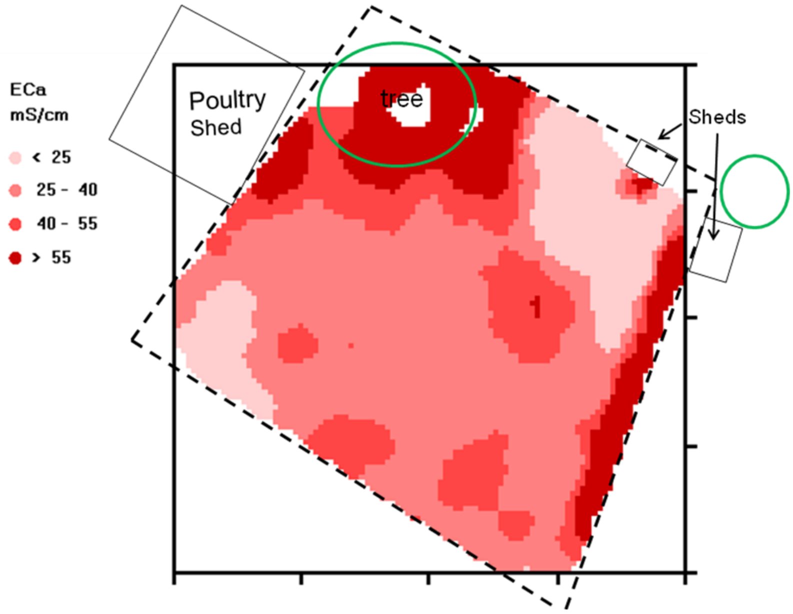

FIGURE 15 – APPARENT SOIL CONDUCTIVITY (EC_A) OF THE SURVEY AREA (FARM 4)

Based on the EC_a map and soil samples collected at the site, selected soil parameters were mapped (Figure 16 to Figure 18).

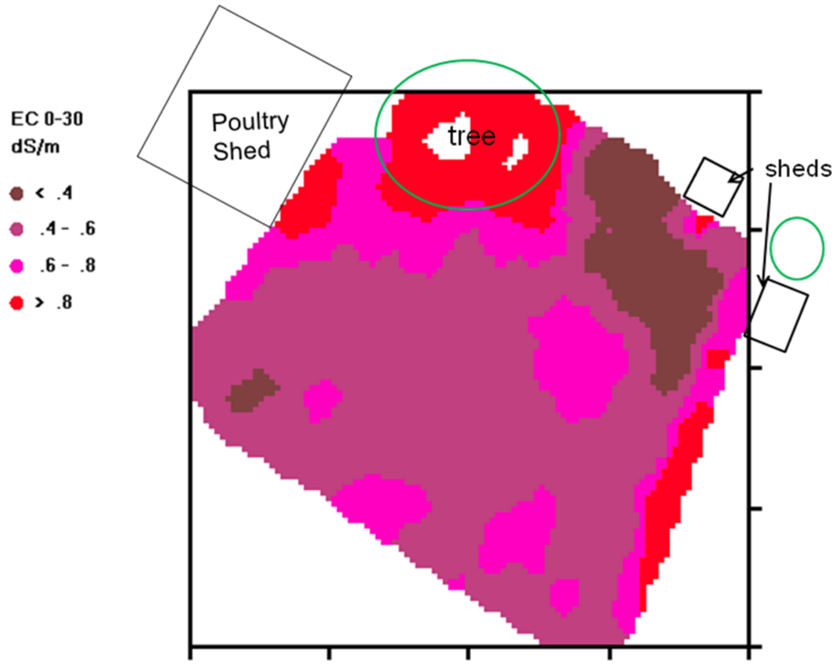

FIGURE 16 – PREDICTED ELECTRICAL CONDUCTIVITY DISTRIBUTION (FARM 4)

Variation in soil conductivity showed a moderate regression relationship with EC_a on this site (R^2 = 0.69). The corresponding EC map (Figure 16) shows a distinct pattern of higher levels of EC close to the shed, around the tree and along the eastern fence line (down slope of the shed). Considering the location of the shed, and from observations on site, the elevated EC levels appear to correspond to the areas where the birds spend most time (close to the shed and under the tree).

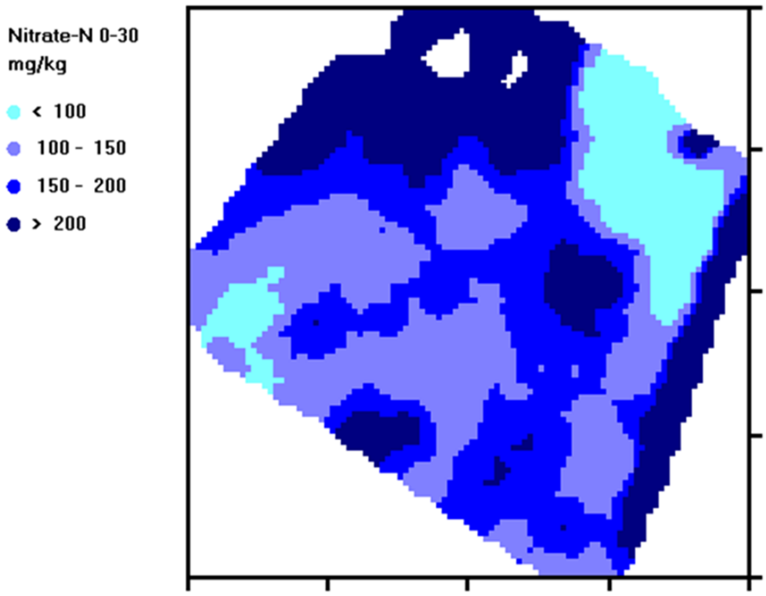

FIGURE 17 – PREDICTED NITRATE-N DISTRIBUTION (FARM 4)

The variation in nitrate N showed a moderate regression relationship with EC_a (R^2 = 0.68). The corresponding nitrate N distribution map (Figure 17) shows elevated levels of nitrate N following a similar pattern to EC.

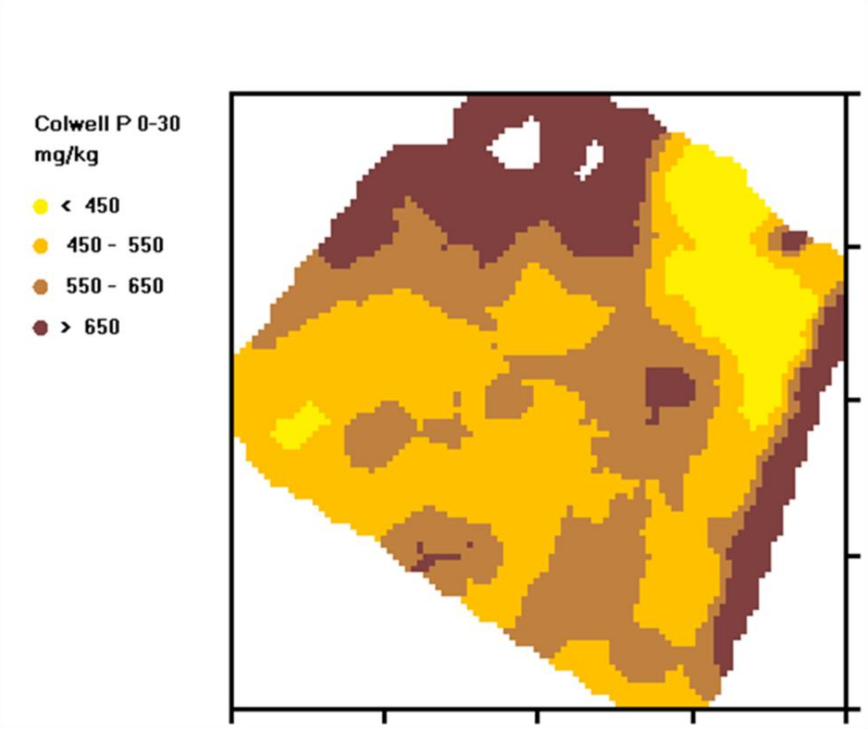

FIGURE 18 – PREDICTED COLWELL P DISTRIBUTION (FARM 4)

Variation in phosphorus showed a moderate regression relationship with EC_a (R^2 = 0.49). The phosphorus map (Figure 18) has a similar distribution pattern to EC and nitrate-N, with elevated levels of phosphorus close to the shed, under the tree and along the eastern fence line.

All three soil parameters had a similar pattern of distribution with higher levels found close to the shed, around the tree and along the eastern fence line (down slope of the shed). These trends appear to be related to poultry behaviour, with higher levels where greater amounts of manure are deposited (close to the shed and under the tree. The band of elevated Colwell P and nitrate N along the eastern fence line may be caused by sheet erosion across the site causing nutrients to accumulate against the fence, or because the fence provides morning shade for the hens, leading to greater levels of manure deposition.

3.4.2 Summary – Nutrient Distribution on Free Range Sites

Results from the EM surveying and soil sampling gave some indication of environmental performance and the sustainability of the industry. Soil nutrient levels were found to vary greatly both within a single free range area, and between farms.

The results from the soil testing showed site means for nitrate-N ranged from 4.7 mg/kg (very low) to 208.8 mg/kg (very high).

Colwell P showed an even greater range in mean values, from 17.5 mg/kg (low) to 853.7 mg/kg (extremely high).

Results from the case study farms are consistent with the findings across all farms. Soil conductivity, levels of nitrate-N and phosphorus (Colwell-P) followed a fairly consistent pattern, with higher levels immediately surrounding the sheds and progressively lower levels as the distance from the sheds increased. In some cases the presence of features such as trees and fences altered the distribution. Trees nearby the sheds tended to be areas of nutrient accumulation because the hens spend more time under the trees and deposit more manure in these areas.

Land features such as drainage lines appeared to influence nutrient distribution at some sites, presumably because nutrients were moving with surface or subsurface water. This was less common than expected.

Older farms tended to have a larger area of elevated nutrient levels close to the shed than newer farms, and generally had higher levels of nutrients across the range area.

Farms that were fenced (see section 3.4.1) tended to have higher nutrient levels across the whole area, because of the higher stocking rate compared to non-fenced areas. It should be noted that the farms with a fenced free range area were also some of the older farms sampled, and the elevated nutrient levels will be related to this also.

At all farms surveyed in the project, the extreme nutrient levels were found within a relatively short distance from the sheds. This has important implications for improving nutrient management on free range farms.

3.5 Nutrient Distribution on Manure Application Areas

Of the 7 manure application areas surveyed as part of the project, one area is presented here as a case study. Results from the manure application areas were less consistent than the free range sites, and variation in soil properties was found to relate more strongly with underlying changes in soil type rather than obvious management effects. This being said, it was clear on at least three sites that manure stockpiles were leading to elevated nutrient levels on small areas of the paddock, and these were identified by the survey.

3.5.1 Case Study Farm 5

The manure application area surveyed on Farm 5 was a 31 ha paddock used for cereal cropping. The paddock is spread with 9.8 t/ha of layer manure every 12 months prior to planting. At this application rate, the mass of nitrogen and phosphorus applied is in the order of 98 kg / ha of phosphorus and 290 kg / ha of nitrogen.

The case study presented is representative of black Vertisol cropping land common on the Darling Downs. While naturally fertile, nutrient levels in these soils have been depleted over the past 75-100 years of cropping and are now quite low in some districts.

Figure 19 shows the apparent soil conductivity (EC_a) distribution of the survey area.

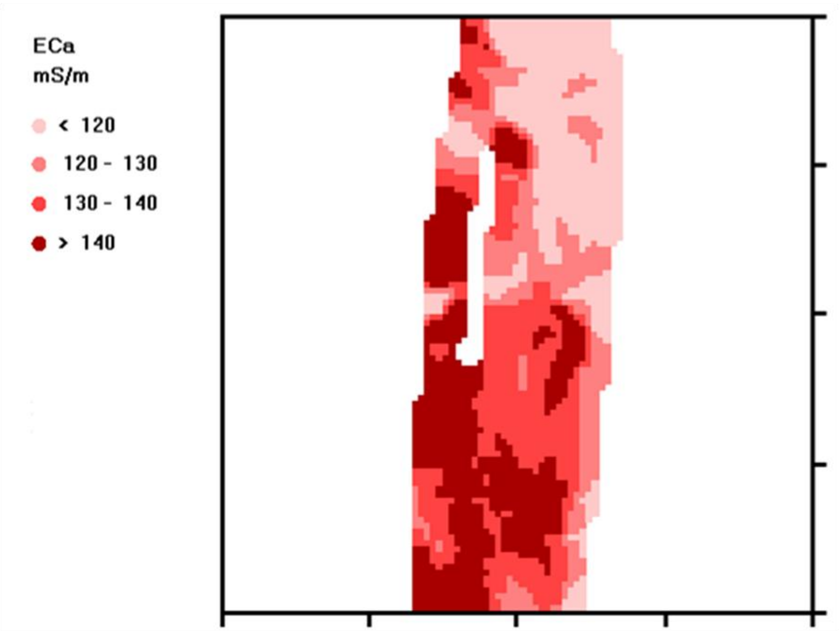

FIGURE 19 – DISTRIBUTION OF APPARENT SOIL CONDUCTIVITY (EC_A) (FARM 5)

Based on the EC_a map and soil samples collected at the site, selected soil parameters were mapped (Figure 20 to Figure 23).

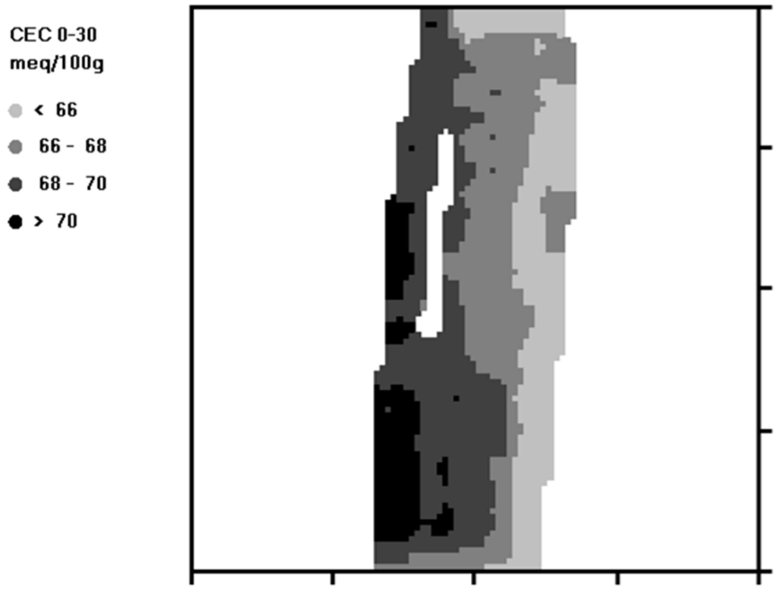

FIGURE 20 – PREDICTED CATION EXCHANGE CAPACITY DISTRIBUTION (FARM 5)

The distribution of CEC (Figure 20) showed a moderate-strong regression relationship with EC_a (R^2 = 0.87). Slightly higher levels were observed along the western side of the paddock, though considering the small range of levels, CEC is fairly uniform across the paddock.

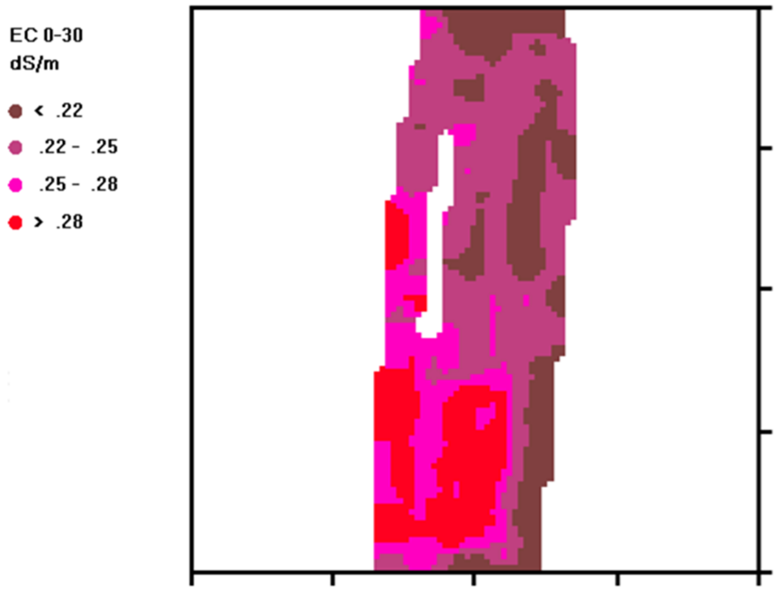

FIGURE 21 – PREDICTED ELECTRICAL CONDUCTIVITY DISTRIBUTION (FARM 5)

EC showed a moderate regression relationship with EC_a (R^2 = 0.82) and the distribution map shows higher levels in the south-western half of the paddock. It was observed during the site visit that manure had been stockpiled in the southwest corner of the paddock, which may partially explain the higher EC levels here.

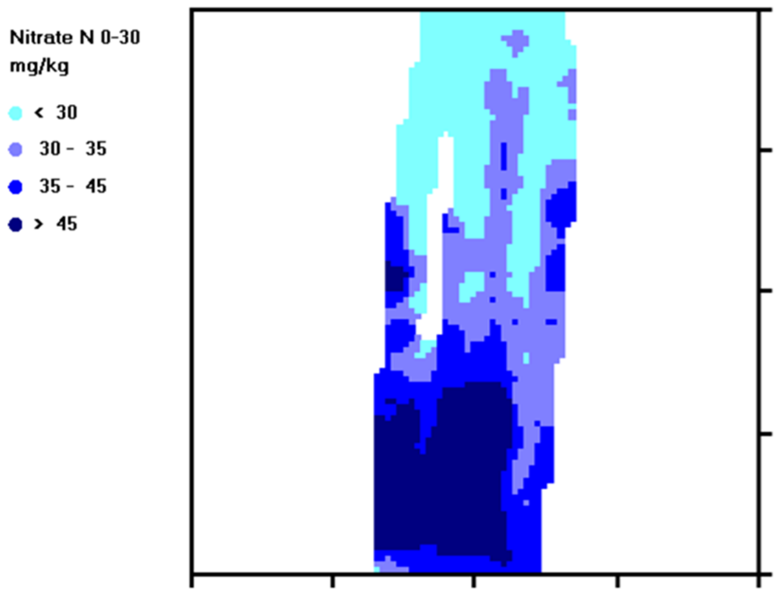

FIGURE 22 – PREDICTED NITRATE-N DISTRIBUTION (FARM 5)

Nitrate-N distribution showed a moderate regression relationship with EC_a (R^2 = 0.69). Levels of nitrate N across the paddock ranged from 23 mg/kg (adequate) to 74 mg/kg (high) with a paddock average of 36.8 mg/kg. This is generally adequate for cereal crop production, though the map shows a pattern of lower to higher levels from north to south. As previously mentioned manure may have been stockpiled at the southern end of the paddock, partly explaining the elevated nutrient levels in this corner.

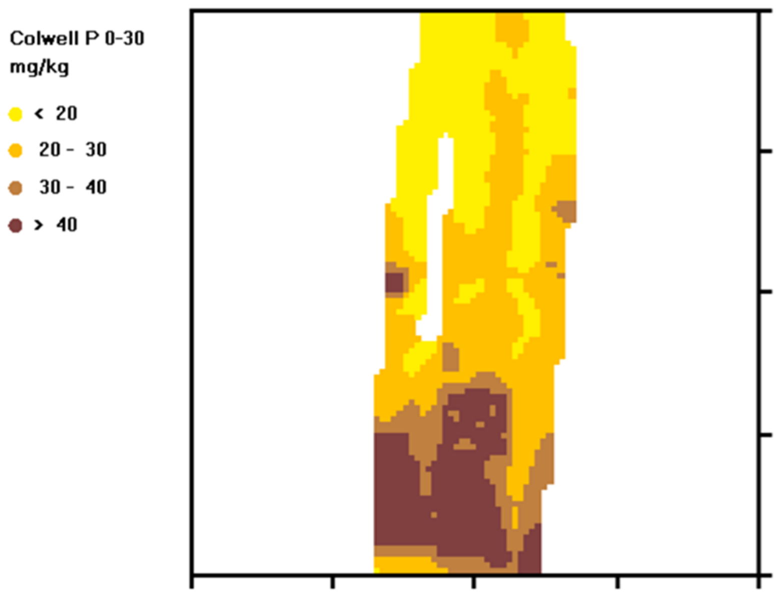

FIGURE 23 – PREDICTED COLWELL P DISTRIBUTION (FARM 5)

Phosphorus showed a moderate regression relationship with EC_a (R^2 = 0.80). The predicted distribution map (Figure 23) indicates that there are slightly higher levels in the south-western corner of the paddock, which is similar to the nitrate N and EC maps.

Phosphorus (measured by Colwell-P) levels across the paddock ranged from 13 (low to deficient) to 66 mg/kg (adequate) with a paddock average of 27.6 mg/kg (low-moderate). Colwell P levels across the paddock are variable, but on the whole are quite low for crop production. This may be the result of long-term cropping on these paddocks, leading to a run-down of phosphorus over time. Soils in the region are also known to be quite variable for phosphorus.

Overall, manure application is considered sustainable at this site based on the observed soil nutrient levels. Manure application is an effective tool to restore fertility to paddocks that have been cropped continuously without sufficient fertiliser inputs. At the rates being applied, nutrient levels will increase over time and should be monitored with soil testing to ensure excess nutrients are not applied.

3.5.2 Summary – Nutrient Distribution on Manure Application Areas

Nutrient levels on manure application areas tended to be within an acceptable range for sustainability when assessed against the thresholds provided by Skerman (2000).

The EM surveys on manure application areas were effective in mapping soil properties such as EC and CEC, which are related soil formation and soil type. This can be useful for precision agriculture applications and can help explain yield variability across paddocks. Prediction of nitrate levels was also reasonably accurate (R^2 values of around 0.7), which may allow variable application of nitrogen fertiliser on some paddocks. Unfortunately, the predicted variability of rapidly mobile nutrients such as nitrate are only representative close to the time of the survey and may be widely different in following years.

In general, the EM surveys identified a weaker relationship between management and distribution of nutrients across manure application areas. This is in itself a good result, as the aim of manure spreading practices is to evenly distribute manure nutrients.

The only exception to this was on paddocks where a manure stockpile had been located prior to manure spreading. These areas often displayed very high results that were not typical of the whole paddock. Identifying these areas highlights the sensitivity of the equipment, but tended to skew the results in some cases. The nutrient hotspots do represent one area of risk for manure application. This could be improved by constructing dedicated storage pads near paddocks where manure is regularly used.

On one paddock the survey identified consistently high nutrient levels, as the result of long term manure applications. The information provided clear direction to the farmer to promote practice change by highlighting the unsustainable nature of manure reuse on this paddock.

3.6 Nutrient Distribution on Caged Egg Sites

Of the two surveys conducted in the area surrounding caged egg production sheds, one is presented here as a case study for comparison with the free range management system.

3.6.1 Case Study Farm 6

Case study farm 6 is a decommissioned caged egg facility that had been used for egg production up to 2003. The site has three sheds, all with earthen floors.

Figure 24 shows the distribution of soil conductivity (EC_a) across the survey area.

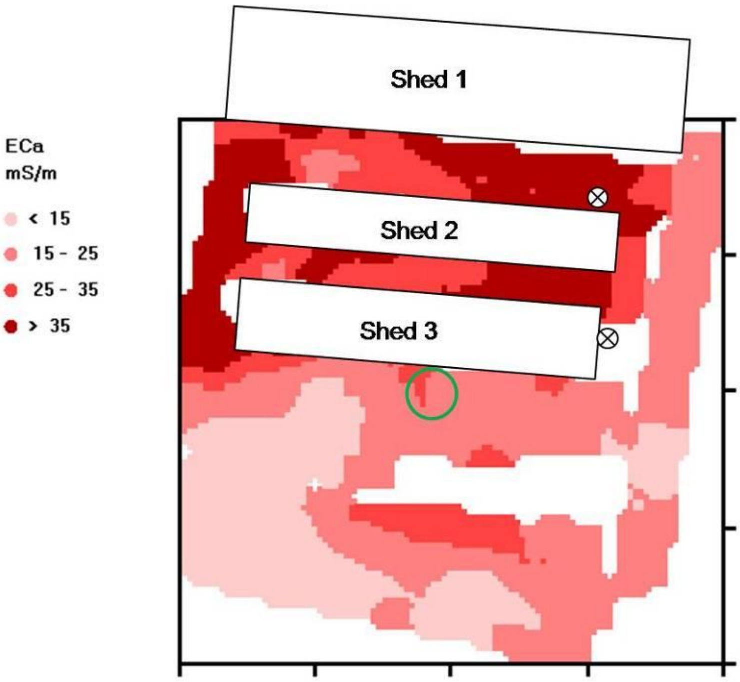

FIGURE 24 – APPARENT SOIL CONDUCTIVITY (EC_A) DISTRIBUTION (FARM 6)

Based on the EC_a map and soil samples collected at the site, selected soil parameters were mapped (Figure 25 to Figure 27).

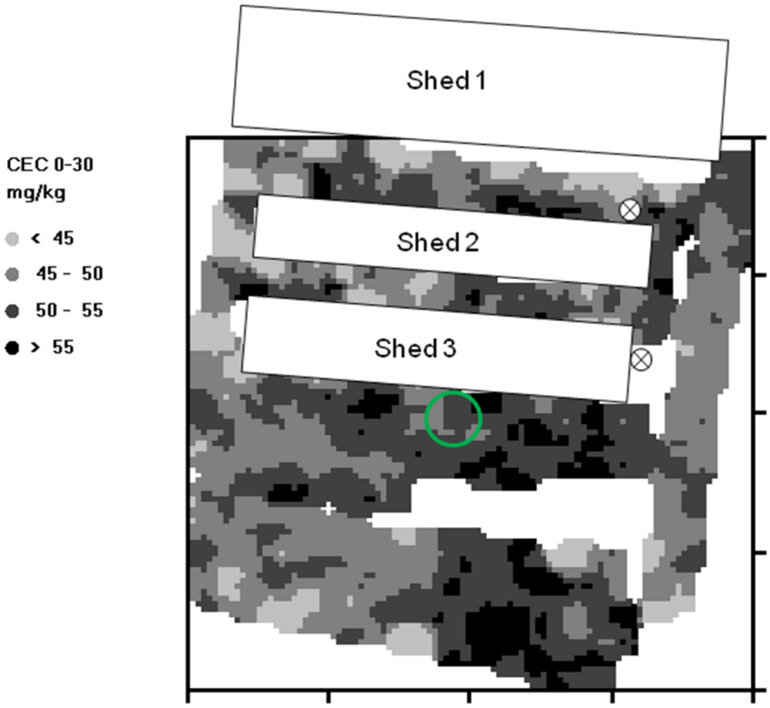

FIGURE 25 – PREDICTED CATION EXCHANGE CAPACITY DISTRIBUTION (FARM 6)

The distribution of CEC (Figure 25) showed a moderate regression relationship with EC_a (R^2 = 0.71). There was no clear pattern in CEC across the site and levels did not vary greatly.

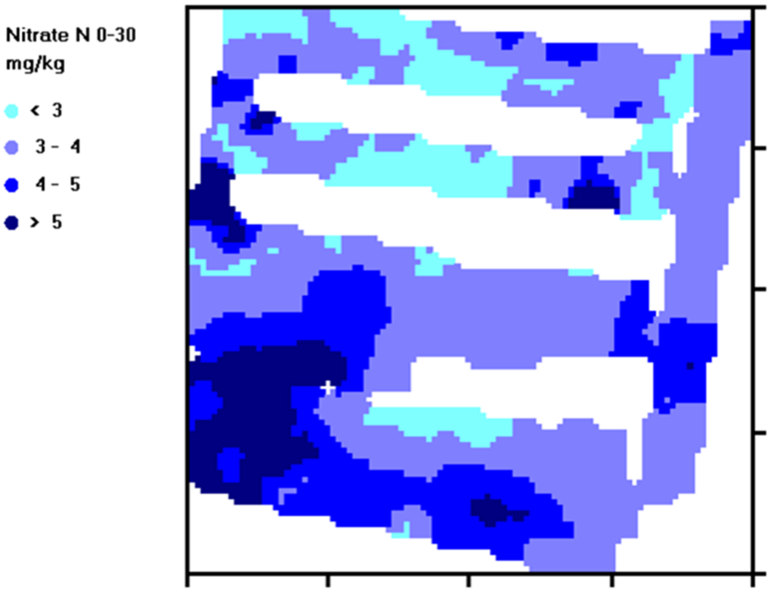

FIGURE 26 – PREDICTED NITRATE-N DISTRIBUTION (FARM 6)

Variation in nitrate N showed a moderate regression relationship with EC_a (R^2 = 0.68). The corresponding nitrate N distribution map (Figure 26) shows higher levels in the south western corner of the survey area, though overall the levels of nitrate-N are very low.

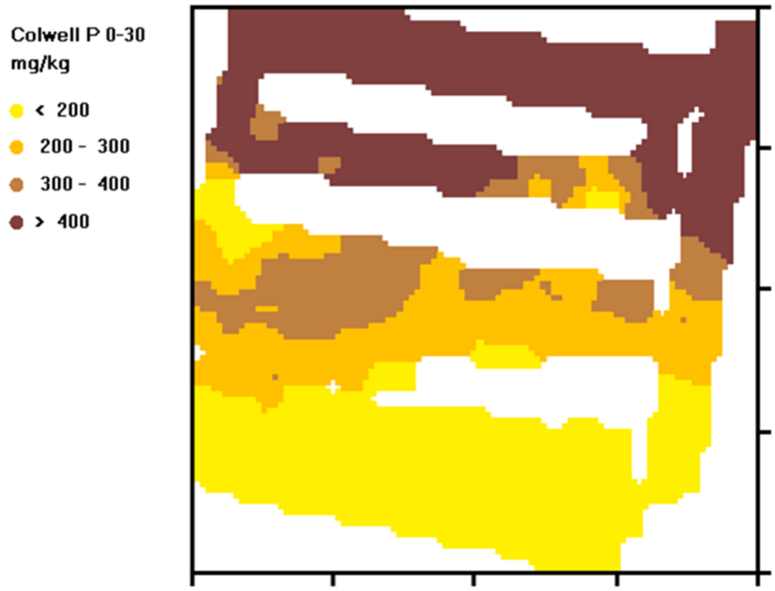

FIGURE 27 – PREDICTED COLWELL P DISTRIBUTION (FARM 6)

Variation in phosphorus showed a strong regression relationship with EC_a (R^2 = 0.89) at this site. The corresponding Colwell P map (Figure 27) shows elevated P levels to across the northern third of the survey area (below shed 1 and between sheds 1 and 2).

Current levels of Colwell P across the survey area are well above the environmental thresholds suggested by Skerman (2000) for this soil type. On discussion with the manager, the only explanation for the elevated levels was from manure cleaning practices over the years, which would have led to a thin covering of manure being left on the ground between the sheds every 2 years. However, the pattern of nutrient levels suggest that phosphorus may also have leached from the sheds over time, leading to moderate contamination of the immediate surrounds even several years after the shed was decommissioned. However, because of the nature of phosphorus and the strong binding capacity of the soil, nutrients do not appear to have moved a great distance from the sheds.

3.6.2 Summary – Nutrient Distribution at Caged Egg Sites

The two caged farms surveyed displayed elevated nutrient levels close to the sheds, possibly as a result of manure handling practices and / or leaching of nutrients from the sheds.

Results for case study farm 6 showed elevated levels of phosphorus in the soil 7 years after production ceased. Phosphorus levels were also quite high in the surrounding land (up to 50m from the sheds. It is not clear if this was related to inherent soil fertility or the presence of poultry farming on the site. Further investigation would be warranted to determine if nutrient levels in adjacent land not used for poultry ware of a similar level.

Considering the highly elevated levels remain close to the sheds the environmental risk from an older, decommissioned shed appears to be minimal.

4 Options to Improve Nutrient Management for Free Range Areas

Poultry farmers have a challenge to manage manure nutrients in a way that benefits both their farming enterprise and the environment. The results of surveys across 14 free range farms show that manure nutrients are not evenly distributed across the outdoor range areas. Nutrients tend to accumulate as highest concentration close to the sheds or near shade areas, even though the birds may range a considerable distance from the shed.

There are two different ways in which nutrients can be managed to reduce the risk of harmful losses to the environment. These are through effectively using the nutrients for plant production, or by containing nutrients to limit losses.

It should be noted that poultry farms (the shed and immediate vicinity) are *net accumulators of nutrients*. This is because far more nutrients are brought onto the site each year through the poultry feed than are exported in the eggs, spent hens or manure removed from the site.

4.1 Reducing Nutrient Accumulation through Nutrient Use on Site

The present study has identified that nutrients accumulate to high levels close to the sheds and in other areas where the hens congregate. Making use of these nutrients for crop production is one way of reducing build-up over time. Several options have been suggested to achieve this, including:

1. Rotating run areas – managing poultry access to small paddocks close to the sheds and harvesting crops from these paddocks on a rotational basis.
2. Using moveable shelters and rotating these to increase the area on which manure nutrients are deposited.

Rotating run areas

Rotating the run areas will allow part of the area to revegetate while other areas are utilised by the birds. This will allow areas to be cropped or pasture to be grown. Because the target is to remove nutrients from the site, the crops or pastures need to be harvested and removed from the site in addition to being grazed by the hens. Several issues arise with this option, namely:

1. The infrastructure costs for fencing the rotation areas can be prohibitive.
2. Rotations will require a higher degree of management and labour input.
3. Harvesting crops or pastures (as hay) may be quite difficult to achieve because of the small areas involved.
4. Yields may be low (resulting in low nutrient removal rates) because of the low rainfall in the region.
5. Nutrients are not deposited evenly (highest concentration closest to the sheds) meaning crop yields may be variable.
6. Many existing free range areas would not be suitable for cropping or hay production because of the location of infrastructure and soil suitability.

Moveable shelters

Moveable shelters often work best with smaller flock sizes. The advantage is that by moving the sheds, nutrients can be spread over a larger area. This type of operation will generally increase the amount of labour required, as tasks such as egg collection must be done by hand. There is still a need to investigate feasible options for moving sheds on larger farms. It may be possible to have 'semi-permanent' sheds that are in place for 1-2 years, however the cost of this arrangement is not known.

Ideally moveable sheds would be located on irrigable land so that maximum crop yields and nutrient uptake could be achieved after the birds are moved from an area.

4.2 Reducing the Risk of Nutrient Loss Off-Site

Even with careful management, there can be a risk of nutrient loss from free range areas. Particularly for farms where re-use of nutrients for crop production is unfeasible, it may be more appropriate to limit losses and accept high nutrient loading on small areas. This approach is taken for other intensive industries such as beef feedlots, where the very high levels of nutrients deposited in the pens are managed to minimise environmental impacts. This is done by controlling leaching and runoff from the site. At smaller feedlots (typically less than 1000 standard cattle units) an appropriate option is to allow runoff to be dispersed across cropping land, where it will seep into the soil and be utilised by crops or pastures. It may be possible to adapt similar approaches (on a much smaller scale) to limit nutrient loss on free range egg farms. This project identified high levels of nutrients close to the sheds (within 10-20m in most cases). These nutrients may be managed by:

- Restricting runoff from entering the site with bunding,
- Directing runoff from the area to a vegetated filter strip,
- Containing leaching (though construction of a compacted pad), and
- Harvesting manure from the area on an annual / biannual basis.

This type of approach may be suited to larger flocks, where the housing sheds are permanently located and stocking densities are high.

Runoff control could be achieved through using earthworks to divert runoff from entering the site, and to drain runoff from the site into a vegetated filter area (VFA). A VFA is simply a vegetated area that is used to capture nutrients with runoff before they enter a waterway. These could be created relatively easily depending on the site, and would need to be permanently fenced to restrict access from the hens or other livestock. It may be possible to lightly graze the vegetative filter strip with other livestock (i.e. cattle) 2-3 times per year, provided groundcover is maintained.

Leaching is particularly concerning in areas with very high nitrogen applications with manure. This could be avoided by compacting or concreting an area around the poultry shed (for 10-20m). This would also enable manure to be collected more easily. Compacting will increase runoff and should therefore be done in conjunction with construction of a VFA.

Manure harvesting could be done on a bi-annual basis using a loader or bobcat to scrape the area. Another option may be to use a sweep attachment similar to those used for street sweeping. This will be important for compacted or concreted pads, because the manure will be highly subject to erosion after heavy rainfall. Likewise a vegetative filter strip will be required to contain nutrients in runoff.

It is important to note that for smaller free range egg farms, the area of high nutrient loading would be comparable to a horse stable or set of cattle yards on a grazing property. These operations are likely to result in similar nutrient accumulation.

Considering the cost of constructing such infrastructure, it would be advisable to conduct more detailed research to allow precise design criteria to be established. For example, the exact distance from the shed that should be compacted and bunded cannot be established from this project alone, though general trends appear evident. Likewise, the size of the VFA will be contingent on the area of water captured on the area annually and the annual nutrient loading from the hens. There is a lack of knowledge relating to nutrient deposition from the hens at this stage, making such estimations difficult without further research.

4.3 Management of Manure Handling and Application

Free range and caged egg farmers remove manure from sheds to be sold or used as a fertiliser on-farm. On several farms, the management of manure stockpiles was leading to elevated nutrient levels in small areas near the sheds or on fields where manure was to be used.

Manure storage arrangements could be improved by keeping manure within the controlled drainage area near to the sheds (as described above), or by constructing specific areas for storage. These areas will require a compacted pad (to limit leaching) and controlled drainage (bunding and a small VFA).

On some farms, high rates of manure were being applied to rectify a long decline in soil fertility as a result of grain cropping. This was found to be sustainable on most paddocks surveyed, however these application rates may rapidly build soil fertility and possibly result in excessive nutrient loads. Soil testing and nutrient budgeting advice is required to avoid these problems.

5 PARTICIPANT WORKSHOP

Following the nutrient surveying and generation of mapping, a workshop was held with the farmers to discuss the findings of the project and investigate ways to improve nutrient management. The workshop was held in Toowoomba on the 12th February, 2010 and was hosted by the Queensland Egg Farmers Association.

At the workshop, a presentation was given to provide an overview of the project including sections on nutrient management, the use of EM technology and presentation of selected case study farms to demonstrate the project findings.

Following presentation of these results, a workshop session was held to discuss options for improving nutrient management on egg farms. This workshop focussed on free range egg farms, as this management system resulted in the highest degree of risk from potential loss of nutrients. Several important points were made during this discussion, and these are outlined as follows:

Egg farms tend to be located in low risk areas. On review of the farms surveyed, it was observed that the majority of free range farms are located in dry land cereal cropping or grazing regions at a considerable distance from the nearest waterway. This means that a large natural buffer is present between most farms and sensitive receptors such as creeks or rivers.

Many farmers have trialled methods to improve nutrient management. Some of these include:

- Rotational grazing of free range areas to decrease stocking rate,
- cropping of free range areas to improve nutrient utilisation,
- using moveable houses to rotationally graze larger areas of land,
- gravelling areas close to the free range sheds (which will decrease nutrient leaching),
- using portable shade structures (which may help to concentrate manure deposition into manageable areas), and
- scraping the area immediately surrounding the sheds to reduce manure build-up.

These approaches generally require greater management and labour inputs from farmers, and in some cases require capital investment. While many farmers had trialled such options, they had often been abandoned because of the higher labour requirements. It was also recognised that farmers couldn't tell if their extra effort was really improving environmental management. This reduced the incentive to maintain practice changes.

It was also identified that some nutrient mitigation options are not suitable for egg farms. During the workshop examples of nutrient management options from other industries such as the feedlot sector were given. One of these options was to capture runoff from nutrient accumulation zones in a storage dam, from which it could be irrigated onto nearby land. This was ruled out as an option for egg farms because of the biosecurity risk that is caused by open water sources and the wild waterfowl that they attract.

Two farmers suggested assessing some of the management practices that they are already doing to show if they would result in better environmental outcomes over time. This would help encourage further practice change in the industry and provide incentive to maintain these practices.

One farmer mentioned that they are about to construct a new, movable duck shed that could be used for a trial site.

It was generally observed that improvements were not made because of the costs involved for additional labour or infrastructure. However, all farmers could clearly see the issues identified by the nutrient surveys and mentioned that for new developments there were many improvements that could be made.

6 CONCLUSIONS AND RECOMMENDATIONS

The project successfully benchmarked nutrient levels on egg farms across the catchment. Surveys were conducted on 14 free range farms (focussing on the free range area) and 7 manure application paddocks (mainly on caged egg farms where manure is used for crop production). Additionally, the area surrounding two older style caged egg farms were surveyed to identify whether these systems also contributed to elevated nutrient levels near the sheds.

6.1 Free Range Nutrient Loading

Results from soil testing across the free range farms showed that in general nutrient levels were high for nitrate (measured as nitrate-N) and phosphorus (Colwell P). Levels tended to be higher than those recommended for manure reuse areas in other industries (i.e. Skerman 2000). Nutrient distribution in free range areas showed a fairly consistent pattern of elevated nitrate and phosphorus close to the sheds. Some older farms had very high nutrient levels even at some distance from the sheds (up to 50m) though it was not clear if this was also driven by inherent soil fertility. To improve the rigour of the research, a replicated trial would be required that contained ‘control’ areas that were not part of the range area.

The area of greatly elevated nutrient levels was generally restricted to within about 20m of the sheds on most farms. However, considering the number of soil samples collected and the resolution of the mapping this could not be considered a precise estimate.

There is currently no way of comparing the nutrient mapping to nutrient excretion from the hens, making predictions of nutrient loading difficult. This is largely because detailed research into the deposition of manure nutrients inside and outside of the hen houses has not been completed. Likewise, the mass balance predictive models for manure excretion which are highly developed for other species such as pigs are not available for hens at the current time.

This information is needed to establish design criteria for controlled drainage and vegetated filter area (VFA) on free range farms.

6.1.1 Recommendations for Free Range Farms

It would be beneficial for the free range industry if an updated guideline were available that set out appropriate design parameters and management practices to improve nutrient management on free range farms. Two research gaps have been identified by this project that need to be addressed in order to inform such a guideline. These are:

- Precise nutrient loading rates for free range areas are not currently known. Research is needed to quantify the level of nutrient excretion from the hens, and the distribution of these nutrients inside / outside of the sheds. This research is fundamental to nutrient management and also other areas of environmental management such as greenhouse gas emission estimation.

- Detailed nutrient distribution data. The current project used a broad scale approach to benchmark performance on a number of farms. These data are not precise enough to inform design criteria for nutrient containment infrastructure. Further research is required to clarify the minimum containment area required for a given stocking density and management system.

It is recommended that Condamine Alliance forward the findings of this research to the egg industry research and development body, Australian Egg Corporation Limited with a view to seeking industry support to address the identified research needs.

6.2 Manure Application areas

EM surveying on manure application areas is very useful for identifying elevated nutrient levels and promoting practice change. Only one paddock in the current project displayed consistently high nutrient levels, however many such areas exist across the catchment. Farmers are rarely willing to make major management changes based on infrequent soil sampling, and EM is seen as a way of giving confidence for such changes.

EM surveying is also useful for determining inherent variability in soil properties that will influence yield and sustainable nutrient usage. This is highly valuable for all farmers who are moving towards a precision agriculture approach to farming.

The project found that most manure application areas investigated had nutrient levels ideal for cropping and not of concern from an environmental perspective. Previous research has shown that on paddocks with differing soil types, split applications of manure would be highly worthwhile and would improve the sustainability of the practice.

Considering this, the EM technology was found to be ideal for benchmarking performance of paddocks spread solely with manure and should be promoted among farmers that utilise large amounts of manure. This would be greatly beneficial for the larger feedlots in the catchment.

The EM surveys identified excessive nutrient ‘hotspots’ in some paddocks where manure had been stored prior to spreading. It is recommended that improved management of manure stockpiling is promoted to farmers.

6.3 Extension and Practice Change

An objective of the project was to help egg farmers to identify areas where improved environmental management was required and to promote practice change. The general interest in the project and the outcomes of the workshop suggest that the project was successful in achieving this goal. The nutrient maps were particularly useful for clearly demonstrating the distribution of nutrient levels.

The workshop identified that while many options were available for improving nutrient management, there were still impediments to practice change. Some of these impediments include:

- The capital or labour costs associated with improved management, and

- Uncertainty of the benefits of improved management.

Some options for improved management have been identified in this report that will cost money to implement. Prior to promoting major management changes, two needs are apparent:

- Guidelines need to be developed to ensure that these management options will mitigate the risks of nutrient losses. This will require research as identified in section 6.1.
- Demonstration of benefits is required to help farmers feel confident their added effort will lead to improved environmental management.

These recommendations could be addressed concurrently or separately. Some practice change options that could be promoted on the basis of this project include:

- Construction of runoff diversion banks around free range areas to divert clean runoff from crossing the site.
- Construction of compacted pads around free range sheds.
- Construction of designated manure storage areas with compacted pads and runoff control.
- EM surveying of manure application areas where high rates of manure have been applied in the past.

Other management options that will improve nutrient management could be demonstrated using EM surveying 'before and after' the management change was implemented. Two workshop attendees mentioned their interest in demonstration works. The specific ideas were:

- Demonstration of frequent manure scraping as a means to reduce the nutrient loading rate close to sheds.
- Demonstration of nutrient loading for newly constructed, small moveable sheds.

These options could be followed up by Condamine Alliance depending on the availability of funding.

7 REFERENCES

Lesch, SM, Rhoades, JD, Corwin, DL 2000, *ESAP-95 Version 2.01R, User Manual and Tutorial Guide*, Research Report No. 146, United States Department of Agriculture, Agricultural Research Service, George E. Brown, Jr., Salinity Laboratory, California.

Skerman, A 2000, *Reference manual for the establishment and operation of beef cattle feedlots in Queensland*, Information Series QI99070, Queensland Cattle Feedlot Advisory Committee (FLAC), Department of Primary Industries, Queensland.

Wiedemann SG, Watts PJ, Galloway JL & Nielsen, WM 2008a, Application of EM Soil Surveying for Mapping Nutrients in Effluent Reuse Areas, FSA Consulting Report 6963/1, Toowoomba, Qld.

Wiedemann, SG, McGahan, EJ & Burger, M 2008b, Layer Hen Manure Analysis Report, Australian Egg Corporation Limited, Sydney Australia.

Wiedemann, SG 2009, Improving Manure Reuse in Intensive Livestock Industries Using Electro-Magnetic Induction Technology – Free Range Poultry Case Study Report, FSA Consulting report number 7080/4, Condamine Alliance, Toowoomba, QLD.