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Through the grass ceiling: using multiple data sources on intra-field variability to reset expectations of pasture production and farm profitability

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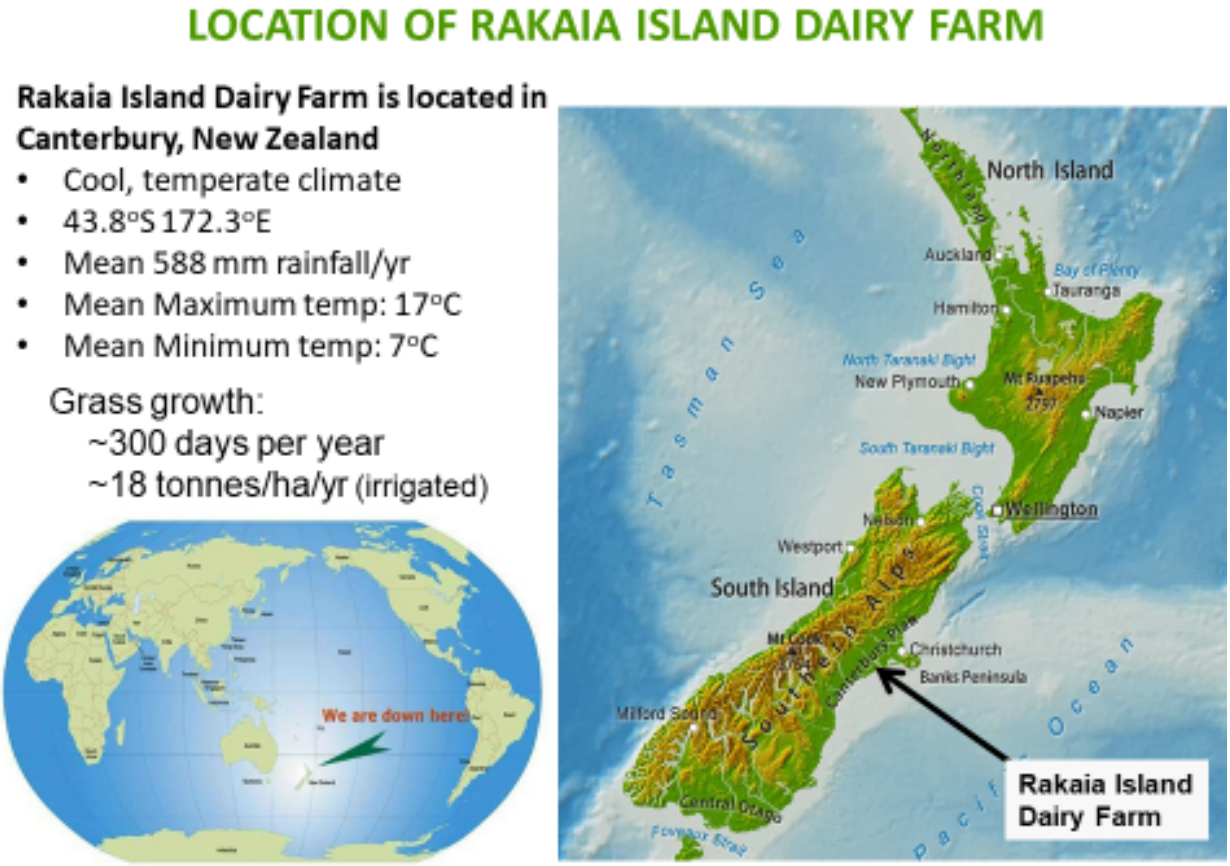
Abstract. Intra-field variability has received much attention in arable and horticultural contexts. It has resulted in increased profitability as well as reduced environmental footprint. However, in a pastoral context, the value of understanding intra-field variability has not been widely appreciated. In this programme, we used available technologies to develop multiple data layers on multiple fields within a dairy farm. This farm was selected as it was already performing at a high level, with well-developed existing infrastructure and high production metrics. All of the fields on this farm were around 4 hectares and had established pastures based on perennial ryegrass/white clover. We developed high resolution data layers on pasture height, soil electroconductivity and soil texture at a pixel size of approximately 4m. Maps of the pasture height of individual fields sampled at the same interval post-grazing (~21 days) were then combined to produce a whole-farm map of relative pasture production. This revealed a strong interaction between irrigation performance, soil bulk density and pasture growth. These patterns had not previously been noted by farm management. In addition, several zones were identified that showed lower relative pasture yield, subsequently demonstrated to be due to high densities of soil-dwelling pasture pests (scarab larvae). As a result of this information, management decisions were made to improve irrigator performance – especially the uniformity of water application – and to address the pest problem by applying a prototype biopesticide. Modelling of the improvements in pasture production that were expected as a result of these decisions predicted an increase in total pasture production to more than 20 t DM/ha/yr (~10%). This exceeds the accepted pasture production expectations for this region and sets a new target for irrigated dairy farms.

Keywords. *Pasture, Dairy Systems, Grazing Management, Irrigation Performance, C-Dax, invertebrate pest.*

Introduction

Intra-field variability has received much attention in arable and horticultural contexts. Measurement and management of intra-field variability has resulted in increased profitability as well as reduced environmental footprint, for example through the use of variable-rate fertilizer or irrigation application (e.g. Robertson et al. 2008). However, in a pastoral context, the value of understanding intra-field variability has not been as widely studied. This project used a co-development innovation system approach (see Turner et al. 2016) to build a detailed understanding of an irrigated pastoral dairy farm system located at Rakaia Island, in Canterbury, New Zealand (Fig. 1). The farm owners, together with researchers and rural service providers collectively examined the performance of this farm to prioritise possible opportunities for improvement. We identified that the key driver of whole-farm performance was the performance of the pasture. Although this farm was already performing well, any increase in the pasture production would likely drive a whole-farm improvement in profitability – providing that it could be achieved in a cost-effective manner.



LOCATION OF RAKAIA ISLAND DAIRY FARM

Rakaia Island Dairy Farm is located in Canterbury, New Zealand

- Cool, temperate climate
- 43.8°S 172.3°E
- Mean 588 mm rainfall/yr
- Mean Maximum temp: 17°C
- Mean Minimum temp: 7°C

Grass growth:
~300 days per year
~18 tonnes/ha/yr (irrigated)

Figure 1. Location and environmental description of trial farm in New Zealand

There are numerous possible approaches to improving pasture production, including introducing improved pasture genetics, optimizing fertilizer and irrigation water application and changing pasture and grazing management. Before decisions could be made on which approach would likely be most effective, baseline information on pasture growth had to be collected. While the farm routinely measured pasture height at paddock scale and was considered to already be very high performing, the decision was made to focus on pasture growth at a much finer scale. Previous work had shown that hyperspectral imagery can estimate pasture *quality* parameters at this scale with some success (e.g. Metabolisable Energy, Crude Protein) but accurate estimation of pasture height has proved elusive with this technique (Yule et al. 2015). A proximal sensor was chosen in this study as it had already been shown to be a useful tool in understanding the drivers of pasture production (Dennis et al. 2015)

In addition, data on some potential drivers of pasture growth would also be measured at within-field scale, including elevation, soil texture and irrigation performance. Once these data were analyzed, priorities for management intervention to improve pasture performance could then be developed. This sub-paddock scale approach, focusing on measurement of pasture height, has only rarely been undertaken in New Zealand pastoral systems before (Dennis et al. 2014) and therefore the potential to drive improvements in whole-farm profitability and environmental performance is unexplored.

Methods

This farm was selected as it was already performing at a high level, with well-developed existing infrastructure and high production metrics: it is 400ha, with 1450 cows, a mix of once a day and twice a day milking herds producing more than 1650 kg MS/ha/yr. All of the fields on this farm were around 5 hectares in size and had established pastures based on perennial ryegrass and white clover (Fig. 2). We developed high resolution data layers on pasture height, soil electromagnetic conductivity and soil bulk density at a pixel size of approximately 4m.

Figure 2. Layout of paddocks on Rakaia Island Dairy Farm

Pasture height

Pasture height was measured with the technique developed by Dennis et al. (2015) using a C-DAX PastureMeter+ tow-behind device (http://www.c-dax.co.nz/index.php?page=shop/flypage&product_id=1000247&parent_cats=8fb6a98cdda3e6ee46d4a736f8efb89d; accessed 14 May 2018). This measures pasture height as the device is towed across the paddock by recording the interruptions to a 'ladder' of infra-red light beams. Pasture biomass may then be then calculated from a set of published calibrations (Rennie et al. 2009). The device is widely used across New Zealand but the data are typically used to estimate the pasture biomass of a whole paddock by averaging all of the readings made in that paddock. However, more recent versions of the device are equipped with GPS and so it is now possible to look at patterns of pasture performance at a much finer scale. We used the device to continuously record along parallel transects approximately 10m apart. These data were then interpolated (a multi-level B-spline using R) to produce a map with a 4m pixel size. Individual paddocks were sampled at the same interval post-grazing (~21 days i.e. immediately prior to the next grazing event) and were then combined to produce a composite whole-farm map of relative pasture production. Maps of intra-field variability taken in summer-autumn on irrigated dairy pastures have previously been shown to adequately represent annual intra-field variability (Dennis et al. 2014; 2015)

Soil electroconductivity and bulk density

An EM38 survey of the farm was performed by a commercial provider (https://www.agrioptics.co.nz/portfolio/em-survey/) along roughly parallel transects approximately 10m apart. Both horizontal and vertical modes were used but the only the horizontal mode data are shown here. In addition, soil samples were taken to 7.5cm depth and analyzed for bulk density. The location of the soil samples was stratified i.e. randomized within zones of similar EM38 readings. The data were then interpolated to produce a map with a 4m pixel size. The resulting EM38 map reflects relative soil water content to a depth of around 75cm, which is also related to soil texture.

Results

Pasture height

Maps of pasture height showed substantial variability within paddocks (Fig. 3). Average values were in line with expectations (~100mm) but the wide range from minimum to maximum (i.e. <20 – 200mm) was not. Moreover, there were clear patterns in the pasture height that suggested irrigation performance was sub-optimal (Fig. 3). Apparent tyre tracks were obvious (and expected) but other circles of compromised pasture growth were also observed. In addition, areas outside the centre-pivot irrigated area that were serviced by an array of smaller, fixed sprinklers indicated areas of high variability and suboptimal production, relative to adjacent areas and to areas under the center-pivot, with substantial variability between the fixed sprinklers too.

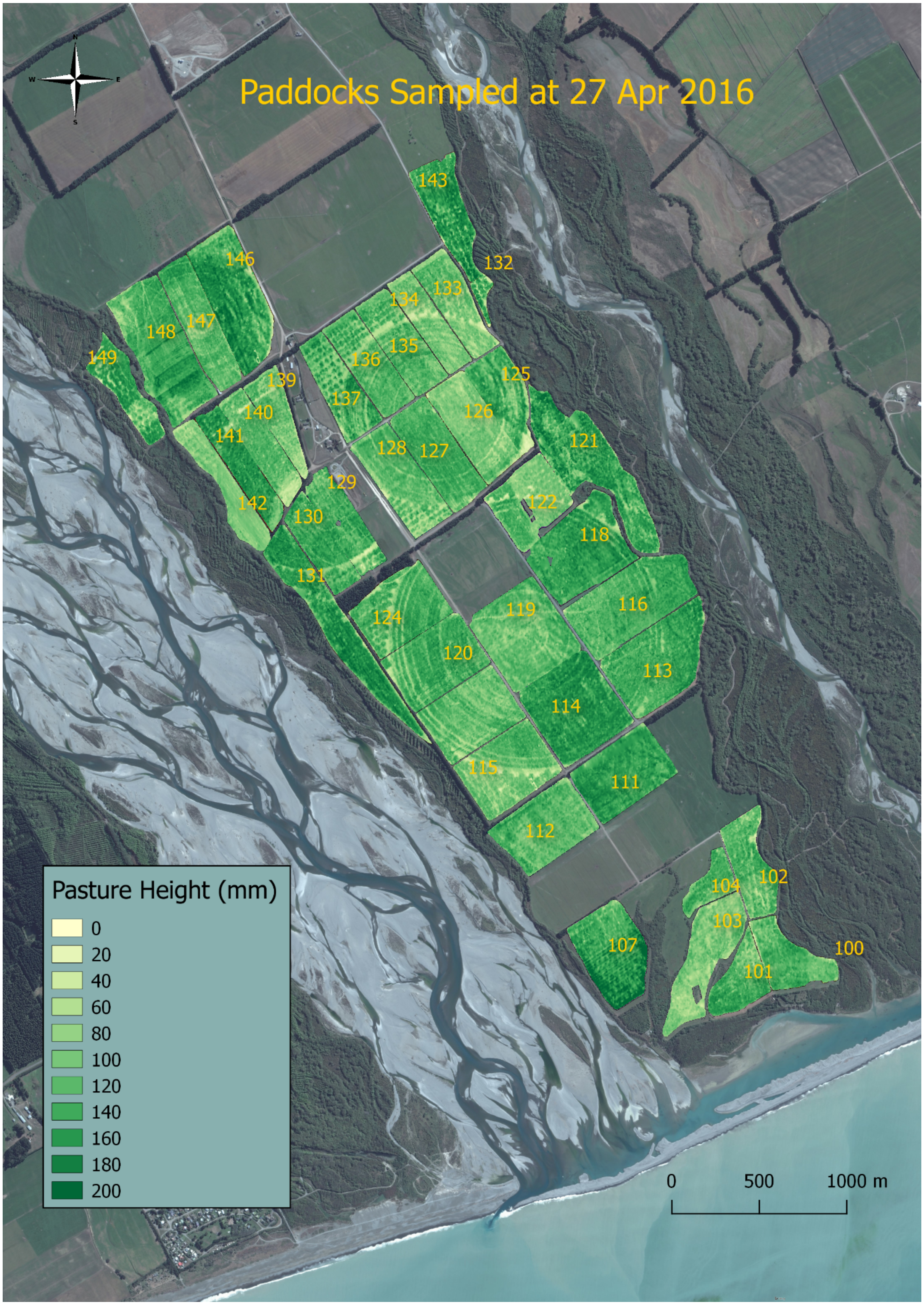


Figure 3. Composite image of paddocks measured at the same time post-grazing (21 days)

Soil electroconductivity

The mapped EM38 values clearly showed the changing soil textures associated with the relatively recent alluvial origin of these soils (Fig. 4). The presence of sub-surface drainage channels was apparent but the impact of this variability on pasture growth was not obvious.

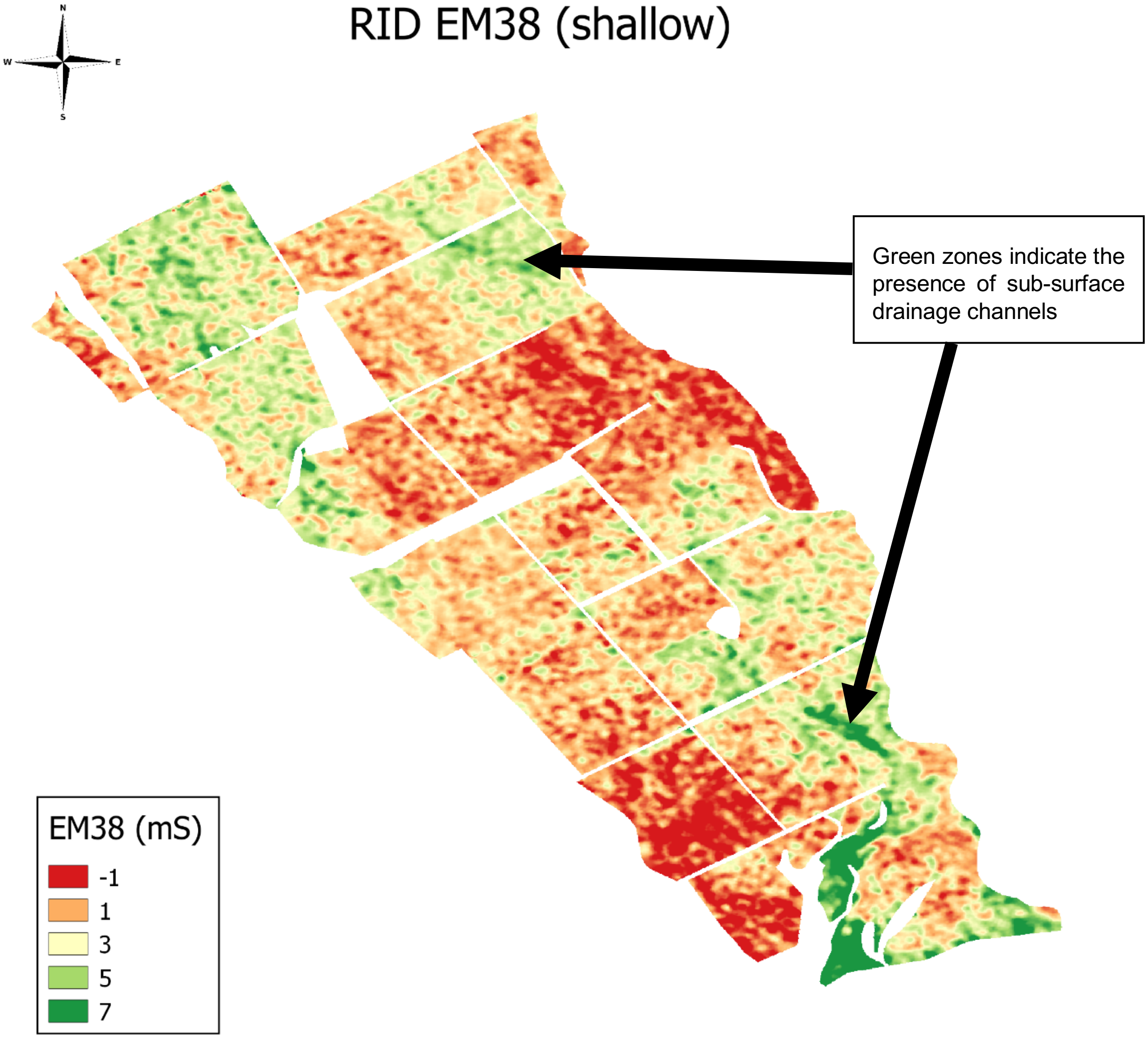


Figure 4. Soil electroconductivity (EM38) interpolated map

Bulk Density

The mapped soil bulk density values also showed the changing soil textures associated with the relatively recent alluvial origin of these soils (Fig. 5). Large areas of the farm had soil bulk densities well below 1.0, indicating light, sandy zones.

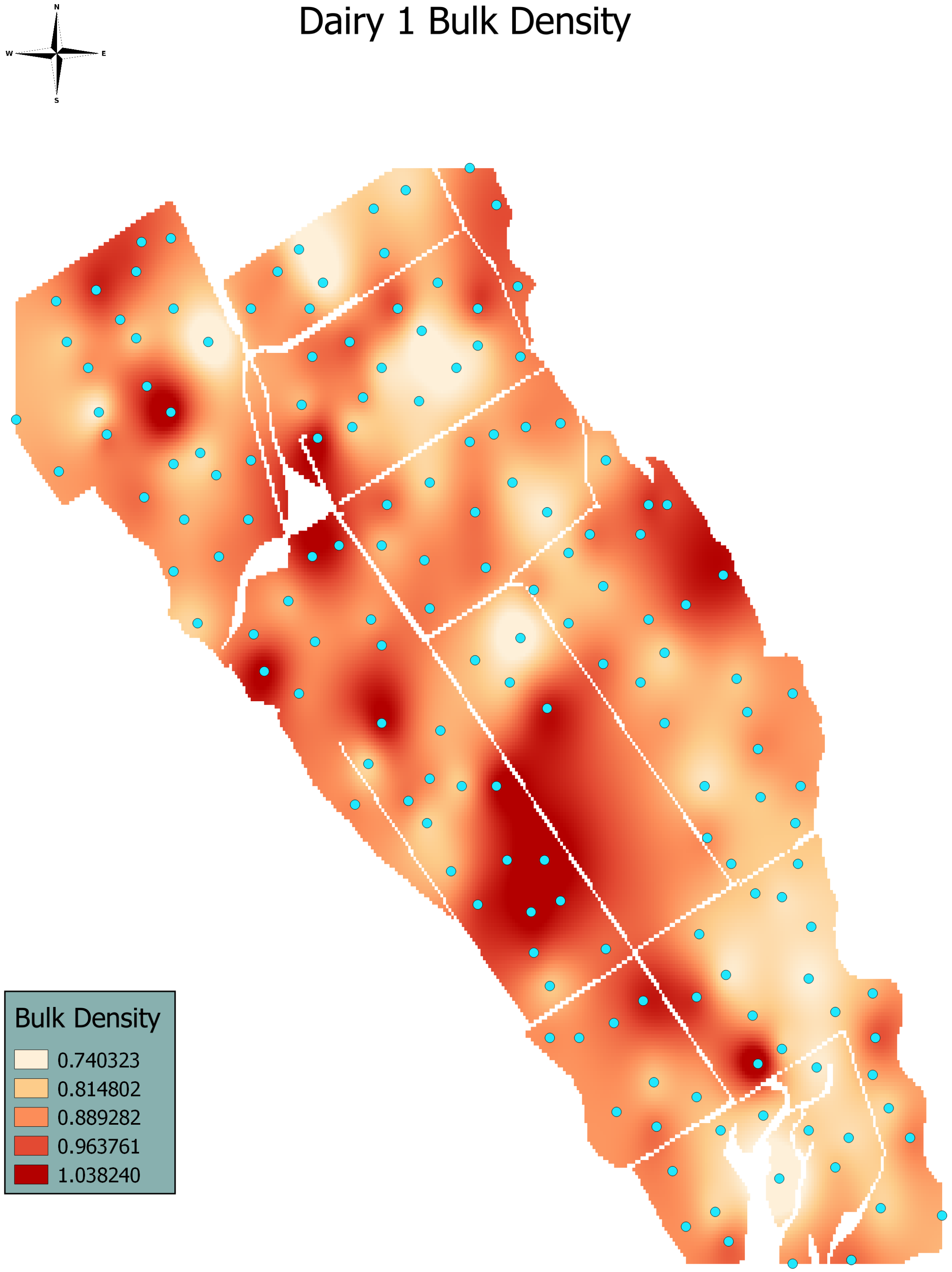


Figure 5. Bulk density of surface soil (to 7.5 cm depth) interpolated map, showing sample locations

Discussion

The co-development process that was used in this project involved regular meetings between the farm owners, researchers, rural professionals and rural service providers. This project team collectively determined the best approach to measure and analyze the key drivers of farm performance. The result was a detailed understanding of pasture performance across the farm, along with knowledge of some of the factors that were important drivers of that performance and agreed identification of the leverage points in the system that were practical and adoptable for the farm managers

As data were collected and analyzed, it became apparent to the project team that the existing irrigation infrastructure – both centre-pivot and fixed sprinkler – was not performing optimally. This is especially critical in these pastures that are established on freely draining, relatively sandy soils. In addition, there were further compromises to pasture growth in an area that had higher pest insect populations associated with it (not shown) and these patterns had not previously been noted by farm management. Modelling of the farm, assuming that these compromises could be effectively addressed, showed that an increase in total annual pasture production of around 10% would be possible. This would raise the potential pasture production of this farm to around 20 tonnes DM/ha/yr – a target hitherto thought unachievable in this area.

The accumulation of the data and knowledge and the process of exploring these in context of the farm business – an innovation systems approach – led to a new understanding for the farm owners. Their concept of production being limited by soil types was self-limiting when they saw the potential already being achieved in the highest performing areas and the opportunities which still exist for improvements in management of the inputs that they can control, i.e. application of water. As the project team has been engaged from the beginning in the entire project, from conceptualization, to selection of measurement methodology, to data analysis and interpretation, there was a high degree of trust in the results by the farm owners. They have subsequently moved quickly to invest in improvements in their irrigation infrastructure and to manage insect-affected areas differently – including the application of a prototype biocontrol agent. The results of these management changes are being monitored to determine if their actual impact is in accordance with the modelled estimated impact. If it performs as expected, this farm will set a new target for irrigated dairy farms in this region.

Conclusion

This project has demonstrated the value that can be generated from understanding patterns of pasture production at sub-paddock scale. It was only by analyzing these patterns that the magnitude of lost production could be determined, at the same time as revealing some of the causes of these losses. The sub-optimal performance of the irrigation infrastructure is concerning and the extent of this problem among the many farmers in this region who use irrigation is currently unknown and demands future study.

In addition, it is important to acknowledge the success of the co-development process used in this project. The close working relationship and trust that built during the project ensured that the farmers were well engaged in the project, had confidence in the findings and implemented management changes quickly. This rapid adoption of changes in response to information derived from more precise data is not always observed but greatly enhanced the value captured from the investment in the project.

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References

Dennis, S.J., Clarke-Hill, W., Taylor, A.L., Dynes, R.A., O'Neill, K. & Jowett, T. (2014) Estimating Spatial Variation in Annual Pasture Yield. In: Proceedings of the 12th International Conference on Precision Agriculture. Sacramento, California, USA: International Society of Precision Agriculture. www. ispag.org

Dennis, S.J., Taylor, A.L., O'Neill, K., Clarke-Hill, W., Dynes, R.A., Cox, N., Van Koten, C. & Jowett, T.W.D. (2015) Pasture yield mapping: why & how. *Journal of New Zealand Grasslands*, 77, 41-46.

Rennie, G.M., King, W.McG., Puha, M.R., Dalley, D.E., Dynes, R.A. & Upsdell, M.P. (2009) Calibration of the C-DAX Rapid Pasturemeter and the rising plate meter for kikuyu-based Northland dairy pastures. *Proceedings of the New Zealand Grassland Association*, 71, 49-55.

Robertson, M.J., Lyle, G. & Bowden, J.W. (2007). Within-field variability of wheat yield and economic implications for spatially-variable nutrient management. *Australian Journal of Agricultural Research*, 56, 553-561.

Turner, J.A., Rijswijk, K., Williams, T. & Barnard, T. (2016), Challenges to Effective Interaction in the New Zealand Agricultural Research and Extension System: An Innovation Systems Analysis, vol. 13, no. 1, Autumn 2016, pp. 35-47, Surry Hills, Australia

Yule, I., Pullanagari, R., Irwin, M., McVeagh, P., Kereszturi, G., White, M. & Manning, M. (2015) Mapping nutrient concentration in pasture using hyperspectral imaging. *Journal of New Zealand Grasslands*, 77, 47-50.