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DEVELOPING AN APP TO ESTIMATE PASTURE FERTILISER APPLICATION ON DAIRY FARMS

Estimating fertiliser application has always been one the main issues on-farm. Optimum fertiliser application depends on many factors, which makes it a time-consuming and expensive process. This article discusses a Lincoln University project that aims to estimate real-time nitrogen application with minimum field sampling and cost.

Managing nitrogen flow

New Zealand is a world leader in pasture-based dairy production, with its associated advantages and challenges. Due to environmental concerns, economic constraints and farm system efficiency expectations, managing nitrogen flow on dairy farms is critically important. Leaching of nitrate-nitrogen (NO_3^--N) is politically the most significant challenge facing the future viability (environmental and possibly economic) of grazed dairy farms. Also, imported nitrogen fertiliser costs New Zealand farmers around USD400 million per year. Dairy farmers in this country use around 63% of the total nitrogen fertiliser, which is about 271,000 tonnes.

Low cost app for farmers

There are a few apps in the market that estimate nitrogen application, but some of them are not accurate or they need farm sampling or lab results. The main objective of a recently developed app at Lincoln University is to estimate nitrogen application with minimum cost and farm sampling to reduce costs and environmental impacts. Using thermal images and artificial neural network modelling together can make a powerful tool to estimate nitrogen application in different conditions on-farm.

After conducting greenhouse and field studies over the last five years, an artificial neural network (ANN) model was developed to estimate the pasture nitrogen

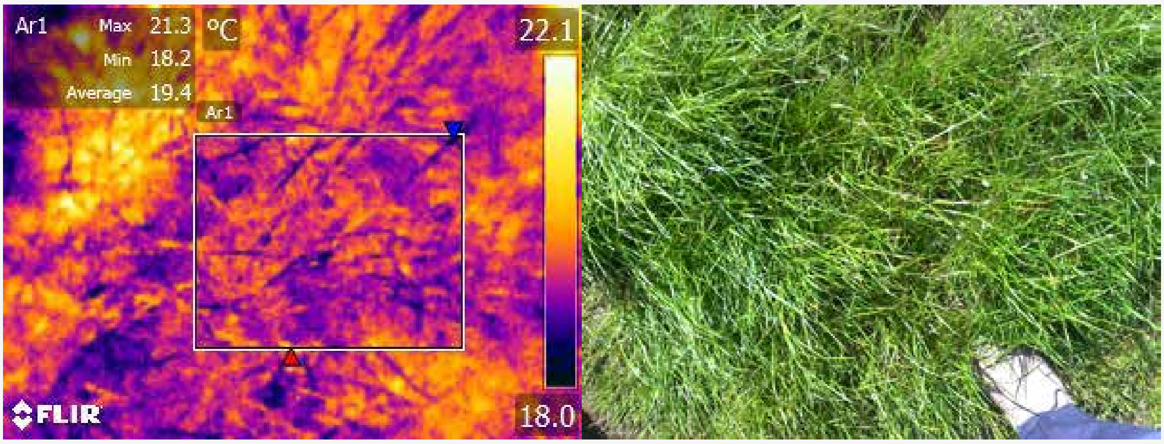

Figure 1: Thermal and digital photos of a spot

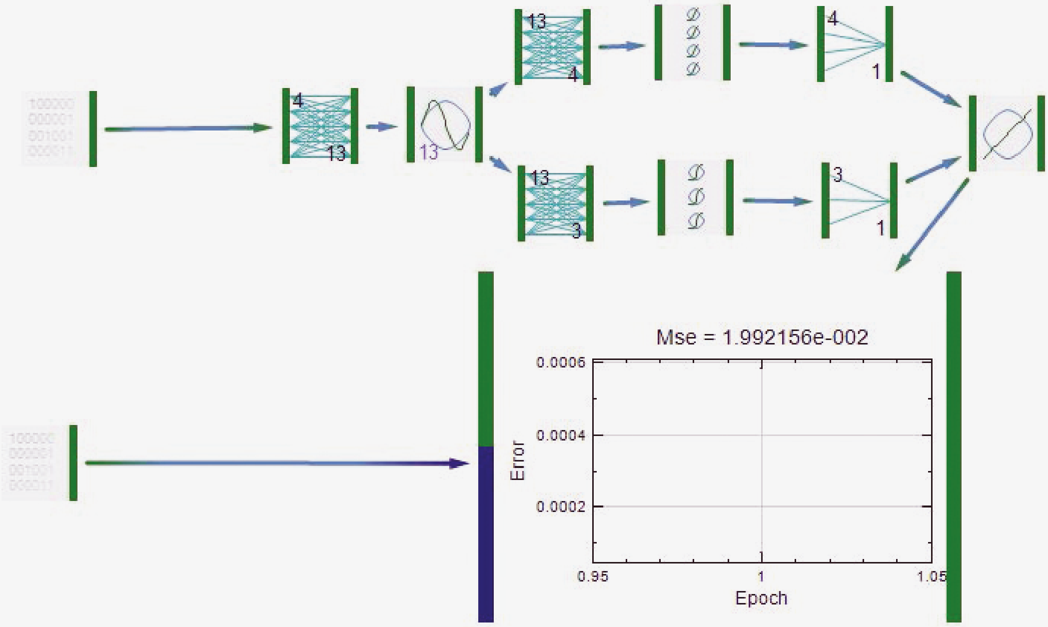

Figure 2: Structure of the ANN model

content using environmental factors and thermal imaging. The model has been designed to inform the fertiliser application of nitrogen, depending on a pasture's real-time temperature and other environmental parameters. The sensibility analysis shows plant temperature is the main independent variable in the developed ANN model.

The proposed app's ultimate purpose is to give farmers an accurate estimate of the optimum nitrogen application rate for their pasture. Farmers will choose a pasture area they want to apply fertiliser on in the dashboard app on their computer or mobile phones. The ANN model will estimate the nitrogen content of the selected pasture area using thermal images by Landsat8, with the final step being to recommend an optimum nitrogen application rate to the farmer. The current prototype uses Landsat8 thermal images with a resolution of 30 m x 30 m. For a 2 ha paddock, it is possible to take at least 23 thermal images. Existing apps can provide air temperature and LUX (solar illumination), but farmers should only need to measure soil moisture.

Development of app

An on-farm field study was developed to estimate the degree of correlation between leaf nitrogen content and the sward surface temperature of perennial ryegrass pasture (*Lolium perenne*) in 2017. A field experiment was also conducted to monitor different environmental factors and measure their sensitivities in the final model. A thermal imaging camera was used for periodic monitoring of the herbage surface temperatures (with a range between 7.5 and 13 µm). Simultaneously, some environmental parameters (including humidity, soil temperature, light intensity and air temperature) were measured in conjunction with herbage cuts to determine the dry matter (DM) yield and herbage nitrogen content (% of DM). The thermal images were investigated to find the

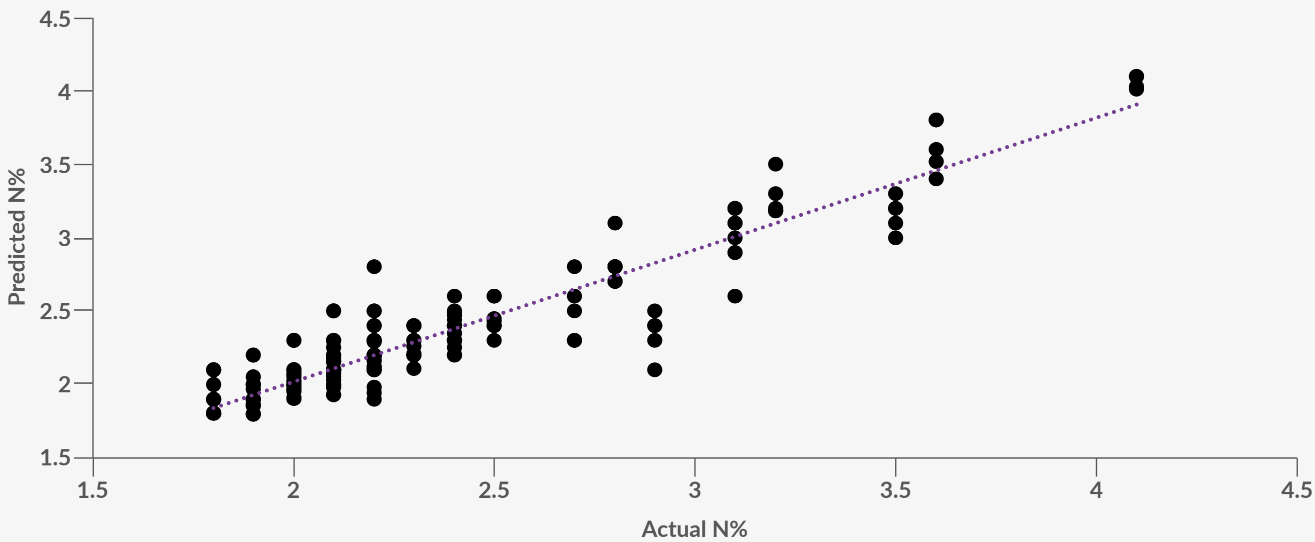

Figure 3: Relationships between actual and predicted pasture nitrogen content (% N) using the artificial neural networks model

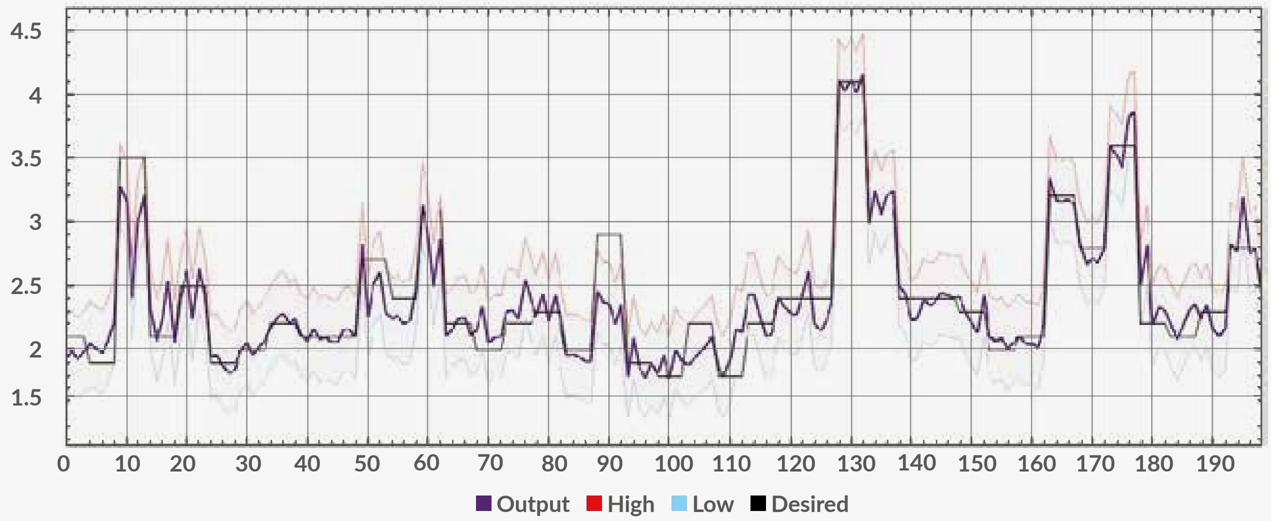

Figure 4: Predicted and actual data on the ANN model

average temperature of the grass leaves *(Figure 1)*.

After testing combinations of the different input variables in the various model structures, four inputs were selected: herbage surface temperature, soil moisture, illumination (LUX) and air temperature. Several model structures and transfer functions were investigated carefully to find a model with a minimum mean square error. These sub-tasks are trained independently using a different dataset from the input samples and their data outputs are summed in the last layer *(Figure 2)*.

The final ANN model reached the finest outcome with a scaled MSE= 1.99\ E-2 (inputs and outputs were scaled between -1 and +1 for the neural networks model). The root mean square errors (RMSE) of the final model were estimated to be 0.12 % N, which was the lowest RMSE between several models examined in this study. *Figure 3* shows the pasture nitrogen content estimated by the model accounted for 94% of the actual variability.

Figure 4 shows the final model estimated pasture nitrogen content (% N) using an error margin of ±0.32% N. To investigate the capability of the ANN model some data samples had been selected randomly as validation data. A comparison of the training and validation data revealed that the links between predicted and actual pasture nitrogen content in both the training and validation data were similar. However, it was recommended to investigate other input variables under different site conditions to minimise the error margin.

Several uncontrolled factors could change the final results, but the results of this study show that an ANN model can estimate pasture nitrogen content (%N) with an acceptably low error. These results could be used to develop a robotic platform to apply variable nitrogen applications based on pasture nitrogen content.

The sensitivity of the output to changes in each independent variable (sensitivity analysis) is estimated by the Peltarion Synapse software. As shown in ***Figure 5***, a sensitivity study of the final model showed that plant temperature (77%) is the most important factor contributing to the output, which was followed by air temperature (14%), LUX (6%) and soil moisture (2%). The sensitivity analysis shows the importance of thermal images to estimate the nitrogen content in pasture.

Suitability for farming conditions

The main challenge of the suggested app is accurate data collection under farming conditions. The sensitivity analysis shows plant temperature is the most significant input variable in the developed ANN model. We hope the satellite images can help us to collect plant temperatures. As already mentioned, existing apps in the market can provide air temperature and LUX, but farmers should only need to measure soil moisture.

As the first step, a UAV thermal image investigated the developed ANN model and the results show the model is capable of estimating the nitrogen content in a pasture ***(Figure 6)***. The UAV thermal images can recognise the areas with a high concentration of urine patches, which can help farmers to manage nitrogen application. However, due to technical and financial limitations we started to focus on satellite thermal images.

The basic prototype based on thermal satellite images was developed during the New Zealand Aerospace challenge. The nitrogen content of physical samples in a few paddocks of the Lincoln University Dairy Farm was compared with the output of the developed prototype, which showed the results are very similar ***(Figures 7 and 8)***. However, the prototype made it easier, faster and cheaper.

The thermal images were collected from Landsat 8 with a resolution of 30 m. If we can access thermal images from satellites with higher resolution, it would be possible to improve the accuracy of nitrogen application recommendations by having a better estimation of pasture nitrogen content of a farm paddock area. Most input variables required for our model and proposed app are either freely or inexpensively available, so the app operation would not be expensive for an end-user – the farmer. The satellite is passing New Zealand almost every week, so farmers can access the data and estimate optimum nitrogen fertiliser application weekly.

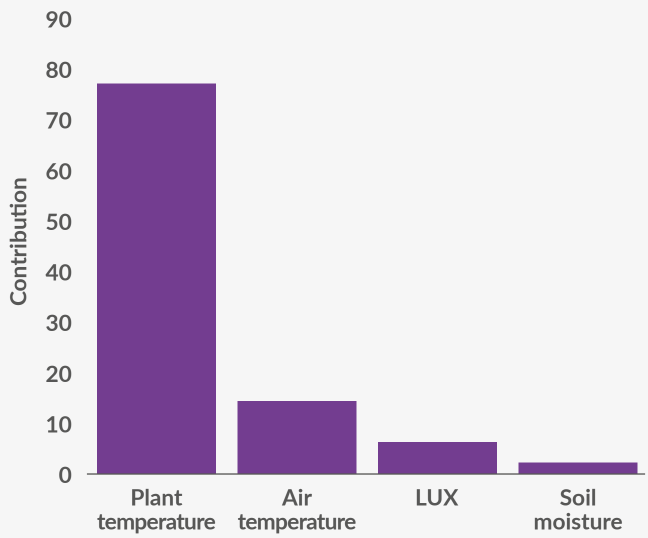

Figure 5: Contribution of different variables to the output of the ANN model app development

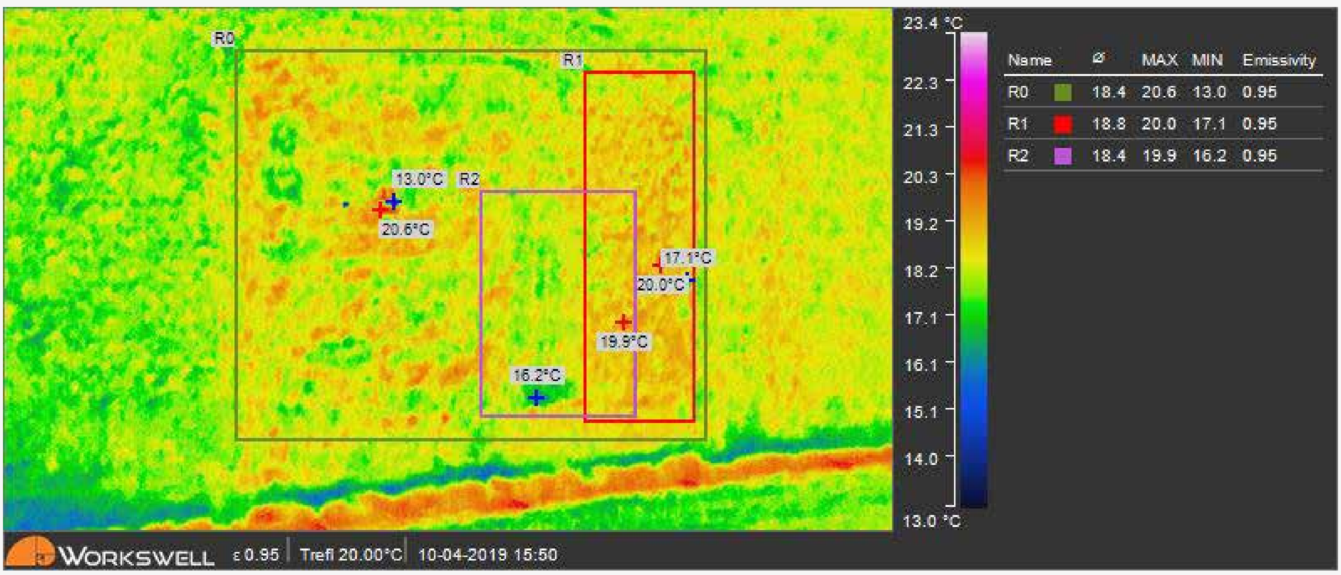

Figure 6: Thermal images from UAV

Projected plan

We hope to improve the app estimating the nitrogen content of perennial ryegrass pasture (*Lolium perenne*) based on the plant's temperatures and different environmental parameters. Based on estimated nitrogen content in the pasture and a few other parameters, we are confident it is possible to develop a professional app to estimate the optimum fertiliser application on dairy farms.

The app can be used by smartphones, laptops, tablets and desktops. It needs more investigation in different regions of New Zealand and the dashboard needs to be developed based on farmers' requirements. If the funds can be found it will be possible for dairy farmers to estimate optimum nitrogen application in a few minutes and almost for free. Also, a similar model could be developed to estimate nitrogen applications for other farm products.

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Figure 7: Thermal images by Landsat8 and the selected paddock in the prototype, which was investigated in this study to develop the prototype and validate the ANN model

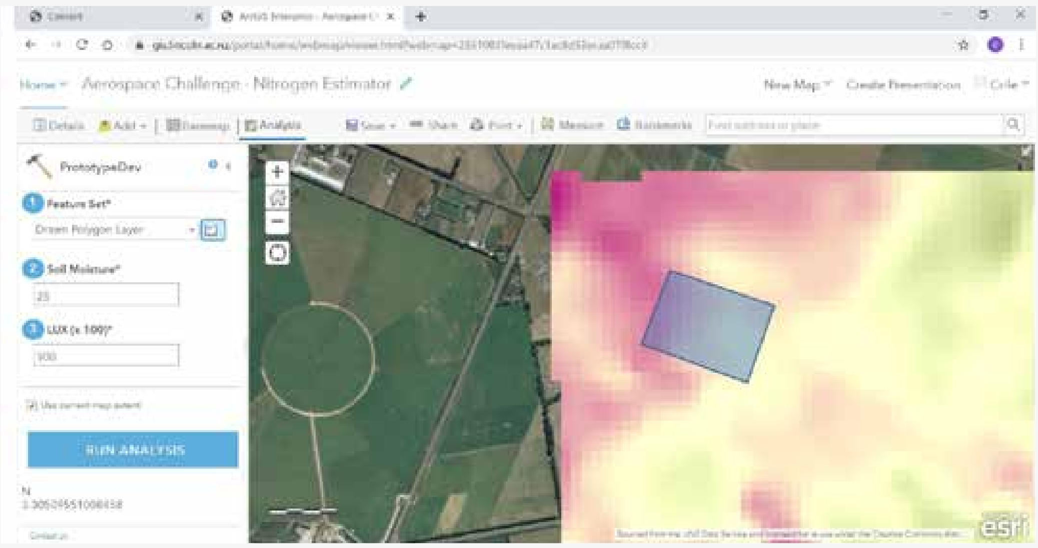

Figure 8: The prototype developed to estimate %N