LEAP – optimising whole farm lime application as a use case to demonstrate the benefits of farm data sharing

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Abstract

Collecting and exchanging farm data in a trusted environment is a major challenge for farmers to make data-driven decisions. To incentivise sharing data off the farm, we created an API-based decision support tool for whole farm liming that provides security, privacy and trust. Data sharing agreements are used to ensure that all data is safely and securely handled and not shared with unintended parties. Secure data transfers are initiated by the farmers through Department of Primary Industries and Regional Developments (DPIRD's) data exchange platform, Extrata, for use in the tool with reports and data returning via Extrata. The tool uses Monte Carlo simulations to generate several possible outcomes accounting for grain yield and farm-gate price changes while being specific to a farm's data. The results provide the whole farm's responses to different liming strategies with comparisons highlighting the best and worst cases, and most likely outcomes of each liming strategy. The results show different financial outcomes and allow the farmer to pick the best one for their situation.

Keywords

Data sharing, Lime, Modelling, Monte Carlo, Data systems, Extrata, API

Introduction

Making timely and complex decisions in the challenging Western Australian farming environment is critical for the long-term viability of the multi-billion-dollar broadacre grains sector. Digital technologies can support farmers to make data-informed decisions that can improve the quality and quantity of their production, and precision placement of inputs. The purpose of this project was to demonstrate the value of sharing farm data with researchers to develop digital technologies and co-designed analysis and visualisations. With advancements in data generating and collection techniques, there are more data flowing through the sector every year. To make that data useful, researchers and technology providers increasingly require farmers to make an enormous sacrifice: control of their data, and in some cases, risking losing their privacy. This is a challenging situation to put farmers through (Simone et al., 2021; Sykuta, 2016) and is clearly recognised by the National Farmers Federation Farm Data Code of Australia (https://nff.org.au/programs/australian-farm-data-code/). Realisation of the potential benefits of data sharing can only be achieved through developing trust between researchers and farm businesses, enabling a willingness to share their data. To help address these concerns, we created a data exchange layer and first application programming interface (API) for DPIRD's Extrata data sharing platform. This is a platform where service providers can extract farmer's data to build data-driven advice and products offering valuable services back to farmers. Lime application was selected as the use case for the Extrata platform, demonstrating the value of sharing data sharing data off farm records. An API-based decision support tool, named LEAP, was created for optimising whole-farm lime application aimed at providing security, privacy and trust. The API has been developed to feed into established farm management platforms to improve data ingestion and visualisation. This new tool reimagines DPIRD and GRDC's popular iLime app based on the Optlime model (Gazey, 2008) as an API rather than a mobile app allowing it to be programmatically called rather than using manual input methods on a mobile device. Furthermore, LEAP builds on the iLime app by optimising lime application across the whole farm, rather than considering individual paddocks. Data sharing agreements were used to ensure that all data is safely and securely handled, used only for the intended purpose and not shared with unintended parties. This project aims to showcase the value of digitising farm records and sharing data by helping growers make informed decisions using their own data to produce customised lime management advice.

Method

We developed the LEAP modelling framework that ingests farm management records and uses an API implementation of iLime. But rather than providing the cashflow and soil pH information for a single strategy in a single paddock as in the iLime app, our implementation uses cloud computing resources to run millions of possible scenarios in a Monte Carlo simulation using the whole farm's data to provide customised liming recommendations for all paddocks on the farm at once. Comparisons highlight the best- and worst-case scenarios and the most likely outcomes of each liming strategy. LEAP is written in the Julia programming language, consisting of tools to automatically source and manipulate data, run a modelling pipeline and report on generated outputs. Briefly, the steps taken by LEAP are i) source data via APIs; ii) manipulate the input dataset into the required format, creating combinations of variables needed in the modelling pipeline, iii) run several iterations of the model by also making use of API calls, iv) combine outputs of all iterations into a dataset and v) send results/outputs back to data originator via API. As part of the work, LEAP was implemented around providing whole farm liming recommendations by taking advantage of the existing iLime app. To achieve that, LEAP i) securely sources data using DPIRD's Extrata Data Exchange Platform API, ii) uses a set of internal tools to prepare the data in the required format that the liming model expects while also creating a range of combinations with the input parameters, iii) runs a set of eight liming scenarios by default, but more or less can be requested, for each unique combination using a Monte Carlo approach and custom API implementation of the iLime model that has been placed into a deployable Docker container, iv) generates a final dataset by combining all of the outputs from each iteration and liming scenario, and v) sends the output dataset via the Extrata Platform API back to the DPIRD's Extrata Platform and then to the grower/farm management platform. The Optlime model which is the base of the iLime app is explained in detail by Gazey et al., 2008. In summary, LEAP is designed to offer a robust solution for automating data sourcing, processing, and modelling with the objective to streamline the entire process from data acquisition to result dissemination, ensuring timely and suitable recommendations for farm management.

Data requirements

Geolocation including, climate, crop and soil data

The iLime model in the LEAP framework requires geolocation of the farm (latitude and longitude), rainfall zone that is automatically sourced in LEAP using the farm's geolocation, and per paddock/sub paddocks in farm, cropping sequence for the last one (1) to five (5) years, yields for each year/paddock/crop, soil physical qualities from 0-10cm, 10-20cm and 20-30cm including: texture, initial pH. If the user is able to provide the following optional data to the LEAP model, the liming recommendations that they receive will be more tailored to their paddocks/sub paddocks: soil physical qualities from 0-10cm, 10-20cm and 20-30cm including: gravel (%), organic C (%), exchangeable Aluminium class, baseline liming strategy (Lime type, Lime source, placement strategy, incorporation method, sequence, and application costs), farm gate price for grain, sheep, and wool, fertiliser usage for the last three to five years, kg/ha applied, and N (the compound + %N). Default values are used for the optional fields that are not provided by the user.

Grain Price and lime values data

If grain price data were not supplied by the farmer, we estimated values using annual port price data from Grain & Graze 3.0 by converting them to farm gate price estimates using calculations to account for i) a grower receival fee (dollars per tonne) per crop, ii) an end point royalty fee (dollars per tonne) per crop, iii) the BAM Act (Biosecurity and Agriculture Management Act) levy (percent of sale value), iv) a GRDC levy (1.02%) and a geospatial data set from the CBH Group that had drop-off locations. The iLime API also requires some parameters to create a custom liming agent, with some liming agent templates from the iLime mobile app saved in the iLime API. Growers can directly specify the optional parameters, or we can work out the optional parameters by using the grower's location against the closest lime pit to determine the transportation distance and an appropriate freight rate, then DPIRD soil scientists best estimates for the purchase, spreading and incorporation costs.

Data modelling pipeline testing

We used a dummy dataset with dummy coordinates placing farms across Western Australia to test run modelling pipeline (Figure 1). This paper presents the liming optimisation simulation results using LEAP from this test. The dataset included the required soils information and three years crop rotation data from four farms, which include~~s~~ four paddocks with different crop rotations (Table~~,~~ 1). The report generated from these data consist of the results from the seven default liming strategies that are provided by the iLime app and a no lime application strategy as a baseline benchmark. The 7 liming strategies are as follow:

1 tonne of lime applied every 10 years, starting at year 1 of the simulation
1 tonne of lime applied every 7 years, starting at year 1 of the simulation
2 tonnes of lime applied every 10 years, starting at year 1 of the simulation
4 tonnes of lime applied in year 1
5 tonnes of lime applied at different points during the simulation. In year 1 there are 2 tonnes of lime applied, following by 2 more tonnes in year 6, followed by 1 final tonne in year 15.
4 tonnes of lime applied in year 1 and incorporated to the 20cm soil depth
4 tonnes of lime applied in year 1 and incorporated to the 20cm soil depth. Additionally, 1tonne of lime is applied in year 10 that is not incorporated to the 20cm soil depth nor the 30cm soil depth.

The results presented here are the product of Monte Carlo methods where repeated random sampling was used to obtain several likely values that may occur from the application of lime to each of the paddocks in this report. These values have been summarised to show the most likely values, otherwise known as the mode. In total 174,960 simulations (possible outcomes from liming) for seven liming strategies, including the no lime application as a baseline benchmark. There were 8,748 simulations for each year of a twenty-year run of an individual strategy.

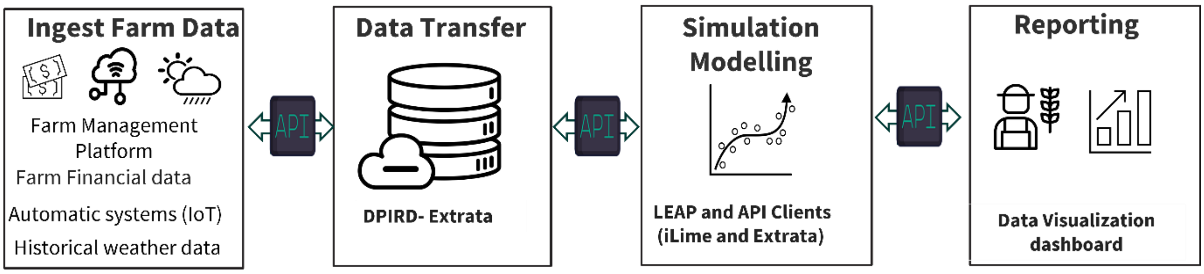

Figure1 Diagram representing the data processing pipeline.

Table1 Description of farm, paddock and crop rotation data used in the simulation

Farm	Paddock	Crop Rotation
Farm1	Paddock1	Barley, Wheat, Barley
Farm2	Paddock2	Barley, Faba Bean, Barley
Farm3	Paddock3	Barley, Wheat, Barley
Farm4	Paddock4	Barley, Barley, Barley

Results and Discussion

Lime optimization simulation output results include dynamics of annual cashflow, cumulative cashflow, yield per year, soil pH in each soil layers and soil exchangeable aluminium for 20 years after start of simulation year. In this paper we are presenting only results from cumulative cashflow and soil pH under various liming strategies. The simulation results from our dataset showed that Paddock ~~2~~ Paddock2 in Farm Farm2 ~~2~~ had the highest final cumulative cashflow in year 20 of 20 for liming strategy of 4 t incorporated to 20 cm value of $935.0 per hectare (Figure 2) and it also had the greatest average annual cashflow with an annual average cashflow of $132.73 per hectare for a liming strategy of 4 t Incorporated to 20 cm. The Paddock4 paddock in Farm Farm4 never had a positive cumulative cashflow.
Simulation results also include the change in soil pH values in 0-10cm, 10-20cm and 20-30 cm soil layers, due to direct application of lime and leaching of alkali in subsoil horizons, for example, Figure 3. shows the soil pH change in 20 years' time under various paddocks at three soil layers under liming strategy 7 as compared to no liming (results from other liming strategies are not presenting here). Results showed that in most of layer's soil pH remains above the starting pH levels whereas under no liming conditions soil pH further decreases for 20 years period. Liming amelioration has an effect on sub-surface layers also for 20 years' time due ~~to~~ not only to lime which is applied directly to the subsoil (by banding), but also from excess alkalinity that leaches in from soil horizons above.

Conclusion

The LEAP model and Extrata platform has demonstrated the value of digitising farm records and sharing data, showing the working data modelling pipeline using the lime decision support application. Empowering farmers to share their data and benefit from the analysis conducted will support Western Australian farm businesses to make confident, data-driven decisions and will support the long-term viability of the Western Australian broadacre grain industry.

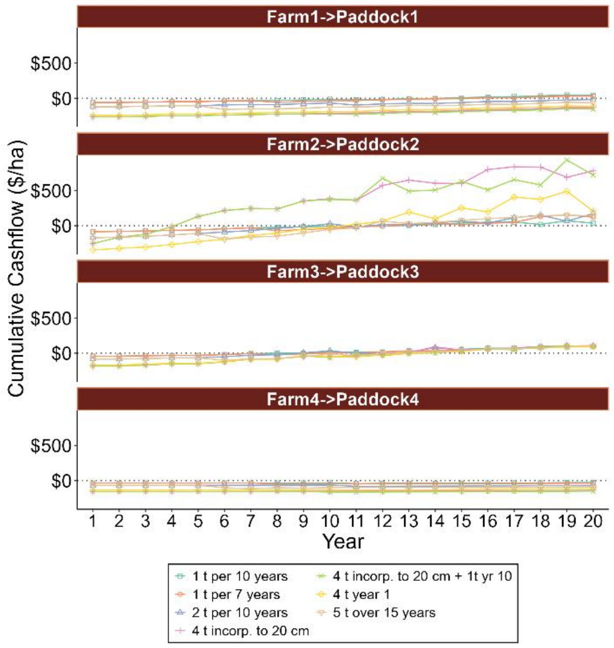

Figure 2. The average (most likely values) Cumulative cashflow, for each of the seven selected strategies expressed as dollars per hectare discounted over 20 years.

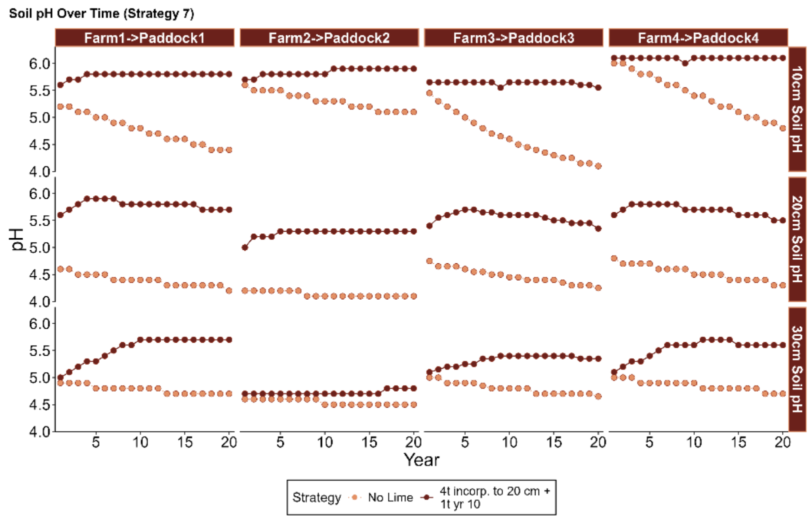

Figure 3. Soil pH values over 20 years for a liming strategy of applying 4 tonnes incorporated to 20 cm plus 1 tonne in year 10 at three soil depths, 0-10 cm, 10-20 cm and 20-30 cm. The average (most likely values) pH for this strategy are represented with the solid line in red, while the average (most likely values) pH for the unlimed strategy are represented with a dotted line in an orange colour.

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