The Soil Tech Project – Translating Soil Science into Digital Soil Management Tools for Agronomists and Land Managers

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Abstract
The Soil Tech Project is a collaborative project aimed at translating existing University of Sydney soil science into a suite of digital soil management applications for agronomists using User Experience Design and Agile Development. The partnership team of soil scientists, developers, agronomists and project manager are working across six development cycles over three years, to translate the science into code that is user centred, and field tested and ground truthed to provide innovative new approaches to soil management. The first development cycle is applying Latin Hypercube Sampling to defined sets of publicly available data, to create contiguous zones across a farm and/or within a paddock. The application then suggests a soil sampling design that ground truths these zones, using fewer samples than would normally be required to identify zones. The application has been field tested by agronomists. Development of this first tool will be completed by August 2019. The overall approach used in the Soil Tech Project is being observed and documented using an Action Research framework, in order to evaluate and replicate this innovative approach to translation of science into digital applications.

Key Words
Soil management, digital soil mapping

Introduction

The Soil Tech Project is a $1.1M Smart Farming Partnerships National Landcare project. The overall aim of the project is to translate existing University of Sydney soil science into a suite of digital soil management tools using User Experience (UX) Design and Agile Development, with field testing on farms by agronomists. The Project is led by Andrea Koch Agtech (AK Agtech) and involves a collaborative partnership of soil scientists from the University of Sydney, developers from the Australian agtech start-up, FarmLab and agronomists from AGRIVision Consultants.

The planned tools include improved soil sampling techniques, better visualisation of available soil data, a farm-level weather forecasting application and better soil management strategies that will help agronomists and land managers reduce the costs and time associated with soil management and crop production. These tools will be available free of charge via the FarmLab website and the code available via Github. The aim is to share the journey of developing this innovative approach as well as the tools themselves.

This Project represents a new approach to innovation in agricultural research and development in Australia. Around $3billion is invested in research and development per annum, however a fair proportion of this does not translate to application or become commercially available. The partnership approach and methodology used in the Soil Tech Project may lead to a new approach for translation of research into application. In addition to the development work itself, an action research project is also being applied to the overall project to formally observe and document the process so that it can be adopted and replicated as a means of translation and extension of research and development.

Work commenced in late 2018, and the first digital soil management tool will be launched at the 19th Australian Agronomy Conference in August 2019. The science underpinning the first tool applies Latin Hypercube Sampling (LHS) to publicly available data sets to indicate where soil testing should be conducted across a farm, or within a paddock.

Methods

The Soil Tech Project will revolve around six Agile Development cycles starting in November 2018 and finishing in 2021. Each cycle kicks off with UX Design to ensure that what is built not only translates the

science, but also solves real user problems. The process is iterative. User centred design usually tries not to pre-empt the solution that emerges from the design process, but in this case, we are marrying up the user experience with existing science. The key will be in understanding what the science delivers and where and how this fits in and enhances current practice in order to improve soil management.

Scientists from the University of Sydney and agronomists from AGRIVision Consultants work closely with the Farmlab developers and AK Agtech to design each soil management app. Each development cycle involves up to five sprints, three or four weeks of coding followed by road testing in the field by AGRIVision. For the latter sprints, field testing will extend to a community of followers, referred to as 'Ground Truthers', in order to obtain feedback from a wide range of potential end users. How the app performs against user requirements is fed back to the developers, who use the information to refine and improve the app in the next sprint.

At the end of the last sprint, the final app will be loaded into the FarmLab platform for anyone to access and use, free of charge. The code will be made available on Github for any other software service providers who would like to integrate these tools into their offering.

By the completion of the Project in 2021, the aim is to have a new suite of science based digital soil management tools that change and improve the way Australian producers and land managers manage soil.

Identification of Soil Science for Translation
As part of the grant application process, the team identified six soil science papers published by the University of Sydney that do not currently have a pathway for development into application, and that hold promise for translation into digital tools for agronomists and other land managers.

The first of these papers, titled 'A conditioned Latin hypercube method for sampling in the presence of ancillary information', authored by Budiman Minasny and Alex McBratney at the University of Sydney has provided the focus for the first tool (Minasny & McBratney, 2006). The authors of this paper are consulting on the project, to ensure that the science is correctly interpreted and applied as the digital tool is developed. The input of their expertise is invaluable.

User Experience Design
User Experience Design, also referred to as UX Design, is a process that puts the user's experience at the centre of the design of a software application. Potential users are interviewed to gain an understanding of how they go about their work and to identify challenges and problems that they face. By gaining clarity around these problems and postulating solutions, the resulting design of the application provides benefits that are user centred. Users are then consulted during the development of the application to ensure that it is working in the intended manner.

Agile Development
Agile Development is an approach to software development that involves iterative and adaptive development by a cross-functional team. The approach integrates user centred design and user feedback during the development process in order to make adjustments during the build. This ensures that the software reflects and meets user needs. It is easier and cheaper to make small coding adjustments and change them often during the build, rather than to code the finished product and find that it doesn't meet the market.

Agile Development was first conceptualised at a meeting of developers in Snowbird, Utah that resulted in the scribing of a manifesto articulating a new approach that prioritised individuals and interactions over processes and tools; working software over comprehensive documentation; customer collaboration over contract negotiation; and responding to change over following a plan (Kent et al., 2001)

Ground Truthing
Each iteration of the application is field tested at the end of each development sprint. During the early part of the development cycle, the field testing is conducted by AGRIVision agronomists. A community of followers has been engaged via the soiltechproject.org website, and some agronomists from this community will be asked to test and 'ground truth' the apps in later iterations.

Action Research
Action research methodology comes from the social sciences. It is an approach to research that enables observation and learning to emerge from a project as an additional outcome to the primary goals of the project, by utilising cycles of 'plan, act, observe, reflect'. For each of the six development cycles during the Soil Tech Project, one action research cycle is being applied. Through this process, the approach we are taking will be evaluated and documented, so that it can be extended to other organisations looking for new ways to innovate and translate existing research into digital applications.

Development Cycle One – Latin Hypercube Sampling

The methods outlined above have been applied during the first development cycle, which aims to translate the science of Latin Hypercube Sampling into a practical application of soil sampling design for agronomists. This paper outlines the results of this development cycle as at the time of writing in March 2018. By the conference in August, the cycle will be complete and the LHS digital app will be launched.

Results

Development of the first digital tool, 'Latin Hypercube Sampling to optimise soil sampling design'
In the early stage of the Soil Tech Project, we identified that the main users of the digital soil management tools will be agronomists. From there, we have interviewed six agronomists to get an understanding of current work practices in soil management, and specifically in soil testing and sampling.

At the time of writing this paper, development of the first digital soil management tool, 'Latin Hypercube Sampling to optimise soil sampling design' was in the second sprint. The first sprint and field test had been completed and the findings were being coded in the second sprint.

Discussions with AGRIVision agronomists, plus interviews with other agronomists conducted during the UX Design process had determined that current practice in deciding the locations for soil sampling occurs in the paddock by the agronomist, following review of any existing datasets (e.g. yield data, NDVI, EM38), and ground truthing the terrain in the paddock. Using this approach, there is currently no way to know what the optimum number of soil samples is for any given paddock.

During the first sprint, algorithms for Latin Hypercube Sampling (LHS) were coded and applied in the tool to create contiguous zones across a farm and within a paddock. Following much discussion and some experimentation, it was agreed that using a multi-year average of publicly available satellite NDVI data for any given farm and/or paddock and running the LHS algorithm, would generate contiguous zones across that farm or paddock. Code was developed to automatically select soil sampling locations within each zone that theoretically enabled ground truthing of the zones.

At the end of the first sprint, the team met at a farm in Victoria and collected soil samples based on the locations indicated by the app. A set of soil samples were also collected along a transect, acting as a control and enabling a comparison of the sample design generated by the tool, versus current practice.

The results of the field testing, i.e. the soil test results, confirmed that the LHS algorithm applied to publicly available NDVI data did indeed create contiguous zones within the paddocks tested. This means that LHS can provide soil zoning, whereas transact sampling usually doesn't.

Soil sampling design using the LHS digital tool will enable the establishment of baseline management zones across farms and/or within paddocks, without the need for a large and costly number of soil tests. By using publicly available data, LHS identifies management zones that can be efficiently ground truthed with a minimum number of soil tests. This will increase the amount of usable management information that can be generated from soil testing, whilst at the same time optimising the number of soil tests and reducing the cost of soil testing.

Conclusion
The Soil Tech Project holds much promise in developing a new approach to translation of science into digital tools, using UX Design and Agile Development. This approach is working well to translate the theory of

Latin Hypercube Sampling into practical application for agronomists and land managers. The results from the first sprint and field testing have provided enough data and practical application to show that the potential of this first digital tool to optimise soil testing across a farm or within a paddock, and at the same time gain valuable zoning information for more nuanced management of soil, is possible.

References

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