

Developing and testing an analysis framework for long-term fertiliser decisions: Deep-P Calculator

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Abstract. Grain growers in Queensland and northern New South Wales are facing a new challenge in crop nutrition management: phosphorus (P) depletion of many soils below 10 cm. Research has indicated potential yield benefits from replenishing P in sub-surface layers (referred to as a 'deep-P' application). However, it was unknown if amelioration had economic merit. The fundamental question of deep-P placement is 'how much P (what rate) should be applied and how often (at what frequency)?' A program of close consultation was implemented, with leading scientists, fertiliser industry researchers, advisors and growers all contributing knowledge. Focus groups, a literature review and case studies were conducted. The iterative process implemented by this project effectively utilised various extension techniques to engage industry and leading researchers. This knowledge was used to develop a framework to produce a web-based tool that answers the fundamental question of deep-P fertiliser placement, 'how much P and how often?'

Keywords: engagement, knowledge, phosphorus, economic, decision support tool, Deep-P Calculator.

Introduction

Grain growers in Queensland and northern New South Wales are facing a new challenge in crop nutrition management: phosphorus (P) depletion of many soils below the zero to 10 cm layer. Research has indicated potential yield benefits from replenishing P in sub-surface layers (10-30 cm) if soil tests indicate a deficiency (Singh, Sale & Routley 2005; Wang et al. 2007; Bell et al. 2012) — referred to as a 'deep-P' application of a P fertiliser. However, it was unknown if amelioration had economic merit. Deep-P placement is a longer-term decision because it involves a large upfront cost as P is mechanically placed at depth (typically 20 cm), with potential yield benefits lasting several years. The soil disturbance and associated soil moisture loss from this application may impact on plant establishment of the subsequent crop if there is limited follow-up rainfall. Hence, the application interval needs to be as long as practically and economically possible. The nature of future seasons is unknown, thus decision making needs to be based on the range of possible outcomes. In common with advisory materials, the median or mean is used as the fundamental guide. The essential question of deep-P placement is 'how much P and how often?' The Grains Research and Development Corporation (GRDC), Department of Agriculture and Fisheries (DAF) and CSIRO invested in a project entitled 'More profit from crop nutrition II – Analysis frameworks to support profitable fertiliser use'. The current paper explores the process this project undertook to develop a framework to assist growers and agronomists with 'deep-P fertiliser' decisions.

Method

Several activities were undertaken within this project to ultimately produce a web-based decision support tool entitled, "The Deep-P Calculator".

Issue identification

Firstly, focus groups were conducted to identify and prioritise crop nutrient management issues. Four focus groups were run, in Emerald, Dalby and Goondiwindi in Queensland and Mungindi in New South Wales, with over 50 growers and agronomists participating. These sessions were designed to capture up-to-date, regionally specific information regarding how industry currently made nutrient decisions, their needs and the role of decision support tools. The information collected from these sessions allowed the team to determine current knowledge gaps in nutrition decisions. As a result the team decided to focus on developing a new framework to calculate the economics of applying P at depth and the risk around this new technology. It was also determined that decisions regarding nitrogen (N) fertiliser rates were paramount when making deep-P decisions. Research shows interactions between nutrients can limit plant growth and that nitrogen can limit the benefits of deep-P (Wang et al. 2007).

A literature review was completed of crop nutrition decision support tools (DST) and their effectiveness (Van Grieken et al. 2013). Recommendations included:

- the target market for DST is advisors
- DST's are best for tactical decisions, such as calculating nitrogen rates
- DST's require a mechanism of training and support.

The team used these recommendations when developing the Deep-P Calculator.

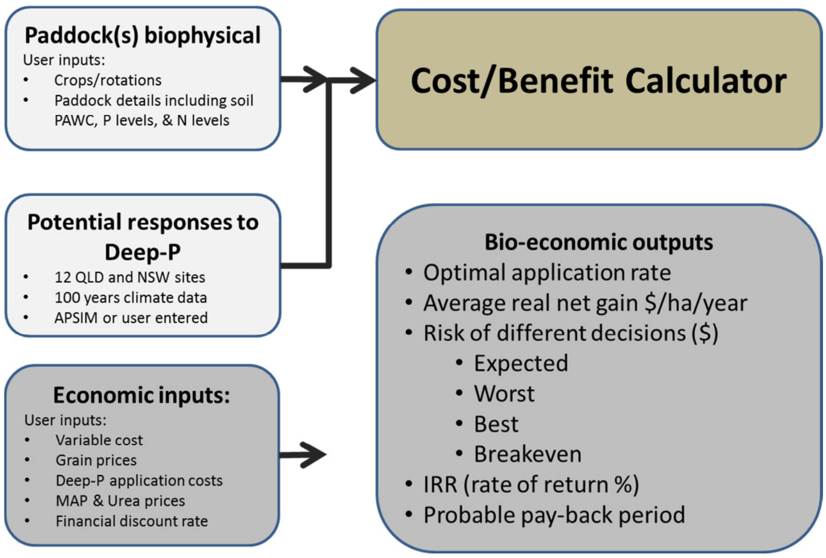
Results

Framework development begins

Deep-P researchers were consulted to gather the most up-to-date understanding so that this could be embedded into the framework. Development of the Deep-P Calculator commenced with a blank spreadsheet. The desire was to represent the pool of available P in the 10-30 cm depth of soil, grain yields with and without the application of deep-P, and the economic benefits over a rotation after applying deep-P before the first crop. However, this was difficult to achieve because:

- Limited data were available for yield responses to rates of applied P (starter) fertiliser.
- Growers apply a 'standard' rate of P fertiliser (30-50 kg/ha/crop of starter fertiliser), based on a low surface soil P test.
- The economic benefits had not been quantified, especially over time (deep-P application is costly and its benefit is longer term).
- Soil disturbance potentially compromises the establishment of the first crop following treatment, introducing extra risk.

Figure 1. Schematic of the bio-economic framework of long-term decisions of deep-P



Nevertheless, the development of the calculator progressed well (Figure 1), largely based on 'rules of thumb' gained in the early research work. Further assumptions were made as advised by researchers and experienced nutrition consultants. Some key rules and assumptions in the early version (later enhanced) included:

- full contribution of applied P fertiliser to the sub-soil P pool
- paddock status based on location, soil water-holding capacity (PAWC) and soil organic carbon
- soil P status based on Colwell soil tests 0-10 cm, 10-30 cm and (preferably) 30-60 cm, with BSES tests giving supporting evidence
- financial returns based on yield increases, crop rotation length, crop types, crop values ($/t), fertiliser and application costs
- modelled (APSIM) yields (Holzworth et al. 2014) provided unconstrained yields based on user's inputs, but can be overridden by the user
- crop yields without deep-P fertiliser based on the research of Bell et al. (2014)
- Colwell P test estimated P pools on a 1:1 basis, i.e. in the 10-30 cm layer a soil test of 10 mg/kg results in a pool of 20 kg/ha available P (i.e. multiplied by two to account for the 20 cm layer)
- all of the soil available P pool is available to the crop in the same way as deep-P fertiliser
- crop demand equals P content of grain yield harvested
- all of the sub-soil P removed comes from the 10-30 cm soil layer
- no P contribution to crop growth comes from the upper soil layer (0-10 cm) or below 30 cm
- no account is made for tie-up of applied P

- yields are discounted if N supply is insufficient to offset N removal in the grain. If an N deficiency occurs, the optimum deep-P rate will be reduced.

In addition, Monte-Carlo simulations of unconstrained model yields with P (and N) provided robust distributions of potential crop yields and returns to use in the economic analysis. Overall, the concept of shifting to subsoil P application was well accepted, even though much of the benefit was deferred.

In collaboration with farmers and advisers, the following six Deep-P Calculator case studies were developed across the Queensland and northern New South Wales grains region to determine the profitability of deep-P, as well as the benefit of nitrogen (N) fertiliser application and its interaction with deep-P:

1. Dalby, Darling Downs, Queensland
2. Moree, Northern NSW
3. Goondiwindi, Western Downs, Queensland
4. Biloela, Central Queensland
5. Norwin, Central Darling Downs, Queensland
6. Tara, Western Downs, Queensland.

The iterative process resulted in huge improvements

Upon release of early results, the Deep-P Calculator was forced to undergo further development to incorporate P decay and the re-supply of available P from soil resistant P supplies. Close analysis of research trial results relative to model results (validation) resulted in changes to the calculator algorithms. Significant adjustments were:

- P requirement was based on total biomass (stem + grain), assuming that P in stubble is not returned to the subsoil P pool within the time-frame of the economic analysis.
- Applied P fertiliser was assumed to become unavailable within the time-frame of the economic analysis, at a decay rate of 10% p.a.
- Fifty percent of crop P requirements are assumed to come from the soil surface (0-10 cm), and 50% from the subsoil (of this, 80% from the 10-30 cm layer and 20% from the 30-60 cm layer).
- If a soil test is not available for the 30-60 cm layer, it is deemed to be the same as for the 10-30 cm layer.
- The contribution from the resistant P pool (as measured by the BSES soil test) to the available P pool (Colwell P) is calculated as a linear function of 0 to 100 % replenishment per annum from the BSES test (range 0 to >100 mg/kg).

The above changes better represent the current knowledge of soil P flows and pools based on field trial results, and comparison of the 'optimum' P rates indicates more modest and acceptable values. The six case studies that were written using the first version of the model were revised using the final version. These new results were reviewed by the case-study participants to ensure they were aware and comfortable with the new results. This framework can be refined further as more trial data results become available in the future.

Road-testing the product

A web-based version of the Deep-P Calculator was created, and updated to reflect the algorithm changes. It incorporates all of the functionality of the spreadsheet version, but the look and feel is modern and user friendly. The web version was 'road-tested' with the original case-study participants, as well as crop nutrition researchers and experts. All suggestions have been incorporated including an instructional video. Most importantly the team are confident with the recommendations produced by this tool.

The trials, tribulations and triumphs

Overall, the development of this framework into its current state has been a challenging process, requiring many meetings with industry experts, revisions of underlying biophysical processes and numerous validations. The biggest challenge was due to the team developing a framework that placed economics and risk around a technology that was not fully understood and where biophysical data was limited. Now that the framework is developed, the opportunities are many.

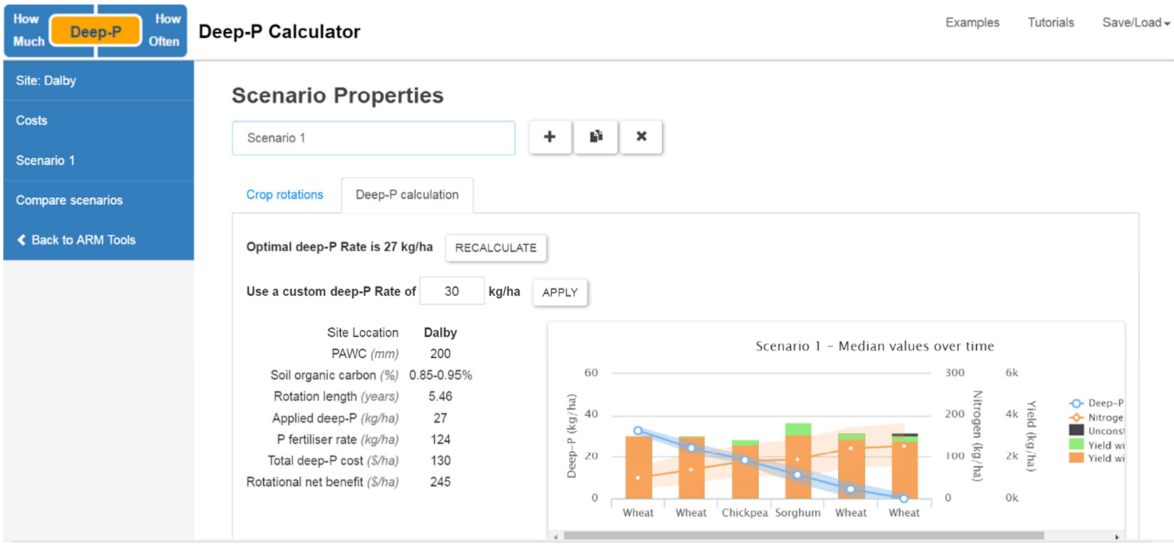
The process has allowed deeper analysis of current trial work, collective interpretation of the results and ultimately a greater understanding of the biophysical relationships. New research to fill the gaps in the data has been engendered by the interaction that occurred during this project. Although challenging, overall the process has been very rewarding for all team members and industry participants, and has resulted in the innovation that is in the Deep-P

Calculator. Of particular value was the engagement of six consultants, each with an interested grower, which allowed the team to develop case studies that were locally relevant. During the process their feedback on the usability and accuracy of the calculator was invaluable. All were very supportive of the project and concepts, and spent considerable time with the team suggesting changes to the format. As a result, the team are confident that a useful, innovative decision support tool has been produced, enabling people to answer the fundamental deep placement of P question; "how much P and how often".

The end result

The final version of the Deep-P Calculator is now available on the web at www.armonline.com.au/deepp/#!/ for growers and agronomists to use to help them calculate their deep-P requirements (Figure 2).

Figure 2. Web version of the Deep-P Calculator



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