**Spatially-distributed on-farm experimentation – a potentially valuable approach to optimising farm business decision-making in cotton farming systems.**

**A report to Cotton Seed Distributors and the Cotton Research and Development Corporation.**

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## Summary

Cotton sector interest in spatially distributed on-farm experimentation (SDE / OFE) as a tool for improved farm business decision-making led to a workshop being held in Narrabri, NSW, on November 24, 2022. This report summarises the workshop process, discussions amongst participants about the value proposition of SDE / OFE and immediate next steps. Of significant interest to workshop participants was the use of strip trials positioned to capture maximum variability in treatment responses and analysed using a moving window average approach and, for whole fields, presentation of gross margin maps to motivate grower practice change. One consultant said about the SDE /OFE approach: "*Makes a lot of sense. I like the methodology – it relates better to the growers*". This report also provides recommendations to progress implementation and adoption of SDE / OFE and to extract more value from existing data to baseline and benchmark crop production. A coordinated and collaborative approach that targets and builds capacity in digital agronomy will help growers and the sector achieve their goals faster.

## Recommendations

The following recommendations emerged from the workshop:

1. Initial trials to demonstrate OFE / SDE (case studies) should be chosen carefully; that is,
    I. Select well-defined issues with straightforward treatments likely to produce large differences in responses for ease of communication and interpretation of results;
    II. Trial leadership will need to be determined on a case-by-case basis whether it be through the hosting farmer, Cotton Seed Distributors, CottonInfo, or other appropriate agencies. However, a clear understanding of the SDE opportunity, alignment of the trial question to the SDE approach and availability of key underpinning data (eg previous yield maps) will be important.
2. Presentation of yield maps – either existing or still to be analysed - as gross margin maps is likely to motivate use and application of spatial data and OFE / SDE.
3. Identify trusted local champions of OFE / SDE – growers and/or consultants - who can communicate the commercial value of the case studies in which they lead and/or participate.
4. Consider the needs of growers, consultants and corporate agronomists in respect of which aspects or experiences of OFE / SDE they are willing to share – process, outcomes or both ?

5. To gain value from OFE / SDE and greater buy-in to it, recover, analyse and make use of the abundance of existing data (e.g. yield maps, remotely sensed imagery) as a parallel activity; a link to existing cotton sector data audits would be valuable.
6. Explore and evaluate options to build capacities and capabilities in digital agronomy in a targeted way.
7. Document and test assumptions as the business model for OFE / SDE evolves, including audience segments, value proposition, delivery channels, data infrastructure, coordination of the data value chain, who pays for what and why.

**Background**

Interest in the use of on-farm experimentation (OFE) as a tool for farm business improvement re-emerged recently (Lacoste et al. 2022) in association with use of digital agriculture technologies (Bramley et al., 2022) such as yield monitors and other crop and soil sensors. Spatially distributed designs (Bramley et al. 2013 and references therein) are implemented over entire management units or in strips which run over the length of a paddock. These trials use farmers own equipment, are embedded within their normal operations and address questions which seek to generate actionable knowledge (Evans et al. 2017) and optimisation of farm business decision-making (e.g. Colaco et al. 2022). As such, they are 'farmer centric' (Lacoste et al. 2022) but given the likely need for spatial analysis of sensor data to generate interpretable results, may often also need to be 'specialist enabled', thus requiring partnership between growers, service providers with skills in 'digital agronomy' and/or researchers.

**Workshop Objectives**

Given recent developments in OFE, Cotton Seed Distributors (CSD) and the Cotton Research and Development Corporation (CRDC) organised a workshop which was held in Narrabri on 24 November 2022. The aim of the workshop was to gain a better understanding of OFE, gauge interest in developing OFE for application in the cotton sector, understand the level of existing service delivery and to consider what might be required to facilitate adoption. The workshop was attended by approximately 20 participants, predominantly agronomic advisors, but also including growers and those engaged in cotton sector research.

**Workshop Process and Discussions**

*Preliminary activity*

Workshop participants were asked to reflect on their past engagement in agronomic trials and consider what they considered to be features of successful trials, and what might have constrained these or their success (Table 1). Almost all identified aspects were either canvassed directly in the subsequent presentations or along with these, inspired the subsequent discussion. Many of these ideas might be unchanged in an informed OFE context; nonetheless, the extent to which they might be indicators of success or constraints or indeed change through use of OFE was addressed during the workshop.

**Table 1.** The successful features of agronomic trials and constraints to their success, as identified by workshop participants prior to discussion of OFE

| Indicators of success | Constraints to success |
|---|---|
| Evaluate treatment – ie best treatment identified | Setting the research question |
| Clear answer | Design needs to be kept simple |
| Ability to monitor effects over time | Lack of uniformity |
| Commercial implications apparent | Temporal variation / extreme conditions |
| Statistically significant results | Customer not satisfied |
| Use/selection of appropriate site | Too much data |
| Fits with other operations | How to communicate the data |
| Efficient and effective | What to measure ? |
| Happy client | Was the right thing measured ? |
| Ability to interpret results in $ terms and/or in respect of environmental implications | Skills / training |
| Access to the right tools | Commercial implementation of results |
| Identification of value proposition to the grower | |

*Workshop presentations*

The presentations by Rob Bramley and Kathy Evans sought to introduce the concept of spatially distributed experimentation (SDE), expose attendees to some key differences between SDE and classical approaches to agronomic experimentation and to outline key steps for successful implementation and the thought processes underpinning them. The slides from both presentations are provided as separate files accompanying this report.

The need or otherwise to consider statistical significance and other metrics of treatment effects was a feature of both presentations, as was a key differentiator of OFE / SDE from more classical approaches to agronomic research in that, rather than trying to avoid or remove the effects of underlying spatial variability in soils or crop performance, these alternative approaches explicitly embrace this variability as an experimental tool. Case studies from the grains and wine-grape sector were presented, including the recent PhD research of Xinxin Song (Song 2022, Song et al. 2022a,b,c) that investigated grapegrower attitudes to OFE and factors underpinning adoption.

During the subsequent discussion, the workshop participants were also shown Figure 1, which is from a 30 ha Chardonnay vineyard in the Griffith region, with the data collected in c. 2005. This type of information was seen as a potential means to motivate practice change and generated significant interest among attendees as discussed in more detail below.

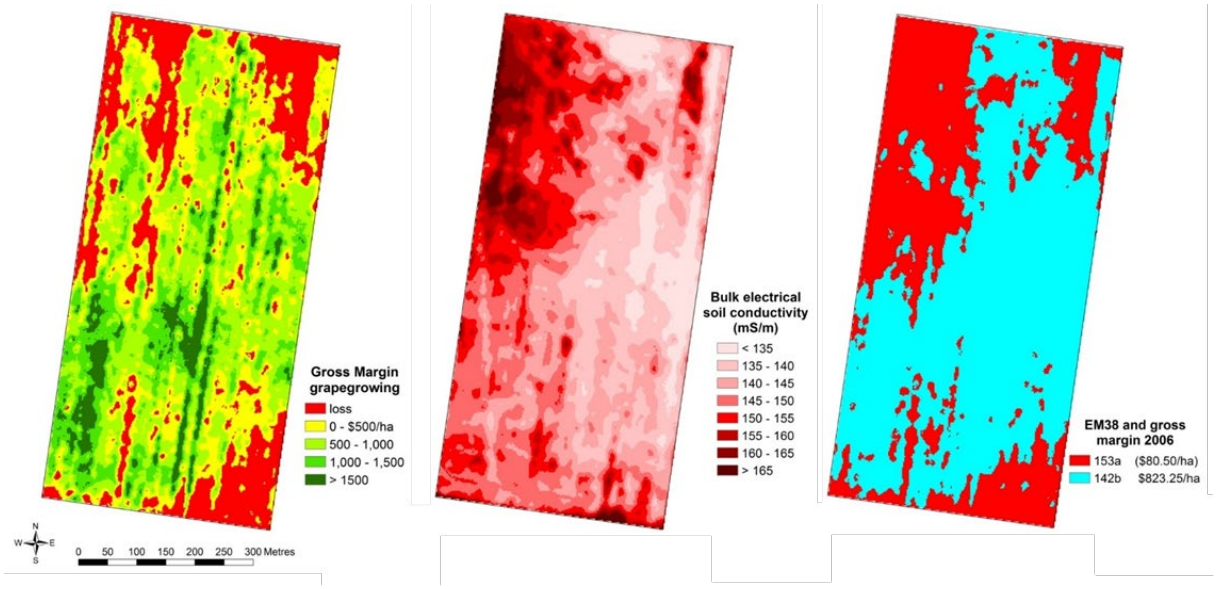


**Figure 1.** The value of information. A viticultural example from the Griffith region.

The left-hand map in Figure 1 is a gross margin map – a simple linear transformation of a yield map, knowing the costs of production and price received for fruit. All of the areas shaded red are operating at a loss; those in yellow have an unsatisfactory return on investment. The centre map is an electromagnetic induction (EM38) soil survey of the vineyard. The right-hand map is the result of clustering the other two map layers together; those shaded red make a loss as a grape-growing entity whilst those in pale blue return satisfactorily; the red and pale blue areas have significantly different EM38 signals. Information such as that shown in Figure 1 can be a strong motivator – to understand the soil constraint which appears to be limiting production / profitability, and perhaps to conduct a spatially distributed experiment to understand how to manage the constraint.

Key points to emerge in the Discussion which followed the presentations included the following:

*Value proposition*

There was general agreement that the SDE / OFE approach had something to offer the cotton sector. When presented with results of researcher-led trials, the question of 'how does this relate to my farm?' - commonly encountered in other sectors – is clearly something which confronts the cotton research and consultant community. One consultant said about the SDE /OFE approach: "*Makes a lot of sense. I like the methodology – it relates better to the growers*". It was noted that, as in many other sectors, many growers are already doing some sort of trialling. Thus, with some carefully chosen commentary, getting broad buy-in to OFE / SDE might not be too difficult.

Underpinning the value proposition of OFE / SDE is the fact that a lot of growers are already collecting a lot of data – yield maps, imagery, etc… However, it is important to recognise the difference between having data and making use of it, and also to recognise that data and knowledge are not the same thing. It was apparent from the discussion that, on average, there is relatively little use of this existing data or indeed, understanding of how to extract best value (i.e. knowledge) from it, although there is a wide range in the degree of data use amongst growers; the cotton sector data audits will assist with understanding in relation to this issue. There was considerable discussion about cost, especially the

cost of collecting/processing data, although one consultant present posed the question: "*what is the cost of not collecting it? This is surely the more important question*." To underpin realisation of the value from OFE in the cotton sector, there might therefore also be a need for some underpinning support in data analytics – for example to assist in yield map generation and zone delineation (e.g. the right hand map in Figure 1; see also below). There was also discussion related to this as to whether the cotton sector needed a specialist to be appointed to support such analytics.

Overall, there was agreement that the cotton sector needed to be exploring OFE / SDE and assessing its value. Staff from CSD were especially keen on being able to access the moving window analysis (along strip trials) as a tool to support their experimentation.

*Resources for OFE / SDE – currently / potentially available or required*

It was evident from the discussion that:

- To varying degrees, growers in the cotton sector have an abundance of data (yield maps, remotely sensed imagery, etc), but with varying degrees of data use;
- This can be enhanced through, for example, freely available remotely sensed imagery at good resolution (e.g. Sentinel, 10 m);
- Some service providers are focussed on providing appropriate data analytics; however, there is no means to evaluate whether outputs are fit for purpose or meeting the required standard, especially with respect to issues such as yield map interpolation;
- At least two service providers already believe that they are providing OFE / SDE as a service:
    - One clearly was, albeit to a limited clientele (~20 trials) in terms of the total number of growers. The other clearly was not; however, by the end of the workshop he appeared to have greater awareness of the difference between his current approach and OFE / SDE;
- One consultant openly admitted that he didn't understand the various geostatistical issues in data analysis - another indicator that service providers operate on a spectrum in terms of their depth of understanding of the data analytics underpinning precision agriculture more generally.
- Of note was the fact that none of the workshop participants were members of (or even aware of ?) the Society for Precision Agriculture, Australia (SPAA – www.spaa.com.au). SPAA does not offer PA services per se. but can be a useful source of valuable cross-sectoral information on precision /digital agriculture; the SPAA membership is grains dominant, but as an organisation, is sector agnostic.

It was clear from discussion that to gain value from OFE and greater buy-in to it, attempting to recover, analyse and make use of the abundance of data already collected needs to proceed as a parallel activity. Figure 1 (above) highlights the type of information that attendees viewed as a valuable means to support discussions with clients. Workshop participants agreed that the left and right-hand maps of Figure 1 presented as (a) a powerful incentive to understand the limitations to production; (b) that doing so was valuable; and (c) that, depending on the nature of the constraint being reflected in these maps, there would be much value in using OFE as a tool to work out how best to cost-effectively address these constraints. It is therefore suggested that, in addition to motivating towards implementation of OFE in the cotton sector, a separate, supporting, but closely linked effort was needed in making use of the myriad of data that cotton growers have already collected – to facilitate, for example, generation of gross margin maps and potential management zones (c.f. Figure 1). Those

who have not collected such data have recourse to historical and freely available remotely sensed imagery, with one consultant attending the workshop noting the close correlation in cotton crops between NDVI and yield. Adoption of tools such as PAT (Ratcliff et al. 2020) or those used by companies such as PCT-Ag might assist with this analysis.

*Building capacities and driving grower demand for OFE / SDE*

The points above tend to support a need for some coordinated 'learning by doing' such as the use well-chosen examples or case studies that include extension to growers to explain OFE / SDE and demonstrate the value. CSD, CRDC, Cotton Info, other agencies (eg Agribusiness) and individual growers will all have roles to play in investing in and generating such case studies.

In later discussion, the value of some 'champions' or trusted voices in helping to carry things forward was noted; anecdotal evidence from the wine sector strongly suggests that even within large corporate companies, for example, local adoption of precision viticulture practices has been highly dependent on a 'local champion' being involved, irrespective of a broader company 'buy-in'.

There was some conjecture about whether the industry needs somebody with PA knowledge to work across industry and across projects or would be better to partner with providers of spatial data. In any case, providers of spatial data represent the mechanics of producing results whereas an agronomist is needed to assist with interpretation. It is important to recognise, in relation to both this point and also the commentary above on data analytics, the desirability of data analysis being done well, using state-of-the-art methods. Most commercial providers of PA services do not do this. A key reason for this is that the map interpolation process can be computationally slow; some PA software simply presents maps as point data; some service providers produce maps of soil properties with insufficient underpinning data. So the decision as to how and from whom to source expertise is one that needs careful consideration. We should be encouraging growers to demand the consultant services that they need, rather than just accepting what service providers are willing to offer; PAT (Ratcliff et al. 2020), which is freeware, can assist with these kinds of issues.

Options for building capacities in digital agronomy include:

- Providing access to the presentations and discussions presented at the workshop, and related materials, to growers and consultants;
- Appointing a local cotton sector data analytics specialist or data wrangler; however, someone new to the sector may not understand or appreciate what they are being asked to do;
- Providing training to build the skills of local agronomic consultants, including through engagement with SPAA;
- Creation or enhancement of a central data platform and/or shared access to analytical tools to enable more value to be gained from existing data, with data sharing if appropriate.
- Use of extension activities linked to OFE / SDE case studies to drive farmer demand for gross margin maps, thus motivating investment in data organisation and processing as value-added service delivery
    - One can envisage 20 growers and their consultant running strip trials and the power of sharing interpreted results

*Experimental focus*

Prior to the workshop, there was an expectation that disease might be the focus for initial adoption of SDE. However, the absence of sensors to measure disease severity, along with other complexities associated with disease trials, means that a trial topic with greater relative ease in data collection and interpretation may be a better choice – at least in the first instance - as a means of gaining experience and traction with the SDE approach.

A lot of time was spent discussing appropriate topics for experimentation using the SDE approach. Disease was fairly quickly ruled out as an initial case study (see above), but with experience and commitment to the required data collection, could certainly be an appropriate trial topic in the future, especially given its importance to the sector and the existing effort expended in developing 'heat maps'. However, there was a lot of interest in trials aimed at variety comparison. Of course, fine-tuning various elements of agronomic management (crop nutrition (c.f. 'Future farm'), irrigation, etc) and its timing were also mentioned. It is suggested that given the desirably 'farmer-led' nature of OFE, albeit noting the above comment on 'local champions', who may need to be from the 'specialist enabler' cohort in the first instance, there is little merit in trying to be prescriptive about trial objectives.

**Next Steps**

The following actions could be taken immediately:

- Organise a meeting with service providers and other key stakeholders who were not present at the workshop to further explain and explore the SDE opportunity;
- CRDC to meet with GRDC to share what was learned from the workshop and to explore a common strategy to facilitate OFE / SDE application and uptake;
- CSD and CRDC, with other partners as appropriate, to explore suitable experiments to use as SDE /OFE case studies; e.g., evaluation of varieties based on existing demand from growers for knowledge of site-specific varietal performance;
- Develop some principles around how OFE / SDE will be organised in the sector and how the SDE opportunity should be pursued, recognising the desirability of growers having a leading role, albeit often with a need for expert support.

See also the recommendations on page 1 of this report.

**References**

Bramley RGV, Song S, Colaço AF, Evans KJ, Cook SE. 2022. Did someone say "farmer-centric" ? Digital tools for spatially-distributed on-farm experimentation. Agronomy for Sustainable Development 42, 105. DOI: 10.1007/s13593-022-00836-x

Bramley RGV, Lawes RA, Cook SE. 2013. Spatially distributed experimentation: tools for the optimization of targeted management. In: Oliver MA, Bishop T, Marchant B (eds) Precision agriculture for sustainability and environmental protection. Routledge, London, pp 205–218.

Colaço A, Whelan B, Bramley R (2022) Better targeted, more precise fertiliser decisions as a counter to rising fertiliser prices – focussing on 3 of the 6 Rs. In: South Australian Grains Research Update, Adelaide, 8 February, 2022. Grains Research and Development Corporation, Canberra.

https://grdc.com.au/resources-andpublications/grdc-update-papers/tab-content/grdc-update-papers/2022/02/better-targeted-more-precise-fertiliser-decisions-as-acounter-to-rising-fertiliser-prices-focussing-on-3-of-the-6-rs (Accessed November 2022).

Evans KJ, Terhorst A, Ho Kang B. 2017. From data to decisions: helping crop producers build their actionable knowledge. Critical Reviews in Plant Science 36, 71–88. DOI: 10.1080/07352689.2017.1336047.

Lacoste M, Cook S, McNee M, Gale D, Ingram J, Bellon-Maurel V, MacMillan T, Sylvester-Bradley R, Kindred D, Bramley R, Tremblay N, Longchamps L, Thompson L, Ruiz J, Garcia FO, Maxwell B, Griffin T, Oberthur T, Huyghe C, Zhang W, McNamara J, Hall A. (2022. On-farm experimentation for global agriculture transformation. Nature Food 3, 11-18. DOI: 10.1038/s43016-021-00424-4.

Ratcliff C, Gobbett D, Bramley, R. 2020. PAT - Precision Agriculture Tools. v3. CSIRO Software Collection. https://doi.org/10.25919/5f72d61b0bca9 (Accessed November 2022).