Supporting and Progressing Enhancement of Performance on-Farm: Farm-PEP

Daniel Kindred[1]*, Pete Berry[3], Sarah Kendall[2], Susie Roques[1], Dhaval Patel[2], Roger Sylvester-Bradley[1]

[1]ADAS Boxworth, Battlegate Road, Boxworth, Cambridge, CB23 4NN, UK
[2]ADAS Gleadthorpe, Meden Vale, Mansfield NG20 9PD, UK
[3]ADAS High Mowthorpe, Duggleby, Malton YO17 8BP, UK.

*Daniel.Kindred@adas.co.uk

Abstract

On-Farm Experimentation (OFE) begins with connecting people and sharing ideas. The question to be asked by OFE emerges from and should be defined by a shared understanding of the problem or issue at hand, accounting for what is published in the knowledge base and any experience garnered either formally or informally. Progress is generally quicker by working together, enabling comparisons across environments and conditions, sharing data on metrics that matter, converging around questions to test and co-ordinate experiments across multiple farms. We are developing a platform (Farm-PEP: www.farmpep.net) to support farmers, advisors, industry and researchers in a 'Learning by Sharing' approach, providing a space to find, reconcile and share, ideas and projects; tools to enable interactive and dynamic benchmarking of metrics across fields and farms; tools putting the robust design and analysis of on-farm trials into the hands of farmers and practitioners; and a place to report findings and distil messages to inform the knowledge base and resolve actionable guidance for farmers.

The Problems & Opportunities

Variation in performance on-farm is huge, at all scales and for all metrics

The cause of most of this variability is unknown and under-explored. Some farms are achieving much more than others but we often do not know why. For the industry as a whole to improve, we must share and distil knowledge to inform best practice.

Whether we are interested in profitability, efficiency, productivity, sustainability, GHG-intensity, biodiversity, resource use, natural capital, soil health or carbon balance, the variability that exists within and between fields and farms is enormous. Yet this variability is largely unquantified and not understood, so the best routes to improvement are not being identified or prioritized. For example, wheat yields achieved on-farm and in trials in the UK consistently range from <6 to >16 t/ha, whilst UK national average yields are stubbornly stuck at ~8 t/ha. Huge attention is given to the variation between varieties but this only accounts for ~1 t/ha, whilst the 10 t/ha range is overlooked! Our analyses from the Yield Enhancement Network are showing that the range in yields is not simply down to soil, weather, variety and agronomy spend, but that there is a real 'farm factor' – the best farms are achieving more than the rest, even after the effects of soil, rotation and climatic differences are accounted for. For the industry to improve its performance we must therefore work out what underpins this variation and what knowledge and practices should be shared. The opportunity is to "Bring the Rest up to the Best" whilst also supporting the best in getting better.

The decision-sphere that farmers face is hugely complex

*Farmers face a huge number of decisions, the interactions between which can be important for performance. To understand 'what works' requires **analysis** of the outcomes of these decision combinations across a range of conditions; to effect changes requires support in the **design** of systems.*

Farmers routinely deal with complicated biological, ecological, meteorological, environmental, chemical, engineering, logistical, social, digital, economic, financial and regulatory systems. Their job is to combine these into a farming system with sets of decisions that optimize performance across a wide range of objectives within their own unique farm environment; each farm is unique due to its combination of soils, climate, history, capacities and attitudes. We calculate that the number of decision combinations faced by UK arable farmers is a quadrillion quadrillion (~10^{30}) when you consider what crop, what variety to sow with what cultivation methods, at what depth, what rate and when, and then what applications of fertilisers, herbicides, fungicides, insecticides etc to make with what products at what dates and rates, considered across the range of possible soil and weather conditions at key timings (Sylvester-Bradley *et al*., 2018). Clearly not all the interactions here are important, but many must be. To understand 'What Works' and to be able to prioritise the most telling decisions for improved practice we need to be able to analyse the outcomes of these decisions across a range of performance measures. By sharing data this is becoming possible, with digital technologies and analytics offering exciting new opportunities. However, the science of decision-making in agriculture (i.e. agronomy, husbandry) is almost absent from the UK at an academic level, and various market failures make it difficult for industry to achieve this alone. To provide valuable support we must recognize the importance of and develop useful rules for *synthesis* and *design* of systems, as well as *analysis*.

The industry does not measure what matters

Monitoring of inputs, decisions made, and outputs are crucial to our understanding of what works; however many producers do not record these variables. Quantitative sharing of data and experiences is needed to progress our understanding of production and environmental metrics locally as well as generally.

In any production system the monitoring of inputs and outputs through the process is crucial to effective management and improvement; with perturbations in inputs & conditions, the continuous monitoring of a process allows understanding of 'what works' to be developed. It also allows any adjustments to inputs or designs of the process to be tested and evaluated, allowing for continual improvement and better design. However, in agriculture many producers still don't adequately monitor or record their primary outputs (yield and quality), let alone make appropriate measurements through the growing cycle. The important inputs are not necessarily those that are bought; e.g. light, water and temperature are the main drivers of crop growth. Farmers are also constrained by long production cycles, having control of perhaps only 30-40 harvests on 20-100 fields in their career. This is not sufficient to test or experience even a fraction of the quadrillion quadrillion possible decision combinations that could be faced. Sharing data and experiences across farms is therefore crucial to making faster progress. The value of benchmarking is well recognized by industry leaders, but we are yet to agree on the important metrics and KPIs. Only latterly have less tangible outputs such as soil health and environmental performance been considered. These will become increasingly important for Environmental Land Management Schemes (e.g. Defra, 2021) and in targeting net zero (or negative) carbon emissions (NFU, 2019). Also, autonomous measuring techniques are not yet available for many of the metrics that are vital to the industry e.g. crop quality, soil water, root depth (Sylvester-Bradley, this conference).

Fragmentation & competition in the current AKIS

There is a large disconnect between what can be put into practice and what counts as formal science, as well as between research projects and organisations.

The Agricultural Knowledge and Innovation System (AKIS) in the UK is highly fragmented (Curry *et al.*, 2012; Klerx & Proctor, 2013) with a large disconnect between practice and formal science. Most of what is done in academia in the name of agricultural research is irrelevant to the immediate needs of the majority of farmers and much of the industry (eg molecular biology on model species). Most of the knowledge and experience that farmers and practitioners take for granted is invisible to science. The problems and opportunities faced by practitioners are rarely recognised by science. Government has stepped away from funding applied R & D, especially that which seeks to further general knowledge for all rather than the development of innovative technologies by selected ag-tech companies. Progress in agriculture is subject to a market failure; most farms are too small to undertake their own research alone; resultant knowledge on better practices is not protectable so it is not easy for its originator to exploit value from their investment; its value on a £/ha basis tends to be modest, whilst it can quickly scale across thousands of hectares to benefit many, but the originator cannot easily extract this value. There is thus a strong case for public or industry-wide funding for collaborative work. This has been recognised by the UK's recent National Food Strategy (Dimbleby, 2021) which advocates a centre for 'What Works in Agriculture', as is being developed by AHDB (2022).

Connected data, sensing technologies & analytics

New digital technologies, systems & services hold massive promise for transformation of agriculture, but there is current frustration at the lack of clear benefits, difficulty in data-exchange, and slow adoption rates. To connect data requires incentives for all to engage, and trust between partners.

The digital age enables the collection, connection and analysis of agricultural data at unprecedented scales that can be used in ways never possible before. Sensing technologies and cloud-based informatics provide ever increasing amounts of information that should help make better decisions spatially and temporally. However, there is frustration from technologists and scientists at the slow rate of adoption by farmers and practitioners, frustration from farmers and practitioners at the lack of clearly evaluated benefits, and the difficulties in connecting and exchanging data across the wide range of technologies, platforms and services (Barnes *et al*., 2019; Ingram *et al*., 2022). There has been much talk of the power of connecting 'big data' but there has been little incentive for many to actually do so; so the benefits that could accrue from wider analysis and analytics to empower better decisions (tactical and strategic) have yet to emerge. No connected data sets yet contain the information needed to answer the questions that the industry really needs answers to. There are issues of trust and value on all sides of the data divide, so the only way for the full benefits to be realised is for any central integrator of data to be a partner or coalition that is trusted by all (Rose *et al*., 2021).

A Groundswell for farm-centric knowledge exchange & knowledge generation

Many farmer-led initiatives have formed in recent years and there is increasing recognition that farm-centric research & Knowledge Exchange (KE) is the most effective route for public funds to support improvement in performance on-farm. There is appetite for collaborative working and citizen science. Science has an important role & could benefit from new approaches to ask & answer new questions.

The most telling innovations and knowledge for agriculture are very often generated on-farm, by farmers, their staff, their advisors, their suppliers, and their customers (Skalsveen *et al*., 2020). Recent years in the UK have seen a real movement to supporting peer-to-peer knowledge exchange

through a wide range of initiatives including AHDB Monitor Farms, Innovative Farmers, LEAF, ADAS' Agronomics and Yield Enhancement Network and BASF's Real Results. Social media via Facebook, Twitter and The Farming Forum enable views and experiences to be shared, questions asked, and answers suggested (Mills *et al*., 2019). Organisations and events have formed from the bottom-up including Agricology, BASE UK and Groundswell. Government has also recognised the power of collaborative co-creation approaches to innovation and effecting change in agriculture, in Europe via EIP-Agri and projects like Euraknos and more recently with Defra R&D Innovation policy in the UK. Whilst these activities have great engagement and demonstrably benefit the farmers involved, they do not yet always fully connect with the knowledge base, and do not necessarily produce outputs with the robustness and credibility necessary for acceptance by the scientific community.

The Solution: Farm-PEP

We have previously described our 'Agronomics' approach to farm-centric knowledge generation (Kindred *et al*., 2016; Sylvester-Bradley *et al*., 2017; 2018) including the management of Farmers Trials and their statistical analyses (Marchant *et al*., 2018) and the sharing of on-farm field-scale data via the Yield Enhancement Networks (YEN; Sylvester-Bradley & Kindred, 2014; Sylvester-Bradley, this conference).

We now run over 200 farmer Line Trials per year for a range of commercial clients, including BASF Real Results. There are now individual YENs that cover Cereals, Oilseeds, Peas, Beans and Forage, as well as YEN Nutrition (that supports benchmarking of grain nutrient concentrations across crops), and most recently YEN Zero (focused on reducing the GHG intensity of cropping). We invoke four pillars within our approach; a shared understanding of **concepts** (1) that determines key measures and **metrics** that can be shared, benchmarked & analysed (2); **design** thinking to identify ideas, questions and potential solutions (3); and on-farm **tests** of decisions, products or systems (4).

We consider this approach to be applicable beyond arable systems and the consideration of yield; it can underpin performance enhancement for any sector, whether the objective is productivity, profitability, sustainability or any other outcome.

We are therefore developing a Performance Enhancement Platform (Farm-PEP) to bring together a community for farm-centric knowledge generation and sharing, along with appropriate tools and resources. The Farm-PEP website (www.farmpep.net) is being co-designed openly to enable anyone to share ideas, experiences, projects and results. These are structured by Topic areas where the knowledge is distilled. Content will be user-generated with a commercial business model that i) supports the crucial job of inter-connecting and distilling Topics and ii) will enable Farm-PEP to be self-sustaining in the long-term.

Farm-PEP will support groups of farmers, advisors, industry and researchers working together on issues of common interest, providing a common online space to share information and connect with other relevant groups and initiatives. Farm-PEP will ultimately provide tools to these groups, enabling easy data exchange so that users can compare themselves to peers using relevant metrics. By maintaining a common dataset, founded from the YENs, we can develop a broad and deep set of metrics from a wide range of farms, systems and environments. Starting with grain yield, we are prototyping 'Dynamic Benchmarking' to enable users to enter their own observation (grain yield or grain nutrient data) and compare this with anyone or everyone else. They can filter subsets of the available data against which to compare: currently soil type, crop type, location and year. Ultimately, we plan to develop this for any metric of any topic with filtering by any factor.

The common dataset allows researchers to ask questions of the data, and to perform multivariate analyses and analytics to derive insights on what is driving differences in performance.

We also plan to develop simple tools that farmers and advisors can use to help them to conduct robust on-farm experiments accounting for underlying spatial variation. The ultimate aim is for these to be made available via the Farm-PEP platform and for meta-analyses across multiple sites to be easily conducted.

We are starting Farm-PEP with a focus on the UK, to ensure relevance to its initial users. However, we recognise the value of working across borders. Indeed, the YENs already have entrants from across Europe and separate YENs have been initiated in Canada and the USA. We are therefore keen to explore possible collaborations and will seek to inter-connect or integrate initiatives wherever possible.

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