Summary report from APPF online consultation with research stakeholders

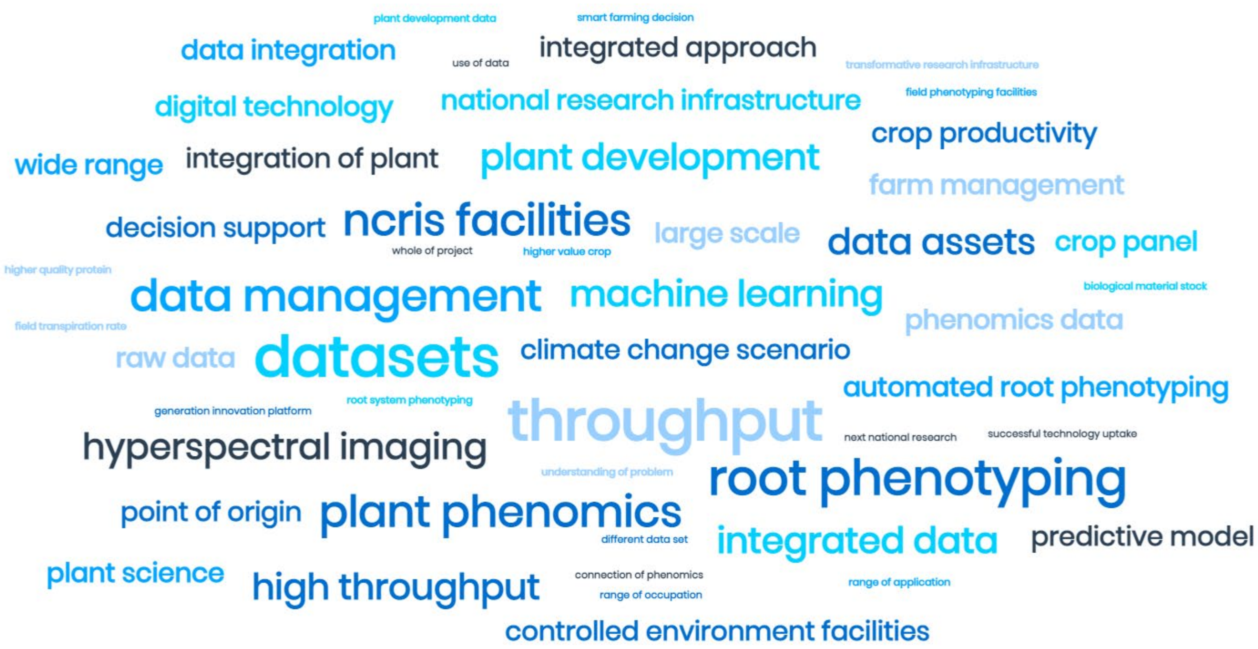
Dec-Feb 2020/21

The APPF has invested in the creation of an online Engagement Hub, to facilitate connections with our stakeholders and users, and also to enable better internal connectivity across the nodes of the APPF. Over the summer period 2020/21, we ran an online consultative campaign which included a survey, ideas wall and chat space. The primary aim was to seek input from our research stakeholders that can be fed into the development of the next National Research Infrastructure Roadmap, and the APPF's own plans for our future. Personal invitations to participate were issued by APPF senior leaders to key contacts, and wider promotion of the campaign was undertaken using social media, university newsletters and the APPF website. Individual respondent numbers were reasonably low, but in many cases represented a wider organisational, team or company view.

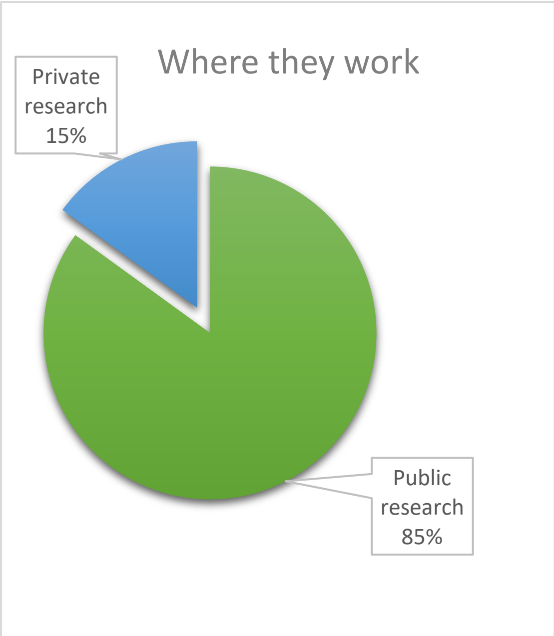
What did we ask?

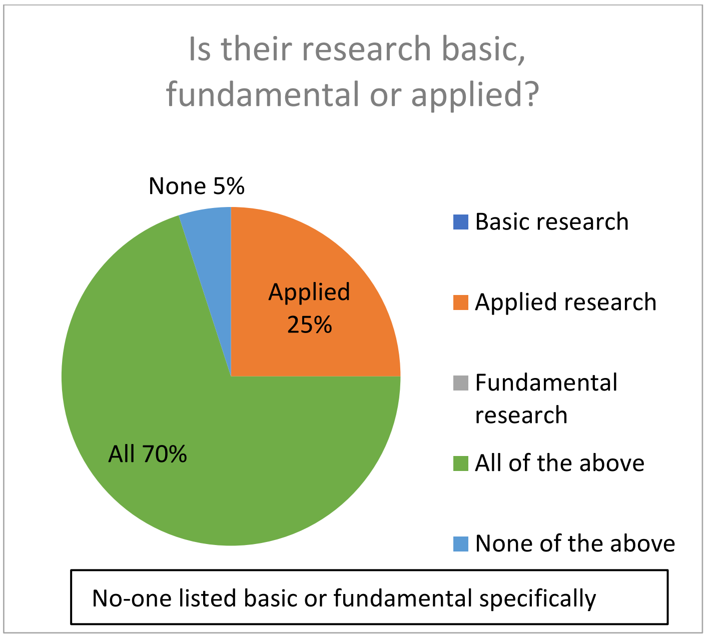
We asked about **current interests and drivers** across plant and agricultural science in Australia. We included questions of the **efficacy of existing research infrastructure** available to Australian researchers and industry to meet their current needs, and we asked about f**uture trends and infrastructure requirements** to facilitate and accelerate innovation in plant phenomics and agricultural science more broadly.=

This word map gives some indication of the key issues, themes and subjects:



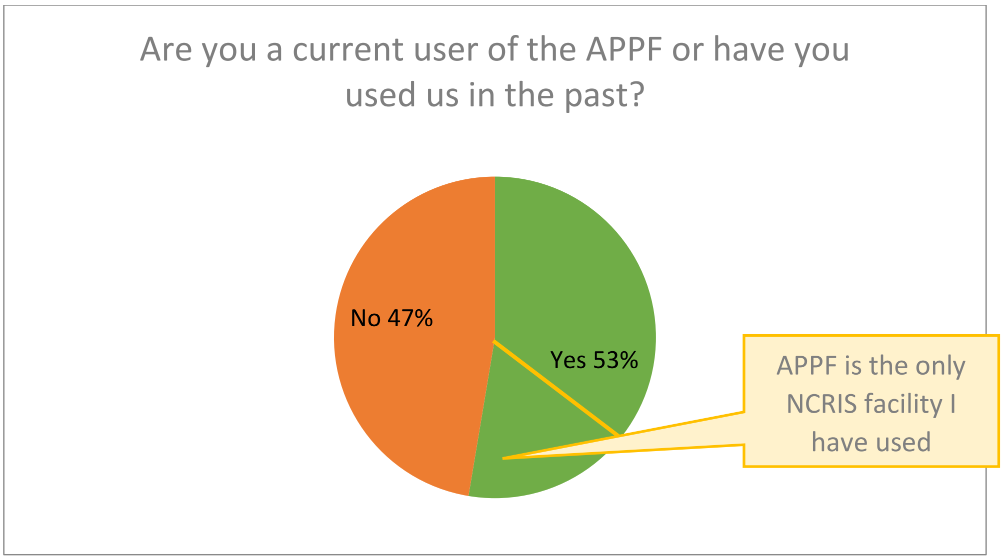
Who responded?





Respondents had a range of occupations, although in the main they were research scientists, professors, associate professors, research fellows and plant breeders.

About half of the people who responded to our consultation were current or former users of the APPF facilities, and for around a third of them, the APPF was the only NCRIS facility they had used.



Field phenotyping is a focus (75%), followed by greenhouse and climate chamber. Cereal crops were emphasised by all respondents, followed by model species and legumes. Pastures and woody species were noted, while horticultural crops and fruits crops were mentioned by just five per cent.

How do our research stakeholders use phenomics?

Our research stakeholders are using phenomics for a wide range of applications and measuring a wide range of traits.

Traits of interest include:

- growth, biomass and yield
- shoot and root architecture
- physiological, agronomical and post-harvest
- leaf, cellular, tissue and flower traits

The main applications of phenotyping in research include:

- sensor development
- screening for biotic and abiotic stress responses
- product development
- plant breeding
- plant physiology Resource-Use-Efficiency (RUE)
- optimisation of growth conditions

Phenotyping systems currently being used include manual, UAVs, portable, and hyperspectral imaging, through to deep phenotyping (CT, NMR etc.).

Not surprisingly, fewer want to use manual systems and there was a strong indicated demand for more access to satellite imagery, deep phenotyping systems, hyperspectral imaging, and cheap/affordable phenotyping tools.

While they are phenotyping mostly at a millimetre (45%) centimetre (85%) and metre scale (65%), it is interesting to note the range of scale respondents would like to observe range from kilometres (41%) right down to micrometres (46%) and nanometres (29%).

Emerging trends, challenges and opportunities facing agriculture and plant science and drive researchers and industry in the coming decade(s)

The question of trends, challenges and opportunities was clearly of great interest with many thoughtful responses. Headline trends, challenges and opportunities included:

- Climate change and crop adaptation, sustainability and quality, heat stress and water deficiency
- Data: dealing with massive amounts generated, data extraction pipelines, centralised repository to enable meta-analysis, throughput, accessibility and storage, and the growing divide between those able to take advantage of digital technologies, and those who can't
- Making phenomics tools easier to use and focussed on solving problems, including agronomy and decision support for farmers
    - Prediction agriculture - digital technologies to support smart farming decisions
    - Application of machine learning and real-time data processing
    - Drone technology – with good analysis tools
    - Application of existing tools to screening for disease resistance, early disease detection both in experimental conditions and farm management
- Agricultural challenges need original thinking and new paradigms
    - We need to increase the rate for yield increases to meet future population, produce more resilient plant varieties adapted to hotter and drier environment and higher value crops

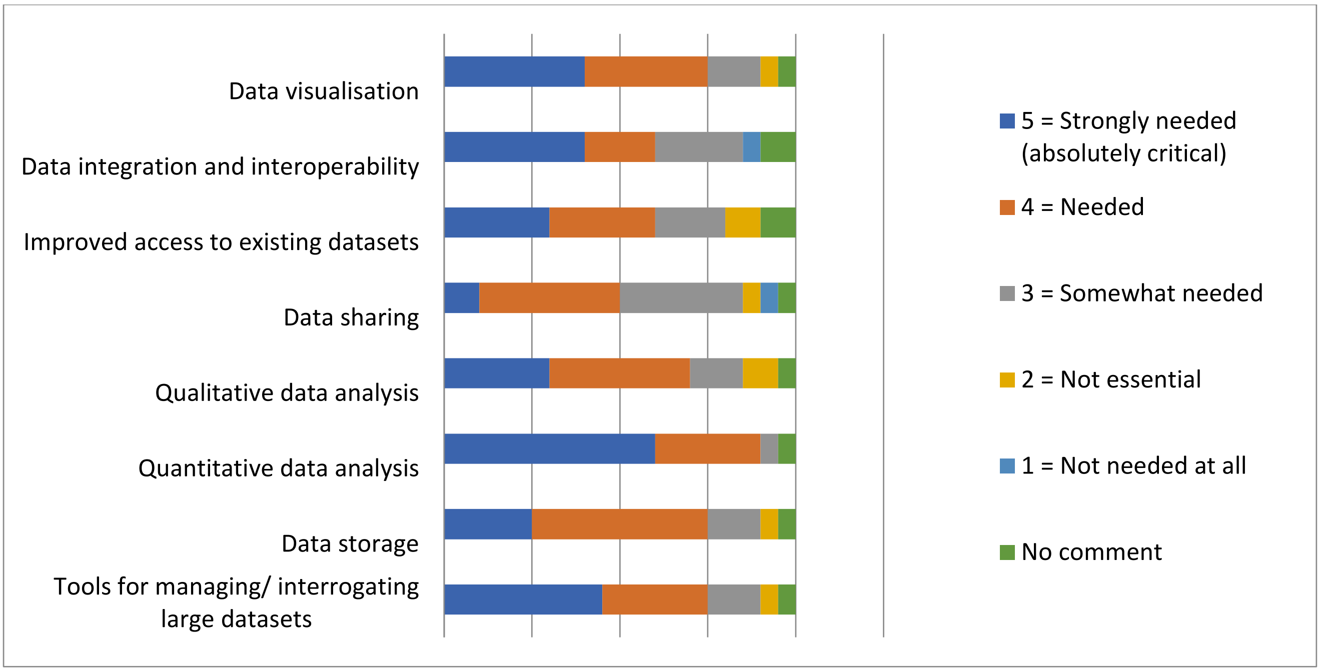
- A focus on productivity and crop performance – designer or engineered, look at complex traits. Dynamics, interactions and system engineering will be key

- Higher demand (Asia) for higher quality protein
- Root phenotyping
- Point of origin tracing, GMO vs non-GMO plant product quality assessment tools and standards
- Leadership, funding and investment

Data management

Our consultation asked about needs in data management, eliciting requests for:

- Simple tools which make complex mathematics accessible to non-experts
- Discoverable and accessible datasets allowing re-use of data and possibilities for collaboration and development of new applications
- Cost effective and accessible storage options, perhaps there is scope for work on new data compression approaches, designed to suit specific purpose
- An element of data management in the context of actual current plant phenotyping ability
- Georeferencing the data
- Capacity to connect data through software as a service (SAAS) pipelines to enable scaling up of processing analysis
- Better software tools to analyse raw data coming from plant phenomics platform at scale.



Integration with other NCRIS facilities

When considering which other NCRIS facilities were important for our research stakeholders, a significant proportion noted that they were users of Bioplatforms Australia, with Microscopy Australia, National Computational Infrastructure, Pawsey Supercomputing Centre, ARDC, TERN and Phenomics Australia also mentioned as being relevant for consideration around integrated approaches.

When asked how their research might benefit from a more integrated relationship with other NCRIS facilities, respondents highlighted several opportunities for access, complementarity, flexibility, and integrated approaches, including:

- Access to **data**, equipment, data analytical tools and expertise, access to other datasets for comparison and **integration** of different data sets
- Integrated approaches leading to stronger commercial offerings and impact
- Advances from integrating data, which an integrated NCRIS relationship could greatly enable
- More integration between NCI and APPF. APPF has growing computational needs but the application process for NCI
- 'Whole of project' engagement with NCRIS giving advice on other services that might aid a project

What technologies would help, and where are the bottlenecks?

Field access was identified as essential with almost 70 per cent of survey respondents asking for on-site non-invasive phenotyping, 53 per cent asked for remote phenotyping (e.g. high-resolution satellite), crop modelling and machine learning. Portable phenotyping was raised by 47 per cent.

The clearest bottleneck was funding (71%) followed by image analysis and existing platform locations. Data management and usage, software, qualified personnel, and inter-connection to other disciplines were also seen as bottlenecks. Throughput, inadequate construction of novel platforms and inadequate access models to existing infrastructure were not rated highly as bottlenecks.

What phenotyping or sensing technology is currently lacking in Australia?

Australia was seen as a world leader in plant phenomics, particularly in field phenotyping and direct application to crops. However, one comment pointed to most technologies being available in Australia, but they haven’t been applied specifically to plant breeding. Another pointed out the technology is available but at a single location, while another said there was too much focus on method rather than application or target.

In terms of specific technology lacking: root and below ground phenotyping were raised by several respondents, including high-throughput automated root phenotyping, root phenotyping at scale, and root system phenotyping facilities.

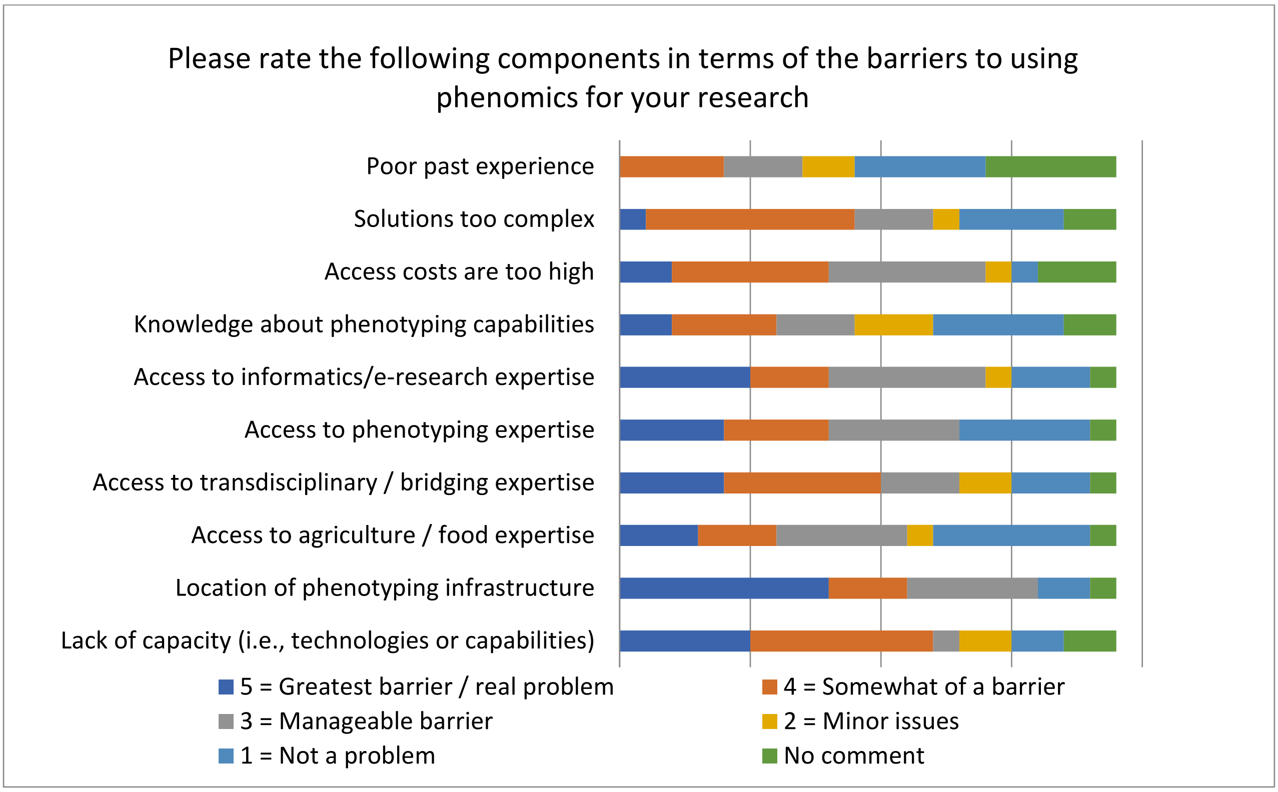
Utilising high-resolution satellite imagery, HR thermal (drone solution) and hyperspectral imaging, high-security facilities, and new sensors were all seen to be lacking, as was a focus on quality trait/compositional assessments of plant materials in a non-invasive way.

Remote sensing for field crops was highlighted, including the need for software analytics of raw data. Another respondent noted a need for phenotyping and sensing technology for multiple diseases and separation from hyperspectral data to aid in identifying severity and/or specific pathogen types.

A final and important point suggested we also need more integration between what the phenotyping community can do and the type of traits and solutions the breeders are willing to invest in.

Greatest barriers to using phenomics in research

Specific comments on barriers noted that researcher/program access may be limited due to IP constraints around data ownership/capability. Another noted that rather than physical infrastructure, it is access to a group that has the ability, will and knowledge to help me in my research that is important. “We need a collaborative environment”. Awareness of phenomics was also seen as a possible barrier, as was any further centralisation of controlled environment facilities.



Phenotyping / sensing needs to accelerate innovation and advances

Scale was identified as essential to accelerating innovation and advances - in more locations enabling movement from specialist facilities and small plot breeding trials to farm-relevant field scale and translation from lab to field. Respondents asked for large scale managed environment facilities with capability to reliably control climate in the field, as well as facilities with advanced sensing and environmental control.

To do this, it was suggested we will need a better understanding of farming, agronomy and the decisions that farmers need to make. Specific suggestions included for:

- High throughput plant phenotyping and automated **root** phenotyping
- Better sensor technology for roots, shoot hyperspec and 3D phenotyping
- More expertise in machine learning, AI and big-data processing to exploit data acquired
- Software development, in line with computational capacity and data storage
- Rapid and reliable phenotyping facilities. Especially for root system studies
- The need to be able to screen new germplasm very early in the selection process
- Scaled up sensing of resource use to guide management and reduce risk
- Infrastructure and tools that operate in high resolution - coupled with analysis and storage
- An ever-increasing focus on low-cost and easily accessible phenotyping, price, ease of use and analytic solutions for a wider adoption
- Infrastructure + expertise in an innovative environment
- Connection of measurements to value chain for food provenance and QA

- The capacity to geo-reference data, connection of phenomics data to yield forecasting models to guide logistics and market participation
- Field transpiration rates in particular at the small scale
- Interdisciplinary collaboration, training of user/expert community around plant phenomics
- Data assets and sharing infrastructure of phenomics data

What are the gaps?

The focus of responses was in providing **open** access, including open-source solutions. Also, there was seen to be a gap (internationally) between breeders, agronomists and farm management.

The survey results again reflected a need for an increased focus on the **farm**, with more involvement from agronomists, better integrated solutions, decision support to farmers and real-time crop monitoring from satellite. This was also explained as being able to move beyond phenotyping to link with the experimental base needed for prediction agriculture approach to broadly-based crop improvement.

Data integration from several sources was seen as a gap, as was the connection between data scales (plant/ paddock scale to regional, to satellite scale). Other data gaps identified included making data products more useable so that each data point has (common) attributes to enable rapid data processing, analysis and reuse, and offering simple and affordable hardware and analytical solutions to solve problems – at a sensible cost.

Plant-focused microscopy and 3D cellular image reconstruction, UAV and robotics and facilities linking with genomics-phenomics and reliable field phenotyping facilities were seen as gaps.

The benefits of freely available major national-scale data assets

When discussing the gaps, we asked about the benefits of freely available major national-scale data assets and all options suggested were seen as needed. Integrated data on plant development and yields across differing environments and treatments (GxExM) was seen as strongly needed and absolutely critical by half of the respondents. As was 'predictive models for crop productivity under climate change scenarios' and 'G2P – Integrated genomic + phenomic datasets for crop panels.'

The APPF can play a key role in establishing data assets

When thinking about the APPF playing a key role in the establishment of data assets of national interest and importance, there were a number of suggestions for consideration, including:

- Open access where possible and the capacity to reuse data, consider privacy, co-ownership
- Good communication with researchers/groups regarding availability/access of various data sets
- Why are datasets needed, by who and for what? What's the actual impact of these datasets relative to cost of provision?
- Need to mature the discussion around data value with appropriate conditions/ restrictions on reuse
- Having a research "panel" of technology end users, to ensure pipeline and applications are development alongside methodology
- Partnerships with RDCs and focus on a few exemplar datasets e.g. National Variety Trials
- Having processes to manipulate and add value to data – available and easy to use
- A core collection of phenotyping of Australian held or developed crops linked to biological material stocks, enabling to request say - BPA to - sequence a gene, analyse a chemical profile etc.

What would national research infrastructure that transforms research and innovation in plant science and agriculture look like?

The findings in relation to this last question point to transformative infrastructure that was high throughput, low cost (free access), applicable in the field, as well as national and distributed to meet both industry and research capacity at the point of origin/action.

Ideally, we would be world leading in new fields for phenotyping with a better overarching model of funding that contains all the funding bodies, and with key facilities (large scale) in major agricultural regions of Australia - linked and jointly funded, and industry-facing.

A transformative research infrastructure would be multi-nodal with overlapping facilities, have specialist sites for high cost or high technical demands, integrated data sharing and analyses, automated data analysis, and training as an essential.

The ideal infrastructure would provide consistent (high-throughput) phenotyping for the most important traits, networked across the country, providing data integration and consistent analyses. It would deliver broad scale from the cell to the satellite across many environments, with consistent reporting of protocols and results, and have shared experiment, data and protocols.

Interestingly, one suggestion was to include social scientists to bring human-centred design to plant phenomics, enabling deeper understanding of problems and opportunities, and a greater focus on priority activities, through increased likelihood of successful technology uptake and impact.