KIT 3.7

Identify engineering solutions to reduce labour costs and/or improve the efficiency of repetitive tasks (including automation and robotics)

Impact	**Growers optimise labour, machinery and other input costs via new engineering solutions that improve the operational efficiency of on-farm tasks, which enhances profitability.**
Summary	• Growers have access to newly developed engineering solutions that reduce operating costs and improve the operational efficiency of repetitive tasks. • Growers adopt engineering solutions and operational practices to reduce costs and improve the efficiency of repetitive tasks.

OVERVIEW

The number and range of opportunities to optimise labour, machinery and related input costs on-farm through agri-engineering and automation is increasing rapidly. The development of enabling technologies in sensing and perception, telemetry, electrification of drive trains and the implementation of controls for improved precision are supporting quick progression toward fully autonomous farm operating systems. To understand the nature of the opportunity in Australian broadacre cropping systems, it is important to first understand the on-farm drivers or constraints to be overcome through development and implementation of new agri-engineering and robotic solutions.

Australian grain growers typically invest heavily in farm machinery compared to many other countries. Many Australian grain growers have a ratio of machinery investment to gross farm income of 0.7 to 1.1[1,2]. A survey of West Australian grain growers completed by Corporate Agriculture Australia has shown that while the discrepancy between the top 20 per cent of farm businesses and the 'average' performing business can be large, even the most profitable businesses still have a machinery investment to income ratio of 0.56 (table 1).

Other metrics related to total plant, machinery and labour (TMPL) can be used as a basis to assess the overall utilisation efficiency of a farm business' investment into machinery and labour. The TMPL metric factors in costs associated with fuel and oil, depreciation, interest on plant and machinery, repairs and maintenance, contract work, wages and imputed labour (generally family labour). Using the dataset presented in table 1, even the most profitable farm businesses in Western Australia spend approximately $670,000 per annum on TPML.

There are many factors that determine if a business is efficient with its machinery purchase and usage. Ownership costs in the form of interest and depreciation are part of this equation but so too are operational costs. Additionally, the timeliness of operations is a critical component but one that is hard to benchmark given it can vary significantly between and within different types of farming businesses. Nationally coordinated research identifying the primary drivers of the yield gap – the gap between what crop yield's growers achieve relative to the modelled estimates of what they could actually achieve – has shown that optimising time of sowing is the most important management practice associated with the closing of the yield gap[3]. However, one of the practical challenges associated with optimising the time of sowing is the ability to cover large areas within a tight timeframe.

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[1] Fact sheet: Machinery Utilisation. (2018). Grains Research and Development Corporation

[2] Fact sheet: Are machinery and labour decisions eroding your profit? (2018). Grains Research and Development Corporation

[3] Hochman, Z., & Horan, H. (2018). Causes of wheat yield gaps and opportunities to advance the water-limited yield frontier in Australia. Field Crops Research, 228, 20-30. doi:10.1016/j.fcr.2018.08.023

Table 1. Machinery and labour utilisation efficiency derived from a survey of West Australian grain cropping businesses between 2009-2013 via GRDC investment RDP00013 – The integration of profit drivers and technical data for more informed decisions.

	Top 20%	Average	Difference	
			+/-	%
Total effective hectares (owned + leased + sharefarmed)	4591ha	4530ha	51ha	1.1
Total cropped hectares	4225ha	3675ha	550ha	15
Cropping % (of effective Ha)	92%	81%	11%	13.6
Total Plant, Machinery, and Labour as a % of income	23.80	27.53	-3.73%	-13.6
Total Plant, Machinery, and Labour $ per effective Ha	$159	$154	$5	3.2
Machinery Investment to Income Ratio	0.56	0.69	-0.13	-18.8

Large-scale farm machinery can cover large areas in small amounts of time but often at the expense of functional redundancy. For example, following a machinery breakdown an entire seeding or harvesting operation will stop if it's dependent on one machine that's critical to the entire operation. When this occurs the proportion of work undertaken relative to the amount of downtime drops significantly. Downtime can also be affected by factors other than breakdown such as time spent roading to the paddock, filling, refuelling and/or making equipment adjustments. Downtime can typically be minimised via use of newer machinery which poses less risk of breakdown during an agronomically time-sensitive operation. However, the high upfront cost and rapid depreciation rate associated with purchasing large-scale new farm machinery (i.e. tractors, combine harvesters and self-propelled boom-sprays) can significantly reduce a grower's machinery investment to income ratio and operating profit per hectare. While other factors such as a low interest rate environment may warrant higher investment in machinery to minimise the risk of downtime, the typical trade-off between downtime/production risk and cost/depreciation rate is represented schematically in figure 1. This relationship leads some growers to utilise contractors to perform certain in-crop operations and helps highlight some of the drivers for lower-cost robotic systems to replace traditional farm machinery requirements.

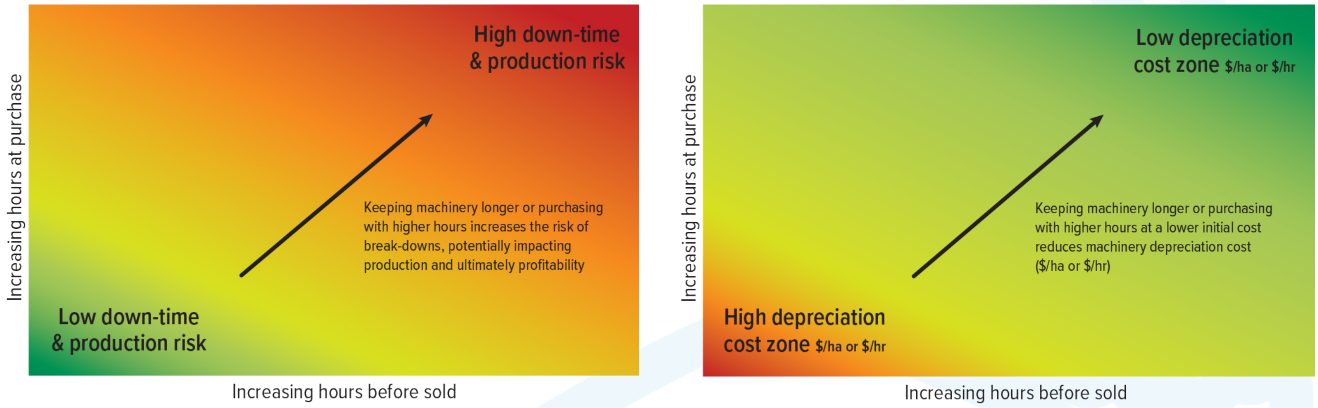

Figure 1: The inverse relationship between low machinery downtime and high cost (i.e. depreciation rate) poses a challenge to Australain grain growers who need low downtime to undertake time-sensitive agronomic operations at scale, but at the same time, want to minimise expenditure on new farm machinery which depreciates rapidly[4].

[4] White and Warrick (2018). Replacing Machinery: Kwinana West, Grains Research and Development Corporation.

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Globally, the demand for new machinery, engineering, and robotics solutions is driven by a reduction in the availability of appropriately skilled staff and a shrinking experienced farm labour pool. The relative technical knowledge requirements for skilled farm labour is also increasing with system specialists often required for the service, repair and maintenance of modern equipment. In addition to addressing skilled labour shortages, automation is often implemented to improve the uniformity and precision of on-farm operations. Evolving robotic systems have demonstrated an ability to deliver a greater level of consistency and accuracy of in-crop operations. Uniformity of an initial operation, for example seeding, enables further autonomous solutions to be applied for subsequent operations such as weed control.

Many robotics and automation solutions typically focus on smaller machines in multiples to reduce functional redundancy and risk of downtime. This is juxtaposed to current conventional farm machinery trends which are for larger more powerful and higher capacity equipment. This evolution is likely to see a combination of approaches adopted by Australian grain growers depending on the agronomic operation, farm scale, farm business structure, financial position and the technical capacity (i.e. state of internet connectivity and landscape features) to implement fully autonomous solutions.

Observations of a still-evolving global autonomous farm equipment sector sees many completely automated solutions focussing on small-module, replicable, and higher-volume production models. The new autonomous farm equipment sector also typically delivers the new technology through new business models such as alternative equipment ownership arrangements as well as different operation and servicing structures including straight lease only options and pay per use fee for service arrangements. The major market for autonomous equipment designed for broadacre and row cropping is in Europe and North America where market forces and market serviceability are more concentrated. While there are some autonomous solutions developed and designed for Australian conditions, many solutions are adaptations or modifications to equipment designed for European or North American broad-acre or row cropping situations.

The introduction of autonomous on-farm operations solutions will need to adhere to regulatory frameworks enabling public confidence in the safe operation of this equipment. These frameworks are likely to be important in helping de-risk the commercial roll-out of autonomous technologies and ensure the prevalence of a social license to operate autonomous technologies on-farm. Compliance requirements around welfare, health and safety of personnel involved in on-farm operations is increasing. As part of this there is also an escalating drive to reduce operator and environmental exposure to risks including fatigue or exposure to chemicals. Engineering solutions with in-built safety features could help see the automation of some on-farm tasks that might otherwise pose an occupational health and safety risk to on-farm staff.

It's clear there are major trends evolving in agri-engineering globally which will affect Australian grain growers. These trends are important considerations when positioning GRDC investments into agri-engineering (including robotic and autonomous) solutions. Primarily, GRDC will look to invest in two complementary areas: The development of new engineering solutions, and the adoption of new and existing engineering solutions.

FUTURE RD&E FOCUS

SCOPE – New engineering solutions to maximise the operational efficiency of repetitive tasks and optimise operating costs

GRDC will look to coinvest in the development of a range of possible agri-engineering solutions, whether they be fundamentally new technologies, adaptions of existing plant and machinery or locally fabricated solutions to meet specific operational needs in Australian environments. The GRDC's primary investment consideration is the value derived to Australian grain growers, which is in turn dependent on factors such as the cost of development and adoption relative to the value derived on-farm. Assessment of the viability of using or establishing distribution channels and having adequate servicing and support structures will also be considered to ensure there is a viable path to market for the outputs of GRDC co-investments in the underpinning science.

GRDC has flexible mechanisms for investment that could include direct co-investment via the Grain Innovate venture fund or co-investment through traditional RD&E channels. Investments in basic research – high risk/high reward opportunities – right through to locally relevant, 'niche' fabrications to value-add the performance of existing plant and machinery in Australian grain production systems are all firmly within the scope of Key Investment Target (KIT) 3.7.

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Investment Outcome 3.7.1 – Growers have access to new engineering solutions that improve the operational efficiency, performance and value derived from existing and new on-farm machinery and physical infrastructure.

Australian grain growers typically have large investments in farm machinery and infrastructure such as silos and grain storage systems. As such, approaches to maximise value gained from existing machinery and infrastructure provide a clear basis to improving their profitability. These approaches could include innovative after-market solutions to improve the field efficiency and/or reduce wear and tear of existing farm machinery i.e. automated solutions that improve the ease of deploying and working with grain bags and bunker tarps for in-field grain storage. There will be clear synergies between Investment Outcomes 3.7.1 and 3.7.3 and those within both KIT 4.3: Improve the reliability and effectiveness of on-farm grain storage to reduce handling costs and capture market opportunities, and KIT 4.4: Improve the automation of transport and handling activities and/or alternative logistics and distribution models to realise greater value capture by growers.

Approaches aimed at improving the efficiency of plant and machinery that's used to perform repetitive on-farm tasks has potential to deliver economic benefits to growers at several levels. The more efficient usage of expensive farm machinery could help in reducing the depreciation rate, running, repair and maintenance costs of that equipment. For example, the engine hours of a self-propelled boom-spray are one of many determinants of its capital value, yet just as many engine hours can be associated with filling, turning and roading (travelling to and from paddocks) as those involved during actual in-paddock spraying. In this scenario, an approach that optimises the path and movement of a self-propelled sprayer from shed to paddock and back and forth to refill stations in between (i.e. mission planning) could help reduce overall engine hours per hectare sprayed. It could also help support the application of foliar crop protection products within agronomically time-sensitive windows. This approach could also involve the construction of low-cost capital items such as chemical batching and induction plants to help save significant time on refilling. At an approximate cost of $10,000 for a chemical handling unit[5], and a nominal cost of $300/engine hour to operate a self-propelled boom-spray, the reduction in filling time could see the capital outlay for a chemical handling unit be quickly recovered.

Investment Outcome 3.7.2 – Growers have access to new engineering solutions and/or robotic systems that improve the operational efficiency and costs associated with repetitive agronomic operations such as seeding, spraying and harvesting.

Agronomic benefits from new agri-engineering solutions could be realised through improvements in the precision of operations (e.g. greater control of seeding depth and targeted spray applications) and/or the timeliness of operations. These agronomic benefits could come from enhancing existing, large scale, traditional tractor-implement configurations and/or via smaller, fully autonomous fleets of agricultural robots. To deliver value to growers through a new agri-engineering solution, it's imperative to understand the nature of the task and the biophysical constraints to realising an improved agronomic outcome, irrespective of the type of agri-engineering solution in question. For example, a fleet of autonomous robots obtaining improved precision of seed placement will be of little benefit if the throughput of the system (hectares covered per hour) prevents a grower from seeding during the agronomically optimal window. In this case, the economic benefits derived from precision seed placement using a robotic system would likely be outweighed by the negative agronomic impacts (yield penalties) associated with missing the optimum sowing window. However, other factors such as a reduction in fuel costs obtained using hybrid systems with electrification or alternative fuels could, in the future, offset the operating costs associated a robotic system[1], thus allowing more units to be purchased to match the throughput capacity of a conventional system. The electrification of powertrains and systems controls (i.e. using electronics instead of hydraulics) is likely to help ease the implementation of robotic systems while also delivering tangible benefits to existing, large-scale farm machinery. Electrification typically offers high-level control of implements and efficient power delivery. Diesel-electric drivetrains developed for autonomous equipment markets may, in the interim, see hybrid drive solutions deployed and adapted to existing engineering solutions. For example, electric drive technology on existing equipment may help accelerate the implementation of fully autonomous systems.

Clear consideration of the agronomic, financial and tactile (i.e. physical and mental) costs and benefits of different approaches is crucial to ensuring that any new agri-engineering solution will deliver a clear benefit to growers and as such have a viable market fit at a given point in time. The commercial viability of any new agri-engineering solution will

[5] Kondinin Group (2019). Farming ahead research report: chemical batching plants.

require not only sustainable sales volumes but the ability to provide timely servicing and support, backup facilities and locally obtainable parts. Leasing models employed by some autonomous solution providers may see an alternative approach to equipment purchase, but they also come with different risks to both lessees and leasers. Engineering solutions or robotic system solutions also need to be suitably robust to be adapted to Australian cropping environments. They need to account for temperature extremes, high levels of dust which can affect the quality of Bluetooth connections between tractor and implement, and heterogenous paddocks with different shapes, sizes and obstacles such as rocks, stumps, trees and power lines. They also need to apply variable rate technology in some way, shape or form to manage production constraints which vary across time and space, such as patches of herbicide resistant weeds. All these factors affect the ability of a new engineering solution to deliver value to Australian grain growers.

Investment Outcome 3.7.3 – Growers and industry have access to new engineering solutions and/or robotic systems that improve the on-farm operational efficiencies associated with the handling and distribution of farm inputs such as fertiliser and crop protection products, as well as farm outputs.

Operational efficiencies associated with the handling and distribution of inputs can have a large bearing on the field efficiency of farm machinery. The efficiency of the operation, whether it be seeding, spraying, spreading or other related task, is affected by the efficiency with which products can be transferred from where they are stored to the application equipment operating in the paddock.

In some circumstances, the handling of inputs prior to commencing an in-paddock operation can negatively impact operational efficiency as much as the operation itself. For example, the mixing of legume inoculant (a slurry-like substance) with legume seed to ensure good nodulation of legume roots involves a process that is tedious and presents occupational health and safety risks to the operator (see[6] for further information). The process is also time-sensitive, in that the time between the mixing of seed and inoculant and planting needs to be minimised to ensure optimal results. An approach to automate a process using a low-cost, fit-for-purpose design that saves labour units and reduces the safety risk to growers and their staff could have a clear impact on operational efficiency. Other rate-limiting steps within an on-farm operation such as the filling of chemical nurse tanks and loading of fertiliser and soil ameliorants into spreaders could lend themselves to automated solutions.

SCOPE – Maximisation of awareness and adoption of engineering solutions that improve the operational efficiency of repetitive tasks

Australia constitutes a very small portion of the world farm machinery market (nominally around 2 per cent). Only a small portion of plant and machinery used on farm is specifically designed for grain production in Australia. Much of the equipment used on farm is adapted to Australian conditions having been designed and fabricated by North American and/or European manufacturers. This has in turn spurred the development of bespoke engineering solutions that meet the needs of Australian grain production systems. Some of these solutions are based on improving agronomic outcomes within a farming system via simply adding functionality to existing machinery, for example, equipping a harvester with a chaff lining chute to enable harvest weed seed control. Others are designed to improve the in-field efficiency of the machine itself, for example, equipping a harvester with a reconfigured feeder to minimise grain losses when harvesting canola with MacDon header fronts (figure 2).

Off-the-shelf technologies provided by original equipment manufacturers and/or after-market providers (e.g. spot-spray systems and autosteer) can have a demonstrable impact on the efficiency of an operation when applied at the scale seen in Australian broadacre grain cropping (see table 1). Some examples include individual nozzle control on boom sprays and sectional and spread pattern control of inputs through adjustable, radar-monitored fertiliser spreaders to minimise under or over-application.

[6] Drew et al. (2012). Innoculating legumes: a practical guide. Grains Research and Development Corporation.

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Localised adaptations of equipment are often more targeted toward a specific aspect of an operation but can still have a significant impact on grower profitability. These low-cost, nimble adaptations can have can a cumulative effect on operational efficiency and farm profitability when applied to repetitive tasks at scale. They can help realise growers realise 'one percenter's – small individual changes that have a large overall impact – from relatively simple engineering solutions[7].

Figure 2: Examples of after-market bespoke engineering solutions developed for Australian grain production systems. A chaff-line chute build using readily available on-farm inventory (left) by grain grower Matt Johnson enables him to concentrate weed seeds in a row of chaff for harvest weed seed control. The Typhoon drum (right) is an aftermarket fix for bulky crop feeding issues when using MacDon header fronts. The spiral drum replacement enables improved feeding and durability to stop choke loads of canola causing damage.

There are multiple opportunities to help growers realise enduring profitability via facilitating the adoption of different types of engineering solutions, whether they be new technologies, existing ones, or local adaptations. Factors affecting adoption are typically related to the awareness of new solutions and knowledge of their fit and cost-benefit within a farming system. From a strategic perspective, it is primarily, but not exclusively local adaptations and inventions where GRDC will seek to co-invest in facilitating adoption. The promotion and/or comparison of commercial new agri-engineering products is not within scope of the KIT. New and existing agri-engineering products can, and should, primarily rely on the business development and marketing functions of manufacturers to support adoption.

Investment Outcome 3.7.4 – Growers and industry understand and have the skills and tools to quantify the range of agronomic, farming systems and farming business benefits of new engineering solutions and practices intended to improve the operational efficiency of repetitive tasks.

Prior to adoption, growers need to understand the range of new practices and engineering solutions available together with the relative costs and potential benefits delivered by these solutions. The new practices referred to here are those that are not yet widely adopted, or those that employ novel equipment, technology or ways of thinking to complete a task.

Growers should be armed with evidence, or the ability to generate evidence that the engineering solution will demonstrably improve profitability for their farming business. As an example, the implementation of sectional control on a boom-spray – the automatic opening and closing of spray nozzles to minimise application overlap – is unlikely to demonstrate significant economic benefit for a treeless, uniform, long-parallel-run broadacre operation in the Victorian Wimmera, but the same technology could see inputs reduced by as much as 15 per cent for the same cropped area in a heterogenous environment such as Brookton, Western Australia. Growers should be able to understand and apply a cost/benefit analysis to help judge the fit of an engineering solution within their own farm business. Ideally, growers will have access to flexible frameworks to aid with these decisions, including the ability to assess on the basis of both qualitative

[7] Fulwood, J. (2020, May 15). Farming on the edge: One-percenters make a difference. Retrieved June 11, 2020, from https://groundcover.grdc.com.au/story/6742671/farming-on-the-edge-one-percenters-make-a-difference/

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and quantitative information/data. Some of these tools are already offered by farm business consultants who are well equipped to aid growers in developing machinery replacement schedules and purchasing decisions based on various financial metrics. Examples of new practices include:

- Lower draft, higher efficacy, shallow-leading tine deep rippers with topsoil slotting plates
- Seed singulation equipment to reduce the costs associated with hybrid canola seed and improve performance
- Improved mixing of topsoil and subsoil layers via adaption of one-way ploughs with larger mixing discs, and invention referred to as the Plozza Plough.

The benefits obtained from implementing more than one agri-engineering solution can quickly compound by means of an additive effect on a subsequent operation. For example, technology to dynamically optimise tractor tyre inflation pressure can reduce the need for tyre ballasting and improve tractive efficiency and fuel efficiency during operation. When combined with in-field efficiencies gained through electric-drive systems and path planning optimisations, there could be compounded gains achieved via improved timeliness of operations and reduced machinery wear and tear, thus also reducing machine depreciation costs. Depending on the stage of the invention, the prospective agronomic and financial benefits to an individual farming business could be demonstrated through agroeconomic modelling and simulation studies provided via farm business consultants, via peer to peer learning networks, and/or via other means.

Investment Outcome 3.7.5 – Growers and industry are adopting engineering solutions and practices that can be used to maximise operational efficiencies and optimise input costs.

This outcome looks to drive uptake of engineering solutions that are fit for purpose and can deliver operational efficiencies to the farming business in which they're deployed. This KIT outcome is closely related to KIT 5.2 which is focussed on understanding grain grower decision making and the drivers for adoption of new technology. Profitability is a primary driver of adoption, meaning in some situations a net increase in inputs and/or operating costs may be required to optimise the profitability of the over-arching farm business. An example of this could occur in which variable rate technology or sectional control is deployed in a paddock zoned according to production potential wherein there's a net increase in inputs, but the zone-based application of seed, fertiliser or ameliorants results in a proportionally greater increase in net profitability.

Another important driver of adoption is the nature of the problem and the tactile benefits of the solution. Engineering solutions that alleviate a strong pain-point during an operation are likely to see relatively rapid adoption by growers. For example, GPS autosteer has seen significant uptake in Australian grain production[8]. There are various drivers for this, but none the least of which has been the benefits to the machine operator who is not left as mentally and physically fatigued following extended periods of monotonous in-field operations such as seeding. In other circumstances a lack of readily accessible information on how to fabricate a niche solution, troubleshoot a machine error code or implement some other quick fix may constrain adoption of engineering solutions. In response to information gaps social media platforms, namely Twitter, have seen a high rate of adoption by growers who use them to seek help from and share advice, tips and insights with other grain growers on various subjects, especially farm machinery and engineering problems.

Some management practices such as Controlled Traffic Farming (CTF) may require investment in the development of a tailored agri-engineering solution – one that can help alleviate a machinery-based constraint to the adoption of that practice. As an example, the shift to a CTF system is recognised by most growers as a long-term goal with a recognition that CTF can reduce soil compaction, improve access to soil moisture at depth and ultimately improve profitability[9]. However, the cost and logistics of transitioning from current equipment to a full suite of machinery adhering to defined wheel track spacings is a barrier to adoption. Engineering solutions that could help facilitate this transition for growers more cost-effectively and seamlessly could help increase CTF uptake amongst growers.

[8] Llewellyn and Ouzman. (2018). Adoption of precision agriculture related practices: status, opportunities and the role of farm advisors. A report for the Grains Research and Development Corporation.
[9] Blackwell et al. (2013). Controlled Traffic Farming. Grains Research and Development Corporation.