Horticulture Innovation Australia

Final Report

Evaluation of automation and robotics innovations: developing next generation vegetable production systems

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Department of Agriculture and Fisheries

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Summary

The project investigated developments in automation, robotics and sensing with vegetable growers by focusing on industry needs rather than the technology. It provided opportunities for discussing and considering which of these technologies might be of most value to their business in the future and included on farm work with grower collaborators to explore process flow/root cause analysis methodology (Lean case studies) and prototype testing (vertebrate pest management).

The target audience was innovative growers and their service providers in three main vegetable growing regions of Queensland: the Bowen/Burdekin, Bundaberg and Lockyer/Fassifern regions; as well as researchers, machine developers and other industry and government organisations.

Grower and industry engagement activities included start and end of project survey interviews, six grower forums and 15 farm visits by researchers in the three target growing regions during May 2015, three regional review meetings in autumn 2016 and a series of follow up farm visits by the project team.

Researchers from the CSIRO and the Queensland University of Technology (QUT) as well as the Australian Centre for Field Robotics (ACFR) at the University of Sydney and the Variable Rate Technology (VRT) team from the Queensland Department of Agriculture and Fisheries (DAF) contributed to these activities. Four editions of the 'QLD Veg Automation Update' were distributed to keep growers and industry informed of project progress.

Farm visits, grower forums and industry surveys created an abundance of ideas on the potential application of automation, robotics and sensing technologies in field and shed operations with some common themes emerging. This '**wish list'** was further refined at regional review meetings and during end of project survey interviews. They are in order of priority:

1 Automated crop health monitoring for strategic targeted crop management based on various vision systems, imaging and sensor technologies to improve efficiency of field operations and better manage production risks. Further resourcing to develop and test these technologies is needed.

2 Autonomous weed management for inter/in row spraying/weed eradication based on weed detection and identification using small autonomous platforms and various vision and sensing technologies. Growers and industry saw this as achievable in the short term and were keen to have QUT's AgBot 2 and ACFR's Ladybird and RIPPA robots demonstrated and tested regionally.

3 Autonomous all purpose, adaptable platforms that are flexible and suitable for a range of tasks across various terrains and farming operations using 'plug and play' interchangeable modules to spray, soil test and assess crop health. A step by step approach using existing platforms to test, develop and implement 'modules' of new technology might bring early benefits. Growers and industry wanted a wide range of potential end users involved in autonomous platform development and on farm testing.

4 Sensing and sensor networks for horticulture to improve field productivity. The technology has application across a range of field, shed and value chain situations including micro-climate monitoring in crops, quality monitoring and maturity testing, product tracking and vertebrate pest management. Some of this technology is already in use in agriculture, for example GPS auto-steer, multispectral imaging (NDVI), load cell yield monitoring and irrigation scheduling.

5 Robotic harvesting of tropical and sub-tropical horticulture crops - step by step approach – overlaps with automated crop management: crop forecasting, maturity assessment, vision systems, sensing, imaging, autonomous platforms, manipulators and grippers. This was seen as THE priority across all regions, as high impact but difficult, was the top aspirational response in surveys and the topic of discussion during most farm visits. It was seen as still some time off in the future and needing substantial R&D investment which probably explains the relatively low ranking.

6 Increased packing line efficiency – defect sorting before product enters the packing line.

7 Increased packing shed efficiency – automated/robotic palletising and product tracking.

For shed operations, the key driver is labour – how to reduce but also how to use technology to simplify packing decisions for staff where there is high turnover and low skill levels. There was some discussion about what technologies might already be available off-the-shelf and the reasons for why these technologies are not more widely used. There is a need for an in-depth review of technologies already available, their application and suitability for horticultural packing sheds.

Through the **Lean case studies**, review meetings and end of project survey results, we know that progress has been made in this area. Equipment is improving with existing graders and defect sorters re-calibrated and several growers investing in this technology over the past two years. Growers are also investigating and improving automated palletising operations.

8 Managing vertebrate pests in vegetable crops based on wireless sensor networks to detect and deter pests such as wallabies in tomato and birds in various crops. Preliminary work with CSIRO is underway with a small wireless sensor network deployed on a Gatton farm as part of the **prototype testing** component of the project. A small DAF innovation project will continue the work during 2017. CSIRO have patented the concept and are in discussion with DAF, industry and Hort Innovation to investigate options for scaling up and fast tracking the this research to commercialisation.

9 Virtual fencing for mixed farming operations based on wireless sensor networks (under CSIRO patent) was of particular interest to North Queensland growers. The start-up company Agersens is currently working towards commercialising virtual fencing for the beef, dairy and sheep industry.

Our project evaluation shows that the number of vegetable growers, agronomists, consultants, regional engineering firms and other service providers actively engaged and aware of developments in automation, robotics and sensing has increased over the past two years and that project activities have contributed to this outcome. We now have a better understanding of:

- Grower and industry priorities for R&D in automation, robotics and sensing
- The challenges, constraints and potential opportunities for commercialisation and adoption of these emerging technologies including return on investment (ROI) and payback considerations
- The applicability of Lean concepts and tools for process flow/root cause analysis to increase productivity of horticultural businesses

There is evidence that the project has contributed to improvements in operations on several farms (grading and defect sorting, machinery shed, staff management).

The project work has identified mechanisms for building effective feedback loops between all sectors of

industry. Webinars, newsletters, workshops, farm visits, prototype testing and grower surveys have all served to enhance industry awareness, communication and collaboration.

Grower targeted activities need to be short, sharp, topical and focused on potential impact on farming operations. Personal relationships and follow up increase the effectiveness of these mechanisms. There is scope to better build on existing regional networks by collaborating to add value rather than competing with the locals.

The DAF/QUT/CSIRO collaboration VG15024 Vision systems, sensing and sensor networks to manage risks and increase productivity in vegetable production systems will address several identified industry priorities but also aims to continue the grower and industry engagement process in the regions.

Project activities have established and strengthened interactions and networks, identified expertise and research capacity for future regional collaborations between growers, industry and researchers. Farm visits by researchers were particularly valuable and may lead to several future collaborative R&D proposals.

There is opportunity to build on the positive media image this technology is attracting for agriculture: an innovative industry with interesting opportunities for the professionals of the future.

Keywords

Automation; robotics; sensing; industry engagement; extension; vegetables; MARS; technology implementation; innovation;

Introduction

Over the past few years, there has been a lot of activity and excitement in the 'Robotics in Agriculture' space. Why is it such a hot topic?

Australian fruit and vegetable growers have for many years faced continuous pressure to supply fresh, perishable product at ever reducing margins. In response, enterprises have scaled up production volumes, diversified their enterprises and markets and continue to strive for greater on-farm efficiencies. Cost, quality, reliability and supply of labour are major constraints to industry profitability, expansion and the development of profitable, sustainable export opportunities. It is this promise of reduced labour inputs coupled with potential efficiency gains that makes automation and robotics look so attractive.

Over the past three decades, a great deal of research has gone into developing mechanisation, automation, robotics and sensing (MARS) technologies. A small percentage of this technology is now considered standard practice in horticulture, for example colour sorters and GPS guidance. Much research however never made it past the prototype stage.

There have been some critical break-throughs in MARS research uptake in the defence, mining and manufacturing industries and some of this work may be of value to agriculture. Over the past five to ten years, state and federal governments and the horticulture industry itself have invested in a number of initiatives to progress MARS innovations:

- National MARRS workshop and report - HG09044 Scoping study to review Mechanisation, Automation, Robotics and Remote Sensing (MARRS) in Australian Horticulture (2009)
- Prioritisation of vegetable crop commodities and activities for mechanisation – VG13081 Tasmanian Institute of Agriculture (TIA), University of Tasmania (2015)
- The Ladybird and RIPPA the weed zipper - VG12104 An intelligent Farm robot for the vegetable industry, Australian Centre for Field Robotics (ACFR) at University of Sydney
- Agbot 2 and Harvey the capsicum harvester – Strategic Investment in Farm Robotics (SIFR) program, Department of Agriculture and Fisheries (DAF) and Queensland University of Technology (QUT)
- GMX-INNOV-312 Adoption of variable rate technology (VRT) in Queensland's intensive vegetable production systems June 2016 – DAF/ Federal Government Caring for our Country (CfoC) project to develop and implement VRT on vegetable farms
- The National Tree project – Federal Government's Rural R&D for Profit, multi-group study led by University of New England (UNE) focusing on satellite imaging of orchards – mango, macadamia and avocado
- And more recently, VG15003 Using autonomous systems to guide vegetable decision making on-farm, VG15024 Vision systems, sensing and sensor networks in vegetables, VG16009 Adoption of precision systems technology in vegetable production and the new Horticulture Innovation Centre for Robotics and Intelligent Systems (HICRIS) at University of Sydney.

Are we now on the cusp of transformational changes in how automation, robotics and sensing technologies are deployed on the farm?

That is the question we explored with growers and their service providers across Queensland.

This project report outlines efforts to increase grower and industry involvement early in the research and development process. Our rationale is that by facilitating end user input early, future technologies are more likely to be fit-for-purpose and once commercialised, be more readily incorporated into field and packing shed operations.

The aim of the project was to engage potential end users - vegetable growers, regional engineering firms (fabricators), consultants, agronomists and other stakeholders – as well as researchers in a process to review current and potential automation, robotics and sensing technologies and identify industry priorities by:

- Focusing on industry needs rather than the technology in the first instance
- Discussing needs and possible solutions – individually via survey interviews and farm visits as well as in group settings at forums and review meetings
- Bringing leading researchers to major Qld vegetable growing regions and onto commercial vegetable farms
- Building communication links between growers, industry and researchers

Our target regions were three major vegetable production areas of Queensland: the Bowen/Burdekin, Burnett/Wide Bay and Lockyer/Fassifern regions.

Methodology

Project delivery was based on participatory action learning principles – plan – do – reflect – decide (Dilworth 1998) with the focus on the end user – vegetable growers, their systems, needs and capabilities rather than the technology. The aim was to better engage growers and industry in the R&D process by developing a shared understanding with researchers of what is possible and potentially of high impact.

The work consisted of two components:

1. A scoping and industry needs analysis to engage growers and industry (and researchers) in evaluating MARS technologies currently under development, explore their potential to improve on-farm productivity and determine/clarify industry R&D priorities. This included a review phase towards the end of the project to confirm priorities and evaluate project impact. Methodology, results and recommendations are described in detail in Appendix I Project evaluation, industry priorities and recommendations.

2. On farm work with grower collaborators to (i) test and further develop prototype technologies if available and (ii) investigate systems analysis concepts and tools. This work is described in detail in Appendix II Lean brief and Lean leaflet and Appendix III Prototype testing: detect and deter ducks in Baby leaf.

Linking and discovery – scoping

Starting with the capability matrix from the 2009 MARRS report (HG9044), team members identified a number of existing and emerging technologies that were likely to be of interest to regional vegetable industries. We visited the following organisations in November 2014:

- The Queensland Centre for Advanced Technologies (QCAT) at CSIRO in Brisbane (now Data61/CSIRO);
- The Australian Centre for Field Robotics (ACFR) at University of Sydney;
- Queensland University of Technology (QUT) Science & Engineering Faculty;
- Technology developers Machinery Automation & Robotics Pty Ltd (now Scott Automation & Robotics) and Applied Robotics Pty Ltd, both at Silverwater in Sydney

The response to the project concept was excellent and researchers and technology developers were generous with their time to demonstrate and walk project staff through a range of complex technologies. These initial discussions updated the project team on current plans and developments including the Ladybird at ACFR, AgBot 2 at QUT and Husky at CSIRO; various UAVs and different vision, sensing, network and data processing systems and prototypes. At that time, we extended an invitation to researchers to participate in the regional industry forums planned for autumn 2015.

Industry surveys and project evaluation

Prior to starting the initial industry surveys, the project team spent some time thinking through what information was required to evaluate project impact and how to best structure activities so they were

focused on end user needs rather than the technology.

Four Key Questions were developed to collect baseline data on awareness, knowledge, attitude, aspirations and current level of engagement. From these, we developed a set of questions to explore the current situation/understanding of automation and robotics amongst growers, agronomists, consultants, engineering firms and other service providers in the target growing regions.

One-on-one personal, semi-structured interviews were conducted from November 2014 through to April 2015 in the target areas. These interviews helped with the design as well as promotion of upcoming industry forums. The survey questionnaire was refined for the end of project evaluation two years later with the initial questions updated to also capture baseline data for the follow on project VG15024.

Start and end of project survey interviews combined with follow up visits by project team members after the May 2015 regional forums helped to further refine project work, promoted project activities and provided insights on constraints and opportunities for implementing innovations (including payback period and costings).

Connecting researchers with regional industries

QUT and CSIRO researchers accepted our invitation to visit representative regional farming businesses and participate in regional forums to highlight their current research experience and activities. Over a two week period in May 2015, DAF project staff conducted six industry forums and took researchers to 15 farms (including 8 packing sheds) in the Bowen, Bundaberg and Gatton districts.

Two forums were held in each region. At the first, researchers from QUT focused on vision systems, manipulators and grippers using their current work on harvesting greenhouse capsicum crops as a practical example. This was followed by a session on QUT's robotics platform, the Agbot 2. ACFR provided an overview of their Ladybird robot via video conferencing.

During the second series of forums, researchers from CSIRO presented examples of their research work on autonomous systems, UAVs, imaging and mapping technologies and wireless sensor networks. This led to a discussion on 'big data' with local input from the DAF Variable Rate Technology (VRT) team.

The forums gave growers, local machine manufacturers, agronomists, consultants and supporting agribusinesses an opportunity to hear about and discuss the latest in automation, robotics and sensing technologies with specialist MARS researchers. Forums were structured so that participants had time to think through and assimilate information, ask questions to clarify concepts and make informed decisions about how the technologies under discussion might be applied on farm. The two week gap between the first and second forum provided space for reflection.

Forums included a process for collecting ideas on potential technology applications and prioritising these ideas using impact and ease of implementation criteria.

This is what the technology can do now. What else might it do? How might this be useful for improving farm and shed operations?

What are the specific industry priorities that we want to follow up in each region?

The forums and farm visits were an unqualified success despite time pressures facing most vegetable growers at that busy time of the year. The May timing was chosen to ensure that visiting researchers

experienced local vegetable production while it was in full swing with crops in the ground and product being sorted and graded in packing sheds.

Farm visits, forums and the earlier industry surveys created an abundance of ideas and information - with some common themes emerging across the three production regions. Methodology and results along with a list of 'emerging industry priorities' and recommendations were described in detail in an interim project report submitted to Hort Innovation in October 2015. An updated version of this report is provided in Appendix I Project evaluation, industry priorities and recommendations.

Revisiting the region

To continue the grower engagement process, project staff held three regional review meetings in autumn 2016 to review, discuss and confirm industry priorities, update industry on technology progress and continue to build regular interactions between growers, industry and researchers (feedback loops).

Project staff facilitated an interactive meeting format using Citrix GoTo webinars to enable researchers from QUT and CSIRO in Brisbane and ACFR in Sydney to present updates on their work. To overcome regional bandwidth (live data transmission) problems, researchers provided voice over video and power point presentations prior to the meetings and were available (on line and on camera) for interactive Q&A sessions during the webinar. This method of 'virtual participation' worked very well with many positive comments from participants.

Topics covered included progress with QUT's Agbot 2 and their robotic capsicum harvester "Harvey"; ACFR's Ladybird and RIPPA the weed zipper; and from CSIRO, an introduction to hyperspectral imaging and update on wireless sensor networks applications. The meeting concluded with a presentation on the 2015 'emerging industry priorities' with participants asked to review, assess and rank these focus areas using a two page form (see Appendix I pages 65 and 66). This form was included in the end of project evaluation questionnaire to expand on the number of people contributing to the priorities consolidation process.

Keeping industry informed

Apart from the extension activities already described above, four editions of the project newsletter, the 'Queensland Veg Automation News' were developed and distributed to promote awareness and inform industry about project activities and outcomes. Team members also presented project information and updates at several industry events. These are detailed under Outputs. We collaborated with local industry organisations, Bowen Gumlu Grower Association (BGGA), Bundaberg Fruit and Vegetable Growers (BFVG) and more recently Lockyer Valley Growers, who distributed newsletters, meeting notices and in North Queensland organised farm visits for the project.

In depth system analysis - Lean

After a competitive tendering process, QMI Solutions (Queensland Manufacturing Institute) were contracted to deliver 'Lean Operational Excellence" introductory workshops in collaboration with the project team. Three growers, one in each target region, volunteered their time and business to participate in these case studies.

Lean is a continuous improvement methodology used in manufacturing and mining to improve productivity by reducing waste and identifying and addressing constraints. The aim of the case study work was to determine if Lean concepts and tools are of value to the vegetable industry, especially for

those businesses that are considering further investment in MARS technologies. See Appendix II for more detail on methodology and outcomes.

Testing prototypes

One objective for the project was to 'ground truth' the readiness of some of the MARS technologies featured in the media by testing one or two prototypes in a regional production area. CSIRO researchers were prepared to be involved and agreed to deploy, evaluate and further develop a prototype autonomous system to detect and deter pest birds. This exploratory work was carried out with the assistance of an enthusiastic Gatton farmer who had experienced regular crop losses and production challenges as a result of ducks feeding in crops. DAF staff procured and supplied off-the shelf sensor parts and assisted with grower liaison and trial deployments. CSIRO supplied their expertise and experience, built the prototype test gear, carried out deployments and analysed the data (free of charge).

Despite our best efforts, we were unable to entice the AgBot 2 and Ladybird (or its spin off robot RIPPA the weed zipper) into the regions for demonstration purposes. However, we appreciate QUT's and ACFR's willingness to provide video footage (some also available on line) of these and other technologies and making themselves available for discussion at webinars. Our request for regional demonstrations may have been a year or so too early as since then the RIPPA featured at the Gatton Horticultural Field Days in July and the AgBot 2 was launched at DAF Bundaberg Research Facility in October2016).

Outputs

Main project outputs as listed in the proposal

1. *Three regional reports detailing an in-depth analysis of the applicability of automation & robotics technologies, available or under construction/conceptualization, by end users, their service providers and researchers that identifies and prioritises technologies that have potential to transform the productivity of vegetable production systems*

This planned output was delivered as an interim project report documenting methodology and results from the initial grower and industry surveys, the May 2015 regional industry forums and farm visits and follow up activities by the project team. The report was submitted to Hort Innovation Australia in October 2015. It was emailed directly to participating growers, agronomists, consultants and engineering firms as well as industry support and research staff. The report was also available on request from any of the project team via the Qld Veg Automation News newsletter.

The report highlighted the differences between the three target regions and provided a preliminary overview of industry priorities for R&D. These priorities were identified by growers, local consultants, agronomist and engineering firms using an impact (on productivity) vs ease (of implementing) process (LeanKaizen 2014). These 'emerging priorities' were discussed and consolidated at the regional industry review meetings held in each region in March/April 2016. The industry priorities list also formed part of the end of project evaluation interviews conducted during November/December 2016. Updated results are incorporated in Appendix I Project evaluation, industry priorities and recommendations. This report will contribute to baseline evaluation data for VG15024.

2. *Completed and documented a detailed systems analysis of field and shed operations with one collaborating vegetable enterprise in each region to provide data to inform in-depth assessment results*

As discussed earlier, we contracted QMI Solutions to conduct three case studies with one collaborating vegetable enterprise in each of the target regions to assess the suitability of 'Lean' concepts and tools for the vegetable industry. The Lean continuous improvement methodology includes process flow and root cause analysis components. Each collaborating business has received a confidential farm specific report from QMI. The contract brief and summary of results from the work, the 'Lean Leaflet', are provided in Appendix II. This leaflet is intended as a resource/information source about Lean analysis for Australian vegetable growers and industry.

3. *Return on investment (ROI)/ risk analysis scenarios to detail investment considerations for selected automation & robotics innovations*

Initial Return on Investment (ROI) work suggested that estimates of payback period may be a more relevant metric for the vegetable industry. From industry survey results, a two year payback period appears acceptable increasing to three years where workplace, health and safety issues are of concern. Some basic calculations presented in Appendix IV show that these expectations are probably not realistic.

While cost and technology gaps remain key constraints for commercialisation of automation, robotics and sensing technologies, industry surveys and other project activities highlighted additional challenges

as well as opportunities for these innovations. They are documented in Appendix IV Challenges, constraints and opportunities.

4. *Half-yearly newsletter summarizing project progress for the national industry plus articles for publications targeting the national vegetable industry*

Four 'QLD Veg Automation News' newsletters were developed and distributed during the project: May 2015, December 2015, September 2016, January 2017. Copies are supplied in Appendix V Communication products. Updates were distributed via regional industry organisations and by direct email to our research and industry contacts including the Australian Melon Association, the Australian Mango Industry Association, the Australian Sweetpotato Industry Association, AusVeg, Growcom and more recently the new Australian Vegetable Extension Network. The last two editions also contain information on project VG15024.

'Market research' on the newsletter for the end of project evaluation shows that with some minor improvements the two page format was well received by growers and industry. However the newsletter tends to get lost amongst the plethora of information that growers and their service providers receive each week (more on that in the Evaluation section). In order to build on our existing industry communication format and linkages, project staff will continue the 'Qld Veg Automation News' format as part of the new VG15024 project in an attempt to create communication continuity and 'brand recognition' amongst the grower and industry community.

Other project outputs and activities

Scoping/linking visits to QUT and CSIRO in Brisbane; ACFR, Scott Automation & Robotics and Applied Robotics in Sydney in November 2014

May 2015 industry forums and farm visits - over 2 days held 2 weeks apart

- Gatton Research Facility, Warrego Highway - Mondays: 11th and 18th May
- Bundaberg DAF Offices, Enterprise Street - Tuesday 12th May & Wednesday 20th May
- Bowen Research Facility, Warwick Road - Thursdays: 14th and 21st May

March/April 2016 industry review meetings

- Bowen Research Facility, Warwick Road – 10 March
- Bundaberg DAF Offices, Enterprise Street – 22 March
- Gatton Research Facility, Warrego Highway – 7 April

Project summaries, interim project report, four milestone reports and this final report.

Start and end of project team meetings plus a number of additional team meetings, webinars and teleconferences

Prototype testing of a wireless sensor network (WSN) for automated vertebrate pest management in a baby leaf crop at Gatton – more detail under Outcomes.

Other industry communications, presentations and conferences

David Carey and Ian Layden attended ACFR's summer school on robotics in February 2105 to gain an insight into R&D on an international scale

Sue Heisswolf presented an overview of the project at a Hort Innovation workshop on robotics in Melbourne in February 2015

Sue Heisswolf, David Carey and Ian Layden participated at the 29th International Horticultural Congress in Brisbane in August 2014 including Symposium 16: Mechanisation, Precision horticulture and Robotics which was particularly valuable to the project.

Sue Heisswolf participated at the 2016 National Horticulture Convention and Global Innovations in Horticulture seminar, 23 to 25 June, Royal Pines Gold Coast and the AgFutures Innovation and Investment conference in Brisbane 22 & 23 November 2016.

Sue Heisswolf presented a project overview and industry priorities at the Agriculture Futures Innovations workshop, Bowen 21st and 22nd August 2015 - organised by Whitsunday Marketing and Development. She was interviewed for a podcast for InfoVeg radio by AUSVEG R&D on September 2015.

Sue Heisswolf and Steve Ginns presented a poster at TropAg2015 Meeting the Productivity Challenge in the Tropics, 16-18 November 2015, Brisbane (see Appendix V).

'Robotics to herald hi-tech production' (Rural Insight - Bowen Independent, Friday April 29, 2016) reported on the project following the Bowen industry review meeting.

David Carey presented a project overview and results to date at the 2016 National Horticultural and Innovation Expo at Gatton 27 & 28 July 2016.

Sue Heisswolf attended the AgFutures Innovation and Investment Conference organized by DAF in Brisbane 22-23 November 2016 .

The project team also provided targeted project presentations at several DAF vegetable team meetings, DAF management meetings and had input to several internal and external strategic policy documents on Precision Agriculture, Innovation and Automation and Robotics technologies.

Industry priorities for R&D in automation, robotics and sensing

The industry priorities developed from the initial industry surveys, the May 2015 industry forums and farm visits and follow up farm visits by the project team identified specific target crops and situations that matched grower needs with technologies that are currently being developed or are at the concept stage. Since the focus was on how different technologies might be applied to improve farm and shed operations, there is understandably a significant overlap in technologies across the nine identified priority areas.

These 'emerging industry priorities' were reviewed and consolidated at regional review meetings and during the end of project evaluation interviews. A two page survey form (attached in Appendix I) was used to collect participant's views on the importance of each priority:

Do you agree or disagree that this is an industry priority where 1 = disagree to 9 = agree?

Please rank in order of priority where 1 = highest priority and 9 = lowest priority

Industry priorities are presented in order of importance based on the MEAN RANKING by participants. The number in brackets represents the mean ranking (29 respondents) followed by the mean scale (39 respondents) to which participants agreed or disagreed that this was an industry priority.

1 Automated crop health monitoring (ranking 5.5, scale 7.5) for strategic targeted crop management – industry saw potential of various vision systems, imaging and sensor technologies to improve efficiency of field operations and better manage production risks, particularly when combined with autonomous platforms. Further resourcing to develop and test these technologies on farm for improved crop health monitoring, early problem detection and strategic, targeted responses to identified problems is needed. VG15024 Vision systems, sensing and sensor networks in vegetables and VG16009 Adoption of precision systems technology in vegetable production will progress this priority.

2 Autonomous weed management (ranking 5.4, scale 7.6) – inter/in row spraying/weed eradication based on weed detection and identification using small autonomous platforms/robots and various vision and sensing technologies. Growers and industry saw this as achievable in the short term hence its relatively high rating. They wanted to be kept informed on progress with the AgBot 2, Ladybird and RIPPA robots and were keen to have them demonstrated and tested regionally.

3 Autonomous all purpose, adaptable platforms (ranking 4.9, scale 6.9) – flexible and suitable for a range of tasks across various terrains and farming operations using 'plug and play' interchangeable modules to spray, soil test, assess crops etc. A step by step approach using existing platforms to test, develop and implement 'modules' of new technology might bring early benefits. Growers and industry wanted a wide range of potential end users involved in autonomous platform development and on farm testing.

4 Sensing and sensor networks (ranking 4.6, scale 7.2) for horticulture – improving field productivity - what can sensors measure? How to apply to improve performance? This technology has application across a range of field, shed and value chain situations. Examples are environmental/ micro-climate monitoring, quality/ripeness/maturity testing/monitoring, vertebrate pest management, virtual fencing, product tracking. Some of this technology is already in use in agriculture - GPS auto-steer, NDVI, load cell yield monitoring, irrigation scheduling and through their everyday interactions with the 'internet of things' – their mobile phone, wireless mouse, IPad and so on.

5 Robotic harvesting (ranking 4.4, scale 7.1) of tropical and sub-tropical horticulture crops - step by step approach – overlaps with automated crop management: crop forecasting, maturity assessment; also vision systems, sensing, imaging, autonomous platforms, manipulators and grippers. This was seen as THE priority across all regions, as high impact but difficult, was the top aspirational response in surveys and the topic of discussion during most farm visits. It was seen as still some time off in the future and needing substantial R&D investment which probably explains the relatively low ranking.

QUT have made significant advances over the past year in robotic harvesting of field grown and protected cropping capsicum using their platform Harvey and associated vision system, gripper and actuator technologies to detect and detach red fruit as part of the DAF/QUT SIFR program. On farm discussions with local growers has improved QUT researchers' understanding of the challenges and complexity of the picking task which in turn has informed fruit gripper design. These advances are transferable to QUT's work in apples, mango, avocado and other fruit crops. DAF's small trees project and The National Trees project led by UNE will contribute to progress in this area as will the QUT/DAF rapid yield assessment component of VG15024.

6 Increased packing line efficiency (ranking 3.8, scale 7.2) – defect sorting before product enters the packing line.

Growers could see that improved automated systems for better sorting out defects early could

potentially half the number of staff needed on sorting lines. Participation in the project led to one grower re-assessing automated grading machines and colour defect sorting. Another grower asked the manufacturer to recalibrate equipment to better grade product to different market specifications. A third grower revisited harvesting procedures to reduce potential yield loss and wastage through cutting immature product (too small) and oversize product coming into the packing shed.

7 Increased packing shed efficiency (ranking 3.5, scale 6.8) – automated/robotic palletising and product tracking. Constraints included the wet environment, limited space available and number of grades packed.

Several Lockyer growers have invested in pallet wrapper equipment to secure produce on pallets so it does not move in transit to markets. This also reduces staff handling times and makes truck loading more efficient. In North Queensland, vegetable growers are organizing a trip to South Johnstone to investigate use of automatic pallet stackers in the banana industry after a visit by banana growers to the Bowen district in 2016.

For shed operations, the key driver is labour – how to reduce but also how to use technology to simplify packing decisions for staff where there is high turnover and low skill levels. There was some discussion about what technologies might already be available off-the-shelf and the reasons for why these technologies are not more widely used. There is a need for an in-depth review of technologies already available, their application and suitability for horticultural packing sheds.

8 Managing vertebrate pests (ranking 2.4, scale 6.0) in vegetable crops - research on wireless sensor networks presented by CSIRO fired peoples' imagination on what might be possible to detect and deter pests such as wallabies in tomato, birds in various crops, ducks in baby leaf and strawberries, as well as wild pigs and flying foxes.

Preliminary work with CSIRO is underway with a small wireless sensor network deployed on a Gatton farm as part of the prototype testing component of VG13113. This work will continue in a small DAF innovation project 2017 and we investigating options for scaling up on farm development of the technology with Hort Innovation (see Appendix III for more detail).

9 Virtual fencing (ranking 1.5, scale 5.2) for mixed farming operations - based on wireless sensor networks (under CSIRO patent) was of particular interest to North Queensland growers. The start-up company Agersens is currently working towards commercialising virtual fencing for the beef, dairy and sheep industry.

Outcomes

All planned project outcomes were achieved. They are detailed below against the four outcomes listed in the project proposal.

1. *Increased number of vegetable growers, regional engineering firms and other associated agribusinesses actively engaged and aware of developments in automation & robotics innovations*

Target: At least 20% of vegetable growers and 50% of local engineering firms within the target regions will be engaged in reviewing, observing, and suggesting ways to improve automated and robotics technologies applications in regional vegetable production systems.

A total of 42 grower enterprises, 5 engineering firms and 6 agronomy/consultancy firms were 'engaged' in project activities (over 70 individuals). Enterprises involved supply a wide range of vegetable products, represent a cross-section of innovative growers in each of the target areas, supply a large section of national winter vegetable production and most have production/marketing links along the Eastern seaboard. This included visits to 15 farms including 8 packing sheds with QUT and CSIRO researchers.

In addition, 26 industry support and research staff participated in activities. The work involved extensive follow up by the project team to check back on early drafts of priorities and action plans/ recommendations with participating businesses in each region.

Our estimates are that well over 20% of vegetable growers in the target regions – possibly representing more than 50% of QLD's vegetable production – contributed to discussions on how to best harness automation, robotics and sensing technologies for improved productivity (and profitability) of vegetable farms. At least 50% of regional engineering firms, consultants and agronomists were involved in the project as were all three industry organisations – BGGA, BFVG and Lockyer Valley Growers.

Growers and industry people enthusiastically contributed to the process. Two half day forums, hosting farm visits, review meetings, follow up visits by project staff and two one hour survey interviews represent a significant investment in time and energy by participants (including researchers). Four grower co-operators in particular (the three Lean case study participants and one prototype testing farm) made a major commitment by investing their time and making their farms and senior staff available to the project.

2. *Identified specific target crops or situations with growers that are matched to developing automation technologies with the aim of fast tracking a commercially acceptable & available product.*

   OR

   At least two prototype developmental automation technologies identified which merit further development with end user participation

The project identified specific target crops and situations matched to developing automation technologies. These are listed in the Outputs section above and detailed in Appendix I Project evaluation, industry priorities and recommendations. As a result of this work, we now have a much better understanding of:

- The potential application of automation, robotics and sensing in vegetable production systems
- Grower and industry priorities for research, development and implementation
- The barriers, constraints and opportunities for transforming industry productivity through automation, robotics and sensing innovations. These are detailed in Appendix IV.

We are fast-tracking development of a prototype autonomous intelligent system for detecting and deterring vertebrate pests with CSIRO based on distributed wireless sensor networks. In collaboration with DAF and a Gatton grower, CSIRO conducted preliminary trial deployments of their prototype system in 2016 as part of this project. A small internally funded DAF innovation project will enable further on farm testing in the first half of 2017. CSIRO have patented the prototype and are in discussion with Hort Innovation, DAF and industry to develop a concept proposal to scale up and progress this technology towards commercialisation. This outcome illustrates the value of facilitating on-farm interaction between growers, researchers and local service providers (DAF project staff).

The DAF/QUT/CSIRO collaborative project VG15024 will investigate technologies that address several industry priorities:

- Robotic harvesting specifically yield and maturity assessment: Vision systems for rapid assessment of capsicum fruit quantity and quality in protected cropping and field grown systems (QUT/DAF)
- Automated crop health monitoring and sensing and sensor networks: Early problem detection based on hyperspectral imaging and crop micro-climate monitoring using wireless sensor networks combined with observation and diagnostics to ground truth (CSIRO/DAF)

All three technologies – vision systems, hyperspectral imaging and wireless sensor networks – deal in large data sets. VG15024 will therefore also provide opportunities for exploring and better managing this aspect of automation, robotics and sensing from a practical point of view. The project will be running in parallel with the ACFR's VG15003 'Using autonomous systems to guide vegetable decision-making on farm'.

3. *Identified mechanisms on which to build effective, regular feedback loops between all sectors of the RD&E continuum operating in the automation and robotics space.*

Our primary target audience was potential end users: innovative vegetable growers, regional engineering firms, vegetable processors, local contractors, agronomists, consultants and other associated agribusinesses in the three major vegetable production areas of QLD. However, we also engaged with key research teams and specialist developers working in automation, robotics and sensing in horticulture.

Bowen Gumlu Grower Association (BGGA), Bundaberg Fruit and Vegetable Growers (BFVG) and more recently Lockyer Valley Growers collaborated in the project by distributing newsletters, meeting notices, helping to organize some farm visits and participating at forums/meetings. National industry groups and key research teams were kept informed through direct email, local grower organisations and more recently, the National Vegetable Extension Network.

Results from the end of project evaluation confirm that progress has been made towards better linking researchers with industry and growers. It provided some insights but also confirmed past experiences of

team members on the difficulties of effectively engaging with and improving communication between researchers, industry and growers – all of whom are time poor. This is considered in more detail in the Evaluation and Discussion section.

4. *Strengthened networks & interactions between different sectors of the industry and identified expertise and capability for future work in vegetable production regions.*

The evaluation shows that broadly speaking, a significant cross-section of the Queensland vegetable industry now has an increased awareness and understanding of what automation, robotics and sensing technologies are currently under development in Australia (and to some degree globally) compared to two years ago. This can be at least in part attributed the project.

There is evidence that there is now a better understanding between growers, industry and researchers – some bridging of cultural differences/world views/drivers and that there are interactions between individuals within the different sectors that were initiated by project activities in particular by farm visits.

The project team, growers and industry also have a better knowledge of the expertise and capacity available within Queensland and Australia for future work in this area of R&D. Obviously much of the technology is still some way from commercialisation however growers can see the potential and are keen to trial prototypes once they become available for in field testing.

Additional benefits/outcomes

The project provided a better understanding of the constraints and barriers impacting on MARS technology development, commercialisation and implementation in the vegetable industry. It also highlighted a number of opportunities. These are documented in Appendix I. There has been a demographic change within the three vegetable regions we targeted with the majority of growers and industry people interviewed less than 50 years of age, well educated, with a professional approach to farming, keen to innovate to improve their business and comfortable with the digital revolution.

The project outputs and activities did not aim to achieve adoption however there is evidence that some practice change has occurred.

The farm visits were a valuable exercise for all participants and provided researchers with valuable insights and an improved understanding of vegetable production challenges. It focused their attention on the high level of manual operations carried out on vegetable farms every day and challenged them to think about issues of reliability, safety, flexibility, robustness, power requirements, service needs, parts availability, uneven terrain, dust, dirt, water, weather, space restrictions and so on. Growers offered comments on existing research efforts and discussions revolved around possible technology solutions for simple everyday farm issues.

One grower has been in contact with researchers to explore a joint research proposal to develop and commercialise robotic harvesting after exposure to DAF/QUT's capsicum work and subsequent farm visit. Another is reviewing the farm's automated grading and colour defect sorting equipment. A third made major adjustments to an auto buncher/washer which had not been capable of performing the task effectively. There is evidence that one or two other growers have made direct contact with researchers after being involved in project activities.

We now have a better understanding of Lean concepts and tools and their applicability to horticultural

enterprises (documented in Appendix II). The Lean case studies resulted in some specific outcomes:

- The manufacturer was asked to recalibrate a grader to better sort defects for pre-pack lines. Future grader recalibrations are planned.
- Some minor shed changes including yellow safety lines on floors and a clean-up of the area, also a 'time management' study with the QA start-up crew; in the machine workshop tidied up and re-structured the area, painted it a lighter colour and installed shadow boards.
- Reviewing shed and field practices to better measure people's work rate and productivity – boxes picked and packed – formalise a system and set a "pack goal".
- Instigating a system for business manager meetings where recurring issues are colour coded – red, amber or green – to highlight an issue as a group 'must fix' priority.

QUT's Agbot 2 and Harvey the capsicum harvester was launched in Bundaberg on 20 October 2016. ACFR's RIPPA the week zipper was trialled on a Gatton farm and on display at the Gatton field days in July 2016. While not directly attributable to our project, we certainly lobbied hard to have these technologies demonstrated in Queensland. We hope that the national mango conference scheduled for early May 2017 in Bowen will be a drawcard for getting these and other technologies into North Queensland for demonstration.

Evaluation and Discussion

The project was delivered on the principle of starting from the ground up rather than research down with emphasis on the needs of growers and their systems. This participatory approach did increase awareness of automation, robotics and sensing technologies in the target production areas. It engaged a significant cross section of growers, local consultants, agronomists, engineering firms and industry organisations across Queensland as well as key researchers in discussions about the technologies and their potential application to field and shed operations. Project outputs and outcomes were delivered as planned. The project has delivered additional benefits: the Lean leaflet, detailed R&D priorities document, a better understanding of (i) barriers/opportunities for technology implementation and (ii) communicating with growers and industry.

Specific activities and tools used

The regional approach coordinated by the local DAF agronomist in each target production area was successful in actively involving a wide cross section of innovative vegetable growers and their service providers in project activities. We had good attendance at the initial industry forums, less so at the review meetings the following year with a number of apologies due to time constraints. Those that did attend willingly contributed to discussions. These 'group' activities were augmented by one-on-one activities: the start and end of project interviews, the farm visits by researchers, follow up farm visits by the local DAF agronomist and on farm work with grower co-operators.

It is well known within industry that it is difficult to get growers to meetings unless there is a crisis. Not all growers enjoy group activities and some have had bad experiences with poorly targeted, lengthy meetings with little outcome or feedback. Time and other priorities are also always an issue. Hence we kept forums to around 3 hours with a one week break in between, involved the local grower organisations and were clear about objectives. The meeting process was carefully designed and successfully encouraged interaction and input from participants. The result was a detailed list of 'emerging industry priorities' on which we could build through farm visits and follow up activities.

Farm and shed visits were invaluable for showing researchers in what context their technologies might one day be deployed. It was a practical demonstration of a range of farming operations, cropping systems and packing shed processes – to see, hear about and experience daily farming activities and productivity challenges first hand from the grower's perspective at peak production. Farm visits created opportunities for in-depth discussions on what might be possible. There are some direct outcomes from farm visits which may have longer term impacts. These include prototype testing of automated vertebrate pest management systems, potential grower/university collaborations to progress robotic harvesting and VG15024 targeting early problem detection in crops based on hyperspectral imaging and wireless sensor networks technology. We strongly encourage future, regular visits to the regions and farms by researchers.

Involvement of researchers and access to prototypes were critical success factors for the project with expert input from QUT and CSIRO staff of vital importance to project activities at all levels.

Despite our best efforts, we were unable to demonstrate or test more than one prototype technology on farm in the regions. However QUT, CSIRO and also ACFR supported the project through 'virtual' demonstrations using the webinar format. That approach worked very well with an excellent response from growers and industry. It is a communication tool we will use more in the future.

Encouraging a shared understanding with researchers started with visits by the project team to QUT, CSIRO, ACFR and two Sydney MARS developers to scope technology developments and extend invitations to visit the regions and participate in forums the following year. We are indebted to QUT and CSIRO for taking up this invitation as their presentations and expertise provided the catalyst for discussions at the industry forums (ACFR contributed via Skype). Further efforts to bridge the cultural gap between researchers, growers and industry would, in our opinion, be time well spent.

Follow through is critical for building effective feedback loops between different sectors of the industry. So is management of expectations.

The project team already has good connections with growers in the three target regions. We know that some in the industry are reluctant to attend meetings or contribute to consultation processes because they so rarely hear back about the outcomes. This is sometimes despite organisers going to some lengths to communicate outcomes via broad brush methods such as newsletters (more below). Some growers just prefer to fly below the radar.

Follow up activities consisted of farm visits by the local DAF team member as necessary to complete the forum process; industry review meetings in 2016 to consolidate industry priorities and end of project survey interviews to provide further opportunity for input and feedback. Lean case study co-operators were given opportunity to reflect on workshops and received a confidential report from QMI. The on farm prototype testing and follow on project (VG15024) represent follow through on industry priorities and will also provide continuity for engagement activities and the QLD Veg Automation Update in automation and robotics.

Engaging with growers and industry

Our evaluation results show that particularly growers but also their service providers suffer from information overload, are time-poor and need to juggle a range of competing priorities. As do we all.

Growers are not a homogenous group and one size does not fit all. People we spoke with obtain information from a wide range of sources. Text and email continue to be important tools for keeping up to date as is the internet and YouTube. Industry and growers are actively searching for specific information.

There is no easy answer. It is a question of where to invest time and resources and for what impact. Texts need to be personal, selective, well targeted and are good for reminders. Emails need a good header that draws people's attention. Emails are often filtered as they first come into the business (by office staff). Electronic filtering and use of key words was mentioned by one consultant. Several growers have given us their personal emails for direct contact.

Talking with people, other growers, local consultants, engineers, managers and key staff in the business remains the most important way of keeping up to date. Our project activities and team members were important sources for information about automation and robotics. Industry contacts mentioned as information sources included local, state and national grower organisations. Few use social media (facebook, twitter). Radio, podcasts and TV did not rate highly for most. Increasingly, as industry further rationalises and enterprises become larger, innovative owners and farm managers get their information directly from involvement at conferences, as executives, board members etc of industry organisations and collaborations with R&D providers.

We based our engagement strategy on a combination of approaches: newsletters (broad brush - to inform and with a national focus): industry forums, farm visits and surveys (to engage – regional focus) as well as on farm testing and case studies (systems development with grower co-operators). It is important to be clear about what each of these approaches might realistically achieve. Webinars are a potentially useful tool for better engaging with growers. The newsletter could be uploaded onto the DAF website so that it becomes more easily available through internet searches.

Our multi-faceted approach worked well to deliver planned outputs and outcomes. It included a substantial one-on-one component which is a time consuming but effective strategy often not factored into projects. It is the best way to build relationships on which all other communication and engagement activities are based. The nature of discussions of (sometimes) confidential information at forums, during surveys and case studies and the willingness of growers to host researchers on farm and show them through packing sheds underlines the value and effectiveness of this strategy.

Managing expectations - myth busting

At the start of the project there was a lot of publicity and excitement about Robotics in Agriculture and this has not diminished. Our project was in part about taking a closer look at what progress had actually been made and to evaluate this progress and potential with growers and industry.

There is a need to better manage industry expectations by finding a workable balance between keeping people interested and informed about what is possible while being realistic about timelines needed to test, commercialise and deploy the innovations. For example, we were unable to bring the AgBot 2 or Ladybird into the regions for on farm demonstration despite grower requests to do so. It is also obvious that much of the technology is still in the research phase and not yet available for on farm prototype testing.

Towards the end of the project, several growers voiced a concern for the length of time it takes for R&D to translate into commercially accessible technology that lives up to its promise. This is not necessarily a negative result but may illustrate that growers now have a better appreciation of what is possible and over what time frame. Examples are the high priority rating for automated weed management vs robotic harvesting. It may be worthwhile to better demonstrate the research effort needed to bring technology to the prototype testing stage so industry can better appreciate the time and resources involved.

Challenges, constraints and opportunities

Cost of technology is only one part of the equation. Based on our inability to get more than one prototype into the regions for on farm testing, there are obviously still significant technology gaps.

Other constraints we encountered included IP issues, both hardware and software, which impact on the flexibility and adaptability of technology to specific requirements. No farm is the same and that applies especially to field operations and explains the higher level of automation in sheds where it is easier to adjust the environment to the machine and standardize product.

Robustness, reliability, servicing, availability of spare parts and speedy repairs are also of concern particularly for technology sourced from overseas. These inputs have a direct impact on downtime and ability to supply product to specifications in a highly competitive market place. Warranty issues may also impact on flexibility where existing equipment is modified/retro-fitted to accommodate new technology. Outsourcing some of these functions to regional engineering firms could in part overcome some of these

problems.

What's changed on farm in the last 10 years?

Some interesting trends have emerged from the Queensland industry surveys:

- The vegetable industry is in the midst of a generational change.
- Attitude to automation and robotics is positive.
- GPS guidance systems are widely accepted and adopted.
- QA systems are in place with widespread use of harvest aides and colour vision graders.
- Large, professional enterprises looking for improvements and efficiencies.
- Widespread use of mobile/smart phones, email and the internet.

These changes present an opportunity. They suggest that compared to only ten years ago, the industry is now in a much better position to adapt and integrate practical automation, robotics and sensing innovations into their farming systems.

Challenges, constraints and opportunities as well as Return on Investment (ROI) and payback period are discussed in more detail in Appendix VI.

Recommendations

What next for the identified industry priorities?

Automated crop management

- Involve a wide range of potential end users, growers, local engineering firms, consultants and agronomists, in autonomous platform development and testing focusing on flexibility, adaptability, robustness, compatibility and modular aspects of the technology.

- Keep regional industry informed on progress with autonomous inter and in row weed management with platforms such as the AgBot 2, the Ladybird and RIPPA and support efforts to have these platforms demonstrated and tested on farms in the regions.

- Support efforts to resource development and on farm testing of vision systems, imaging and sensor technologies for improved crop health monitoring, early problem detection and strategic targeted responses to identified issues. VG15024 and VG16009 will progress R&D in this area.

- Two UAVs have been purchased by local agronomists over the past year for on farm trials (one in Bundaberg with CQU support, one in Bowen). It would be worth supporting these initiatives through training on imaging (multispectral, hyperspectral), data management/interpretation to ground truth and better linking with other work in this area for example, VRT and Precision Agriculture.

Wireless sensor networks

This technology, in particular when combined with intelligent data management/training systems, underpin other potential technology applications: crop health monitoring, in crop environmental monitoring (soil and ambient), product tracking/monitoring through the supply chain, vertebrate pest management, virtual fencing, yield monitoring, variable rate and precision agriculture approaches.

During forums and farm visits, growers and industry saw the potential contribution this technology could make to increased productivity and better managing risks with some components already available of the off-the shelf. There is a need to further develop, integrate and test these component technologies and approaches on farm with growers, agronomists, consultants and machine developers to fully realize the benefits that these innovations could bring.

Vertebrate pest management – detect and deter

A small DAF innovation grant will continue development of a prototype autonomous vertebrate pest management system on a Gatton farm in the first six months of 2017. The system is based on wireless sensor network technology and CSIRO/Data61 capability in developing intelligent systems. CSIRO have patented the concept and are keen to scale up this area of R&D.

While vertebrate pest management did not rank in the top five industry priorities it causes significant crop losses for some farmers with no effective solutions currently available. Our payback calculations (Appendix IV) show that an autonomous vertebrate pest management system is likely to be cost effective and have significant environmental and ethical benefits.

Robotic harvesting

As part of the DAF SIFR program, QUT has made significant advances over the past two years in robotic harvesting of protected cropping capsicum using their platform Harvey and associated vision system, gripper and actuator technologies to detect and detach red fruit. These advances are transferable to QUT's work in apples, mango, avocado and other fruit crops. DAF's small trees project, the National Trees project led by UNE and the QUT rapid yield assessment component of VG15024 all contribute to ongoing progress in this area of R&D.

While still some time in the future, robotic harvesting of tropical and sub-tropical crops now looks more achievable than it did two years ago. Growers/industry/research collaborations to progress this area of technology are worth considering.

Increased shed and packing line efficiencies

Some changes have occurred during the life of the project, for example, improved defect sorting by recalibrating existing or purchasing new graders, grower plans to further investigate automated palletizing. There is a need for an in-depth review of technologies already available, their application and suitability for vegetable packing sheds. This review needs to go beyond a desk top study and include farm visits, discussions with growers, local engineering firms, machine developers and researchers. Machine performance, work rates, service reliability and back up need to be part of that conversation.

Process flow analysis - Lean

While the Lean introductory operational efficiency workshops delivered by QMI need substantial reworking to improve their relevance, we think there is value in Lean concepts and tools for the Australian vegetable industry. Collaborating growers have made some improvements to their business operations as a result of participating in the workshops and it would be interesting to revisit growers in a year to see if any additional changes have been made.

Communicating and engaging with growers

The survey results confirm feedback from growers and industry to project team members over the past decade or two. Communication and engagement activities need to be short, topical, interesting and to the point: well targeted emails and texts; newsletters with headlines and action shots; interactive meetings to give people opportunity to discuss ideas, have input and assimilate learning. Distil the main points and paint a picture. Build on what your audience knows already. Focus on what is new. What is useful for improving the business?

In particular, how will participants be updated on impact/outcomes if they were asked to provide input to a consultation process?

Two questions to consider:

What is the most efficient way for the person to provide feedback/input? What evidence do they have that this time has provided a return/was time well spent?

Follow up if that is what was promised. Provide continuity and evidence to growers and their service providers that their input has been listened to and acted upon.

The project evaluation shows that people get their information from a variety of sources, are increasingly digitally literate and actively searching for information. The internet, YouTube, webinars and to a lesser degree social media are excellent tools for facilitating feedback loops between researchers, industry and growers. However one-on-one interactions continue to be important for building relationships, relevance and trust which add value to other communication methods.

Specific tools and approaches

'Market research' on the two page newsletter confirmed that the format with some minor improvements is on target. We did not unearth any ideas on how to better distribute and have it stand out amongst all other information people receive in their emails and on their desk. Investing time to build relationships with people helps to have newsletters, emails, texts and meeting invitations recognized as personal (and therefore of potential value as opposed to spam). While newsletters have their limitations, they are a good tool for concisely and regularly summarizing project progress, are a readily available communication resource and we are looking at ways of making it accessible on demand via the DAF website.

There is a need for clarity about what different communication and extension tools might logically achieve – broad brush (to inform) vs specific, resource intensive (to engage, develop, implement). Growers, engineers, agronomists and consultants keen to get involved and help with on farm prototype testing and development at the earliest opportunity.

Following on from the successful webinar format of the regional industry review meetings, the project team used webinars for ad hoc project team meetings and for setting up the process flow analysis (Lean) work with QMI and grower co-operators. Webinars show promise for better linking up researchers, industry and growers and we will make more use of this tool in the new project VG15024 for example, for annual regional meetings and interactions with grower levy payer partners.

From the evaluation results, there is no doubt that bringing researchers into the regions and onto farms was a valuable exercise for all involved. It may be worth taking growers and regional industry people to research facilities to provide context and insights on how research is done and how it works. This would further facilitate a better understanding between different sectors of the RDE continuum, help to manage expectations and bridge the culture gap between researchers, growers and industry.

Scientific Refereed Publications

McCool, C., Sa, I., Dayoub, F., Lehnert, C., Perez, T., Upcroft, B., 2016. Visual detection of occluded crop: For automated harvesting. *2016 IEEE International Conference on Robotics and Automation (ICRA)*, Stockholm, 2016, pp. 2506-2512.
doi: 10.1109/ICRA.2016.7487405
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7487405&isnumber=7487087

Intellectual Property/Commercialisation

The CSIRO has a proven track record of successfully deploying large numbers of sensor nodes within autonomous systems for environmental and animal monitoring. In consultation with growers and agronomists and with support from the DAF project team, CSIRO has developed a concept based on this expertise for long term effective deterring of vertebrate pests from a single system. The CSIRO concept has led to a provisional patent (AU2016902680).

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Limpus, Sarah; O'Halloran, Julie; and Layden, Ian (2016). Final report for GMX-INNOV-312: Adoption of variable rate technology in Queensland's intensive vegetable production systems, June 2016.

Lean concepts and tools including LeanKaizen 2014 Impact vs Ease matrix http://www.lean.org/ sourced 25 January 2016

National MARRS workshop and report - HG09044 Scoping study to review Mechanisation, Automation, Robotics and Remote Sensing (MARRS) in Australian Horticulture (2009)

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Staff of Bundaberg Fruit & Vegetable Growers (BFVG) and Bowen Gumlu Growers Association (BGGA) provided much appreciated support with Sarah Simpson, Industry Development Officer for BGGA distributing forum invitations, taking forum minutes and organizing all farm visits in Bowen and Gumlu. Our thanks also to Mary Firrell and Leith Stewart from DAF for help with forum set up and note taking.

We would like to express our thanks to growers in all three regions for hosting us on their farms, allowing us into their packing sheds, participating at forums, review meetings and surveys and freely sharing information and ideas. Contributions made by owners/managers/staff of local engineering firms, crop consultants, agronomists as well as researchers from Central Queensland University (CQU) added another perspective to discussions and we thank them for their input.

In particular, we would like to thank our four grower collaborator:

- Leanne and Wayne Born, David Holt and Brock Sutton and their staff for participating in the Lean case studies at a busy time of the year and willingness to share confidential information with us
- Desleigh Jackwitz for making time and her farm available for testing CSIRO's prototype vertebrate pest management system

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Appendices

Appendix I Project evaluation, industry priorities and recommendations

Appendix II Lean brief and Lean leaflet

Appendix III Prototype testing: detect and deter ducks in Baby leaf

Appendix IV Challenges, constraints and opportunities

Includes example Return on Investment (ROI) and payback period calculations and gross margins

Appendix V Communication products

Includes QLD Veg Automation Updates, project summaries and poster

Project evaluation, industry priorities and recommendations

Sue Heisswolf, David Carey, Steve Ginns
Department of Agriculture and Fisheries Queensland

Appendix I for final report - January 2017

Project Number: VG13113
Evaluation of automation and robotics innovations:
Developing next generation vegetable production systems

DAF/HIA co-investment project

VG13133

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Summary

Australian fruit and vegetable growers have for many years faced continuous pressure to supply fresh, perishable product at ever reducing margins. In response, enterprises have scaled up and continue to strive for greater on farm efficiencies. Increased adoption of Mechanisation, Automation, Robotics and Sensing (MARS) technologies could potentially deliver significant increases in productivity by maximising input efficiencies particularly labour while reducing production costs and risks. This technology based evolution will assist the Australian fruit and vegetable industry to compete internationally and help drive export market development.

This document updates the Interim report for VG13113 submitted to Hort Innovation in October 2015. It summarises efforts to date to increase grower and industry involvement early in the research and development process to ensure that future technologies are fit-for-purpose so that technologies can be more quickly incorporated into field and packing shed operations. For that purpose, the project team engaged with a range of potential end users – vegetable growers, regional engineering firms, consultants, agronomists and other service providers – as well as researchers to evaluate current and potential automation, robotics and sensing technologies.

The aim was to identify industry priorities by:

- Focusing on industry needs rather than the technology in the first instance
- Discussing possibilities with potential end users – individually via survey interviews and farm visits as well as in group settings at forums
- Bringing researchers into the regions and onto farms
- Building feedback loops between end users, industry and researchers

Our target regions were the Bowen/Burdekin, Bundaberg and Lockyer/Fassifern Valley areas– the three main vegetable production regions of Queensland. The project team conducted:

- Start of project industry surveys using personal interviews to gather baseline data on current thinking, current level of technology implementation, experience and opportunities for future innovation (October 2014 to April 2015).

- Six industry forums (two each in Bowen, Bundaberg and Gatton) and 15 farm visits over two weeks in May 2015 plus a number of follow up farm visits by project team members to complete the engagement process

- An industry review meeting in each target region to consolidate industry priorities, update participants on R&D progress and continue to build feedback loops between growers, industry and researchers (March/April 2016)

- End of project industry surveys in the target regions to evaluate project impact and complete the industry priority consolidation process (November/December 2016)

Four newsletters, the QLD Veg Automation Updates, were also distributed to keep growers, industry and the national vegetable industry engaged and informed of project progress.

The forums gave growers, local engineering firms, agribusiness and industry support staff an opportunity to hear about and discuss the latest aspects of automation, robotics and sensing research with leading researchers from Queensland University of Technology (QUT) and the CSIRO. The Australian Centre for Field Robotics (ACFR) contributed via teleconference. These local forums and farm visits were an unqualified success despite time pressures facing most vegetable growers at this busy time of the year. The May timing was to ensure that visiting researchers experienced vegetable production while it was in full swing with crops in the ground and product being processed in packing sheds.

Farm visits, forums and the earlier industry surveys created an abundance of ideas and information with some common themes emerging. These 'emerging industry priorities' were categorised into nine theme areas and reviewed and consolidated with growers and industry at regional review meetings in autumn 2016 and during the end of project evaluation interviews. Results from this consolidation process are:

1 Automated crop health monitoring (ranking 5.5, scale 7.5) for strategic targeted crop management – industry saw potential of various vision systems, imaging and sensor technologies to improve efficiency of field operations and better manage production risks, particularly when combined with autonomous platforms. Further resourcing to develop and test these technologies on farm for improved crop health monitoring, early problem detection and strategic, targeted responses to identified problems is needed.

2 Autonomous weed management (ranking 5.4, scale 7.6) – inter/in row spraying/weed eradication based on weed detection and identification using small autonomous platforms/robots and various vision and sensing technologies. Growers and industry saw this as achievable in the short term hence its relatively high rating. They wanted to be kept informed on progress with the AgBot 2, Ladybird and RIPPA robots and were keen to have them demonstrated and tested regionally.

3 Autonomous all purpose, adaptable platforms (ranking 4.9, scale 6.9) – flexible and suitable for a range of tasks across various terrains and farming operations using 'plug and play' interchangeable modules to spray, soil test, assess crops etc. A step by step approach using existing platforms to test, develop and implement 'modules' of new technology might bring early benefits. Growers and industry wanted a wide range of potential end users involved in autonomous platform development and on farm testing.

4 Sensing and sensor networks (ranking 4.4, scale 7.2) for horticulture – improving field productivity - what can sensors measure? How to apply to improve performance? This technology has application across a range of field, shed and value chain situations. Examples are environmental/ micro-climate monitoring, quality/ripeness/maturity testing/monitoring, vertebrate pest management, virtual fencing, product tracking. Some of this technology is already in use in agriculture - GPS auto-steer, NDVI, load cell yield monitoring, irrigation scheduling and through their everyday interactions with the 'internet of things' – their mobile phone, wireless mouse, IPad and so on.

5 Robotic harvesting (ranking 4.4, scale 7.1) of tropical and sub-tropical horticulture crops - step by step approach – overlaps with automated crop management: crop forecasting, maturity assessment; also vision systems, sensing, imaging, autonomous platforms, manipulators and grippers. This was seen as THE priority across all regions, as high impact but difficult, was the top aspirational response

in surveys and the topic of discussion during most farm visits. It was seen as still some time off in the future and needing substantial R&D investment which probably explains the relatively low ranking.

QUT have made significant advances over the past year in robotic harvesting of field grown and protected cropping capsicum using their platform Harvey and associated vision system, gripper and actuator technologies to detect and detach red fruit as part of the DAF/QUT SIFR program. On farm discussions with local growers has improved QUT researchers' understanding of the challenges and complexity of the picking task which in turn has informed fruit gripper design. These advances are transferable to QUT's work in apples, mango, avocado and other fruit crops. DAF's small trees project and The National Trees project led by UNE will contribute to progress in this area as will the QUT/DAF rapid yield assessment component of VG15024.

6 Increased packing line efficiency (ranking 3.8, scale 7.2) – defect sorting before product enters the packing line.

7 Increased packing shed efficiency (ranking 3.5, scale 6.8) – automated/robotic palletising and product tracking.

For shed operations, the key driver is labour – how to reduce but also how to use technology to simplify packing decisions for staff where there is high turnover and low skill levels. There was some discussion about what technologies might already be available off-the-shelf and the reasons for why these technologies are not more widely used. There is a need for an in-depth review of technologies already available, their application and suitability for horticultural packing sheds.

Through the Lean case studies, review meetings and end of project survey results, we know that progress has been made in this area. Equipment is improving with existing graders and defect sorters being re-calibrated and several growers investing in this technology over the past two years. Growers are also investigating and improving automated palletising operations.

8 Managing vertebrate pests (ranking 2.4, scale 6.0) in vegetable crops - research on wireless sensor networks presented by CSIRO fired peoples' imagination on what might be possible to detect and deter pests such as wallabies in tomato, birds in various crops, ducks in baby leaf and strawberries, as well as wild pigs and flying foxes.

Preliminary work with CSIRO is underway with a small wireless sensor network deployed on a Gatton farm as part of the prototype testing component of VG13113. This work will continue in a small DAF innovation project 2017 and we investigating options for scaling up on farm development of the technology with Hort Innovation (see Appendix III for more detail).

9 Virtual fencing (ranking 1.5, scale 5.2) for mixed farming operations - based on wireless sensor networks (under CSIRO patent) was of particular interest to North Queensland growers. The start-up company Agersens is currently working towards commercialising virtual fencing for the beef, dairy and sheep industry.

Summary of evaluation results

The majority of people interviewed were in the 30 to 49 age group and had trade, diploma or degree qualifications in agriculture, mechanics/engineering or business. Most were either from farming families or had many years' experience in agriculture (depending on age). For growers, a generational change is occurring with sons and daughters taking on the business and succession plans in place or already executed.

Each business had carved out a 'market niche basket' to which they grow and pack according to suitability for their business, as opportunities arise and to spread risk across several markets. Rationalisation of the vegetable industry continues with some growers exiting the industry, larger growers expanding production and most looking to diversify into other enterprises and markets with a keen interest in getting into or expanding on exports. There has been a trend towards diversifying into fruit crops.

Labour is by far the most important production/business cost for growers interviewed, followed by packaging costs and in the case of North Queensland, freight costs. Cost pressures, slim profit margins and getting a return on capital as well as accessing and keeping markets are issues. Weather, varieties and pest and diseases create headaches for growers as does labour: increasing costs but also coordinating, managing and hiring large numbers of staff; dealing with personal issues; availability and access to skilled, experienced and reliable people.

Key Question 1. How actively engaged and aware of developments in automation & robotics innovations are growers and industry service providers?

The evaluation showed that growers and industry had a better awareness of specific automation, robotics and sensing technologies than they did two years ago and that the project contributed to this outcome. There appeared to be an improvement in how well connected, involved and informed growers and their service providers felt about progress in this area of research and development. Most were happy with their level of connection however almost half were interested in being more involved and most would like more input on what R&D is happening on automation and robotics. Time was a constraint for greater involvement and input.

KQ 2.What is the individual's current knowledge, attitude and aspiration when it comes to automation & robotics?

The evaluation showed that growers and industry respondents had a better awareness of specific automation, robotics and sensing technologies at project end and that the project had in part contributed to this increased knowledge. Respondents were even more positive about automation and robotics than they were two years ago. Words used had changed to include:

- Exciting, awesome, love idea of it, passionate about it
- Integral and way of the future, inevitable, necessary especially with regards to reducing labour inputs, remaining viable, competitive and sustainable.

In general, aspirations had not changed however in some instance they were more realistic and specific. Responses to the question "if there was one other thing you could automate" included:

- Automated/robotic harvesting or aids to harvesting although growers understood that this technology was still some way from realisation.
- Automated weed management with one grower stating that he would like to trial a customised Bot within 12 months.
- Disease identification, nutrient and irrigation management to apply foliar fungicides, automated bait spraying for Queensland Fruit Fly, robotic scouting, drones and satellite imagery to better manage crops.
- Automated planting which is a change from two years ago. Planting has not been a focus during other project activities.
- In the packing shed, all tasks including automated dipping (for pest and disease control), palletising, labelling, better defect sorting, (capsicum are not round so do not rotate) and packing were listed.

Key Question 3. What level of technology is currently implemented on farm?

Over the past two years, growers have improved packing lines by modifying graders, extending packing lines or investing in new graders and palletising equipment. Awareness and use of GPS, VRT, yield monitors, crop/soil mapping and automated irrigation systems has increased. Two agronomists have bought drones for trialling with growers. Several growers have made or are planning major systems changes to accommodate new machinery or with a view to future automation. Awareness of land management issues and their possible impact on farming practices featured more strongly in end of project interviews.

Cost pressures, labour issues and the need to find efficiencies are driving these changes, however better water efficiency, reducing environmental impacts, more flexible management and market and/or product diversification also play a role.

Respondents said that automation in packing sheds would continue to increase and improve. In field, automation and robotics would continue to take gradual steps forward as technology improves, becomes more user-friendly and affordable. Some thought that it was a long way off. A theme throughout interviews was the need for greater researcher, industry and grower collaboration to develop and demonstrate technology benefits.

Participation in the project led to one grower re-assessing automated grading machines and colour defect sorting. Another grower asked the manufacturer to recalibrate equipment to better grade product to different market specifications. A third grower revisited harvesting procedures to reduce potential yield loss and wastage through cutting immature product (too small) and oversize product coming into the packing shed.

KQ 4. What are the individual's current networks and interactions in the automation & robotics industry? How can these be strengthened?

Text and email continue to be important tools for keeping up to date. The internet and YouTube are important for industry and increasingly growers who actively search for specific information. Talking with peers and others including growers, local consultants/agronomists, local engineers and managers and key staff in the business tops the list of information sources. The project team and other local DAF staff are a part of this communication network.

Project activities have had an impact with project team members seen as a source of information on automation and robotics. Industry contacts included local, state and national industry organisations. At present, few use social media such as facebook or twitter although this may change in the future. Radio, podcasts and TV also did not rate highly as a source of information on automation and robotics.

The newsletter 'market survey' showed that while content and format of the two page QLD Veg Automation Update worked well, its distribution could be better targeted in Gatton and Bowen/Burdekin regions. In Bundaberg, newsletter distribution via BFVG appears effective.

Some suggestions for strengthening current networks and interactions include:

- When designing project activities, recognise the problem of information overload and the limitations of different communication methods and distribution tools
- Avoid contributing to the problem by hard filtering information prior to sending and use concise descriptive headers for emails
- Get project information onto websites so interested growers and industry can find it when searching for information
- Webinars have great potential as a means of better linking up growers, industry and researchers
- Social media is not a major tool for keeping up to date at present but that may change in the future

Don't underestimate the impact of word of mouth. Personal relationships built over time and based on trust form the basis for effective networking and communication. They help to make emails and texts stand out amongst all the other information growers and industry receive providing they continue to be well targeted and enhance not detract from personal capital that individuals have built within a network. Look for ways of value adding to existing local networks by collaborating not competing with local and regional service providers.

Keywords

Automation; robotics; sensing; industry engagement; extension; vegetables; needs analysis; project evaluation; MARS

Introduction

This document updates an interim report submitted to Hort Innovation in October 2016. It incorporates outcomes from industry review meetings and end of project evaluation results.

The interim report summarised findings of an extensive needs analysis designed to engage with a wide range of Queensland vegetable growers and industry service providers (local engineering firms, consultants, agronomists and other support staff) in order to determine industry priorities in automation and robotics research, development and extension (RDE). It followed on from activities to scope current technology and R&D capacity available in automation, robotics and sensing by the project team.

The needs analysis was based on start of project industry surveys (October 2014 to April 2015) and six industry forums (two each in Bowen, Bundaberg and Gatton) and 15 farm visits over two weeks in May 2015. It included a number of follow up farm visits by project team members to complete the engagement process. These activities created an abundance of ideas and information with some common themes emerging.

'Emerging industry priorities' were consolidated at industry review meetings in each target region during March/April 2016 and at end of project industry surveys 2016 to evaluate project impact (November/December). Information from the project evaluation will contribute to baseline data for VG15024 Vision systems, sensors and sensor networks to manage risk and increase productivity in vegetable production systems.

An important aspect of the project was to engage growers and industry in the innovation process by providing them with opportunities to evaluate the potential of current and future automation, robotics and sensing technologies and how these might improve their farming operations.

This is what the technology can do now. What else might it do? How might this be useful for improving farm and shed operations?

In order to achieve this, we aimed to:

- Focus on industry needs rather than the technology in the first instance
- Discuss possibilities with potential end users – individually via survey interviews and farm visits as well as in group settings at forums
- Bring researchers into the regions and onto farms
- Start to build feedback loops between end users, industry and researchers

Our rationale for this approach was that by involving end users early in the design and innovation process and facilitating interactions between researchers and potential end users, technology was more likely to be fit-for-purpose and hence more likely to be adopted widely, and quickly.

The target regions were the Bowen/Burdekin, Bundaberg and Lockyer/Fassifern Valley areas– the three main vegetable production regions of Queensland.

Methodology

The needs analysis consisted of a series of grower and industry interviews (surveys), regional industry forums and farm visits. Prior to starting activities, the project team spent some time thinking through what information was required to answer the broad question:

"How can the vegetable industry best take advantage of automation and robotics to remain competitive on the world market?"

For project evaluation purposes, this planning phase also involved an in depth analysis of project outputs and outcomes as outlined in the project proposal using Bennet's hierarchy of evidence and log frame concepts (Roberts and Coutts 2006) to determine the key questions against which to collect data. These key questions are:

KQ 1. How actively engaged and aware of developments in automation & robotics innovations are growers and industry service providers?

KQ 2.What is the individual's current knowledge, attitude and aspiration when it comes to automation & robotics?

KQ 3. What level of technology is currently implemented on farm?

KQ 4. What are the individual's current networks and interactions in the automation & robotics industry? How can these be strengthened?

Grower and industry surveys

Regional surveys were carried out prior to the industry forums and farm visits to gain an understanding of the level of grower knowledge, interest and experience with on farm automation. These surveys provided an insight (baseline) on grower and industry observations, opinions and desire to address productivity issues and drivers with automation and robotics innovations.

A questionnaire was developed to collect data against the four key questions. It consisted of a series of open-ended questions to guide the conversation during face to face interviews. We also took the opportunity to collect potentially useful demographic, production and marketing information at the start of each interview. This questionnaire was fine tuned for the end of project evaluation surveys and included additional questions to gather data for VG15024.

After considering the aim of the survey, we decided to select potential interviewees based on crops grown, size of farm, markets targeted and our perceived assessment of an individual's interest in automation and robotics technology. The objective was to engage with a wide cross-section of the vegetable industry in the three target regions focusing on individuals that were likely to have capacity and interest in being involved in the MARS space (Mechanisation, Automation, Robotics and Sensing). However, project activities were open to anyone interested in getting involved and we followed up on several requests and suggestions.

We used a similar process to select industry service providers for interview – agronomists, consultants and in particular, specialist local fabricators (engineering firms) who in many instances have built, serviced and modified horticultural farm equipment for many years. In selecting these

service providers we were guided by local growers' suggestions on whom to interview and followed up on a number of these suggestions.

Our aim was to follow up interviews two years later to measure project impact. Since the selection process was not random, **data cannot be statistically analysed**. The interview questions with a summary of results against each question are presented at the end of this document (Attachment I).

Regional industry forums

As outlined in our project proposal, the focus of the work was on the needs of the end user, their different cropping systems, capabilities and crop requirements rather than the technology in the first instance. The question we wanted to answer was:

"What are the specific industry priorities for follow up in each of the three regions?"

The facilitation process for the industry forums was designed to present participants with a wide range of current and developing automation, sensing and robotics technologies (see Figure 1 below) in such a way that encouraged participants to think through the implications and potential application of this technology within their farming operation (or business operation in the case of engineering firms, consultants, agronomists).

"Step by step improvements…….this is what we have now ……..what if we could…….?"

The rationale of this approach was based on a much shortened process from the Problem Specification Workshops used by the Centre for Tropical Pest Management in the 1990's (Norton 1999, Norton 1996). It included adaptations of the KJ-Technique (Spool 2004) and pin card technique (Geschka 1981) to collect ideas from participants using sticky notes (post-its) at the end of each presentation/questions/discussion session (see example forum agenda in Attachment II). These individual 'ideas on sticky notes' were displayed on venue walls and collected over the two forums in each region for later re-organisation and prioritising.

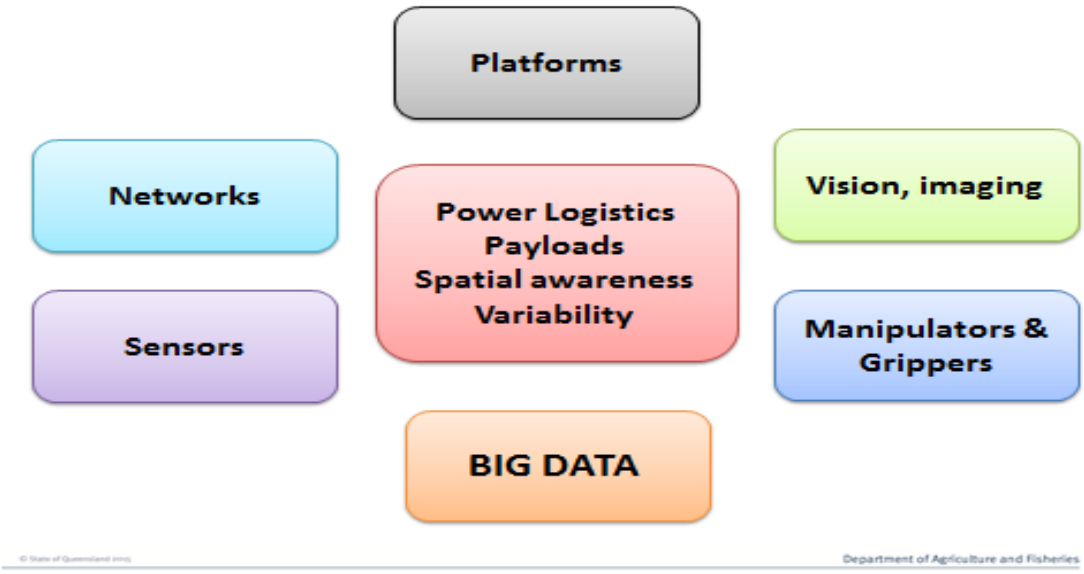


Figure 1: Various components of automation, sensing and robotics technology covered at the industry forums.

At the end of the second forum, participants were asked to group similar ideas together and re-organise these within an impact vs ease matrix (Figure 2). This matrix tool in effect provided the criteria to help with prioritising of ideas captured on sticky notes against the objective: improve productivity/reduce labour. It encouraged participants to think about:

- how big an impact solving the issue or implementing the idea might have on their farming business
- how easy or difficult the issue/task/technology might be to solve/develop/implement

These groups of ideas were then voted on by industry members to determine priorities using the "sticking dots" method (From Mycoted – see link in references). Only participants with "skin in the game" took part in the prioritisation process: one set of six "dots" per enterprise – grower enterprises, engineering firms and local agronomists.

In Bundaberg due to time constraints at the second forum (a lively discussion was in progress at the time), grouping of ideas and voting was conducted on farm in the weeks following the May 2016 forums. We also ensured that growers that had attended the first forum but were unable to attend the second Gatton and Bowen forum had an opportunity to contribute to the prioritisation process by visiting these growers on farm after the forums.

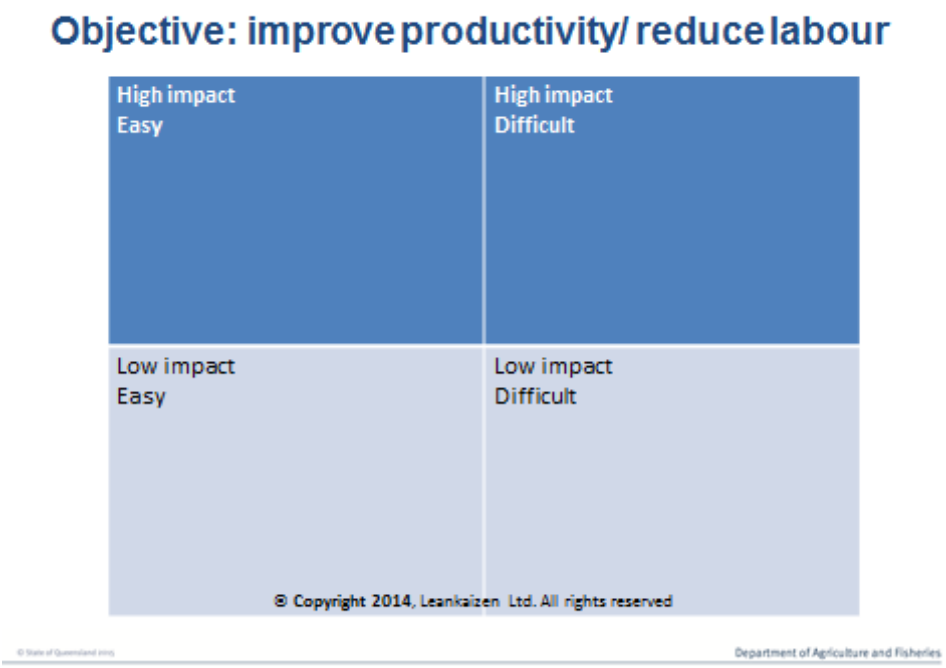


Figure 2: Impact vs Ease analysis - criteria used to re-organise ideas on sticky notes in preparation for prioritisation (Leankaizen 2014).

The regional industry forums were carefully planned, with thought given to the topics presented by each researcher and the order and manner in which subjects were presented. We wanted the regional forums to provide an overview of current MARS research both locally and around the world with a focus on potential application in the horticulture industry. Questions and discussion between presenters and the forum participants was encouraged to help everyone to better understand the complex technologies and concepts involved – including constraints and challenges presented by

horticultural production systems and operations to the development and implementation of these technologies.

In addition, the forums had to fit within a time frame that we thought growers could manage to commit to at a busy time of the year – two sessions of three hours each, one week apart, held in each of the three major vegetable production regions of Queensland. Despite the time limitations and complexity of information presented, the process worked well and was robust enough to use for follow up prioritisation on farm with individual growers.

Farm visits

The farm visits were primarily designed to expose MARS researchers to a range of farming operations, cropping systems and packing shed processes. The concept was to invite leading researchers on farm to see, hear about and experience daily farming activities and productivity challenges first hand from the grower's perspective. The farm visits provided an opportunity for growers and researchers to interact one-on-one while standing in a crop or observing a packing shed operation while having productivity challenges explained to them. A range of ideas on how automation, sensing and robotics technologies could be applied to increase the productivity of various horticultural processes/tasks was discussed. These ideas were captured by the project team and contributed to the list of emerging industry priorities.

Industry review meetings

To continue the grower engagement process, we held three industry review meetings – one each in Bowen, Bundaberg and Gatton – during March/April 2016 to update industry on R&D progress, consolidate industry priorities and start to build regular interactions between growers, industry and researchers (feedback loops). To provide continuity, these annual meetings will continue as part of VG15024.

Project staff facilitated an interactive meeting format using Citrix GoTo webinars. This enabled researchers from QUT and CSIRO in Brisbane and ACFR in Sydney to present updates on their work. To overcome regional bandwidth (live data transmission) problems, researchers provided voice over video or power point presentations prior to the meetings and were then available for Q&A sessions during the webinar. The meeting concluded with a presentation on the 'Emerging industry priorities' with participants asked to assess and rank these using a two page form (see Attachment III). This form was included in the end of project evaluation interviews to expand on the number of people contributing to the priorities consolidation process.

Newsletters

Four QLD Veg Automation Updates were produced by the project team to promote awareness and inform industry about project activities and results. Local industry organisations – Bowen Gumlu Growers Association (BGGA), Bundaberg Fruit and Vegetable Growers (BFVG) and Lockyer Valley Growers distributed newsletters to their members. The updates were also emailed direct to state and national industry organisations, researchers and industry contacts.

Testing prototypes and system analysis (Lean)

This involved intensive work with four collaborating businesses:

- Deployment of a prototype wireless sensor network on a Gatton farm to develop an autonomous system to detect and deter ducks in Baby leaf – methodology and results to date are detailed in Appendix III
- Delivery of 'Lean Operational Excellence' introductory workshops by the Queensland Manufacturing Institute (QMI Solutions) in collaboration with the project team. Three growers, one in each target regions, volunteered their time and business for these case studies. Methodology and results are detailed in Appendix II

Overall results

The prioritisation results are based on in depth engagement with 53 businesses through a combination of personal interviews, participation at industry forums, review meetings and/or farm visits. There is significant overlap between these different methods of data collection with some individuals attending both forums, the review meeting, hosting a farm visit and taking part in initial and end of project survey interviews. A small proportion of enterprises took part in only one of the engagement activities. Figure 3 summarises the number of enterprises involved and crops represented in surveys, forums and farm visits. Three additional enterprises contributed to review meetings.

Figure 3: Enterprises engaged through industry surveys, farm visits and regional forums.

In addition, 26 industry support or research staff participated at regional forums including presenters (QUT, CSIRO, DAF, ACFR via skype) and staff from Bowen Gumlu Grower Association (BGGA), Bundaberg Fruit and Vegetable Growers (BFVG) and Central Queensland University (CQU).

While these individuals assisted with ideas generation, they did not participate in the voting process to determine the initial industry priorities. A summary by region of people interviewed, farms visited and forum participants is provided in Figure 4.

Figure 4: Summary of people interviewed, farms visited and forum participants.

Regional industry forums

As described earlier, six 'Veg Automation' forums were held over a two week period in May 2015. The forums consisted of two three-hour sessions in each target production region structured around presentations by researchers from QUT in the first week, followed by a similar round of forums a week later with researchers from CSIRO. Forum dates and locations were:

Gatton Research Facility, Warrego Highway Mondays: 11th and 18th May

Bundaberg DAF Offices, Enterprise Street, Tuesday 12th May & Wednesday 20th May

Bowen Research Facility, Warwick Road Thursdays: 14th and 21st May

Presentations exposed growers and industry to current and previous automation and robotics work carried out by highly regarded Australian research providers. The regional forum sessions allowed growers and industry to learn from existing automation and robotics research experience and think about how this expertise and technology could best enhance local farming tasks. The logic for scheduling regional industry forums in this way was two-fold:

- Attendance and participation in a three-hour forum is more achievable for busy vegetable growers at a busy time of year.

- The complexity of the information presented and its potential fit within current vegetable production systems is more easily absorbed in two chunks by participants - growers, industry, researchers and project team members. This participatory format allowed time for learning and reflection between forums. Informal discussion and feedback since the regional forums has confirmed that this was a worthwhile approach (based on action learning concepts - see Dilworth 1998).

The two forum approach in each regional production hub also made it possible to deal with the quite complicated travel logistics of fitting three forums and up to eight farm visits across three regions into a five day working week.

Several weeks prior to the forums, we provided a short 'brief' to researchers which outlined the areas of technology within automation, sensing and robotics we wanted them to focus on in their presentations. There is some overlap of expertise and current research activities between CSIRO and QUT so the brief ensured diversity of information for each forum with minimal content overlap. The forum notice for the Gatton forums is included in Appendix III to illustrate process and content.

The flexibility and willingness of QUT and CSIRO presenters to tailor their content and examples to fit within this brief was one of the reasons for the success of the forums.

Week 1 - Forum One – 11 to 15 May 2015

QUT presenters: Tristan Perez, Chris McCool and Chris Lehnert. Tristan leads the DAF funded Strategic Investment in Farm Robotics program (SIFR).

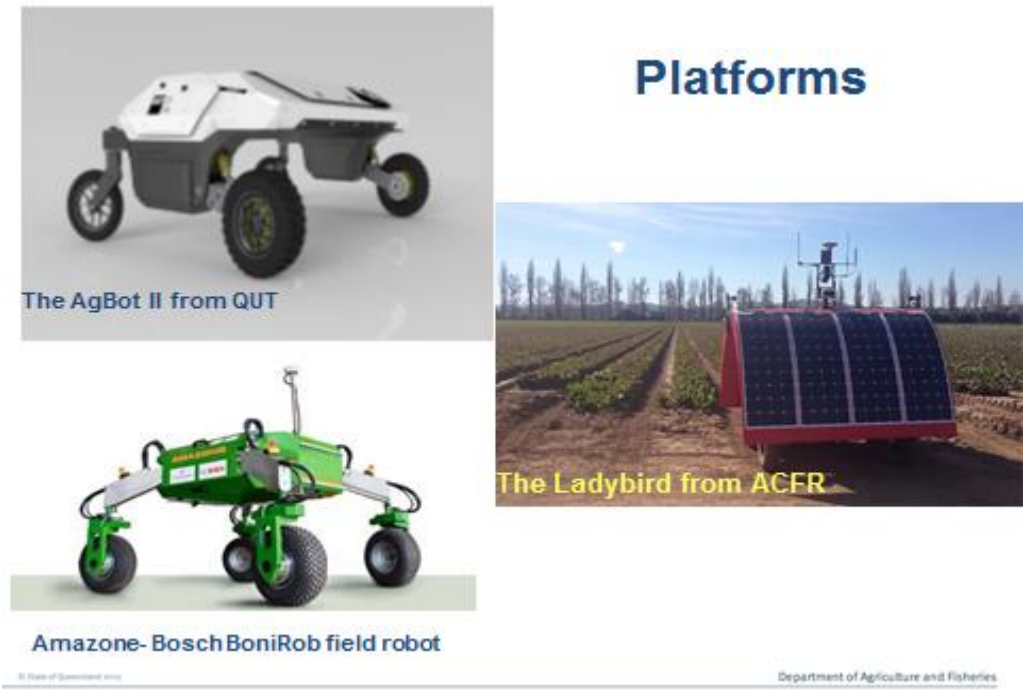


Figure 5: Ground platforms discussed at industry forums.

Researchers from QUT outlined the current state of machine vision systems, manipulators and grippers available to the agricultural industry using their knowledge of worldwide developments and their current work in protected cropping and field grown capsicum crops as practical examples. This

presentation led to a discussion about how these devices would be mounted and used in the field, a great lead in to the session on ground platforms and their design features: QUT's AgBot 2 and the Ladybird from ACFR (Figure 5). Forum participants found this quite engaging and challenged researcher assumptions and design ideas – a useful discussion for all.

James Underwood from the Australian Centre for Field Robotics (ACFR) at University of Sydney provided an interactive voice over video on the Ladybird platform (VG12104) and was available for questions and discussion via Skype®.

Week 2 – Forum Two – 18 to 22 May 2015

CSIRO presenters: Adrian Bonchis and Phil Valencia have experience and well-established national and international R&D links across a wide range of technical areas in automation, robotics and sensing.

The second round of regional forums focused on autonomous systems using current commercial application of this technology in the mining industry to illustrate potential on farm and in shed applications. A range of imaging and mapping technologies were discussed and explained which again led to some good questions and discussion. CSIR0 presenters also touched on and gave practical examples of unmanned aerial vehicles (UAVs) and their potential applications and limitations.

Queensland examples of data gathered remotely using wireless sensor networks and their potential application in horticulture led into a discussion of issues around accessing and using 'Big Data'. This session segued into Precision Agriculture concepts, its fit with automation, robotic, sensing and 'Big Data' and was well illustrated by the on farm Variable Rate Technology (VRT) work of DAF researchers Ian Layden, Julie O'Halloran and Sarah Limpus (GMX-INNOV-312 Caring for our Country project).

Farm visits

We visited a total of 15 farms including eight packing sheds over the two weeks supplying the following products: capsicum, chilli, tomato, pumpkin, melons, zucchini, cucumber, sweet corn, green beans, broccoli, cauliflower, cabbage, sweet potatoes, ginger, lettuce and baby leaf salad as well as blueberries, mango and avocado.

Main ideas, opportunities and issues discussed during farm visits are outlined in the regional summaries which follow.

Industry review meetings

To continue the grower engagement process, we held three industry review meetings in autumn 2016 – one each in Bowen 10 March, Bundaberg 22 March and Gatton 7 April. The purpose of these regional meetings was three fold:

- Review and confirm emerging industry priorities with growers and their service providers
- Update regional industry on progress in automation, sensing and robotics R&D
- Continue to build feedback loops between growers, industry and R&D providers

As mentioned earlier, researchers from QUT, CSIRO and ACFR participated in the meetings via Citrix GoTo webinars. Despite some early teething problems, this method of 'virtual participation' worked

very well with an excellent response from meeting attendees. Our thanks to Chris McCool and Tristan Perez (QUT); Phil Valencia and Peyman Moghadam (CSIRO) and Salah Sukharieh (ACFR) for their professional presentations and willingness to try out this meeting format.

Topics covered included QUT's Agbot 2 and their robotic capsicum harvester Harvey; ACFR's Ladybird and RIPPA the weed zipper; and from CSIRO an introduction to hyperspectral imaging and update on wireless sensor networks applications. The meeting concluded with a review and consolidation of 'emerging industry priorities'.

Apart from Bowen, turn out at these meetings was less than expected at 25 people and 13 enterprises in total. However, the project team received a number of apologies, with growers citing other commitments not lack of interest as the reason for being unable to attend. In fact, there were a number of requests for future activities. In response, specific questions to explore more innovative, targeted ways of engaging with growers and industry were included in the end of project evaluation.

Regional summaries

As described earlier, a central activity of the May 2015 forums was to collect participant ideas on how various automation, robotics and sensing technologies could improve on farm operations. Growers, local engineers and agronomists were then asked to group these ideas or potential solutions based on their perception of whether if implemented, this would have a high or low impact on farm costs and productivity and **their own individual judgement** on whether this would be **easy or difficult** to achieve. Growers, local engineers and agronomists then voted on these "groups of ideas" to determine the highest priorities. They are listed in the individual regional summaries in order of number of votes received. Only those with at least one vote are included.

Key observations and insights from farm visits are included in each regional summary. Results from the industry surveys that inform the prioritisation process are also highlighted. These are primarily based on responses to:

Q4 What do you see happening in the industry over the next two or three years (with regards to automation and robotics)?

Q10 If there was one (other) thing you could automate on your farm what would it be?

and

Do you have any other comments you would like to make?

This wish list of 'Emerging industry priorities' was presented for discussion, ranking and consolidation at the industry review meetings the following year (autumn 2016) and included in the end of project evaluation surveys. Thirty-nine people contributed to the consolidation process.

Bowen/Gumlu/Burdekin region

Fruit and vegetable production from this region in North Queensland is worth at least $500M per year with the tomato industry alone estimated at $185M. It is the largest winter vegetable growing region in Australia and employs up to 5000 people peak season. The region is the main national

supplier of field grown winter/early spring tomato, capsicum, green beans, sweet corn, zucchinis, pumpkins, melons and eggplant. The main fruit crop for the region is Mango.

- Vegetables are almost exclusively grown using trickle irrigation with the majority transplanted into plastic mulched beds – beans, sweet corn and some cucurbits are direct seeded
- Vegetable, mango, beef mixed farming enterprises are common
- Seed costs have increased dramatically especially for tomato (need to use new hybrids with disease resistance)

Priorities from forums

(10 people representing 6 grower enterprises and 1 engineering firm)

High impact/easy:

- Inter-row spraying/slashing of weeds using vision systems & autonomous platforms (8 votes)
- Vertebrate pest management (wallabies) (3 votes) and virtual fencing in mixed farming operations (3 votes) using wireless sensor networks
- Driverless (autonomous) tractors to power existing implements particularly crop sprayers as an intermediate step which could be more quickly adapted to existing systems (2 votes)
- Automating bucket tipping in tomato harvesting operation (2 votes)

High impact/difficult

- Automated mango harvesting (4 votes)
- Improved efficiencies in tomato processing plant - vision systems, sensing (3 votes)
- Hyperspectral imaging to improve weed management (3 votes)
- Replacement vision systems to improve those currently being used (2 votes)
- Automated protein bait spraying (2 votes) and pesticide targeting to specific plant parts (1 vote) using platforms, vision systems, sensors

Low impact/easy

- Automated plant hole drench injection in plastic/trickle irrigated systems (WHS issue) (2 votes)

Ideas from farm visits

Six farm visits including four packing sheds - tomato, capsicum, zucchini, green beans, mango

- Automated mango harvesting
- Improve defect sorting vision systems (blemisher) currently in use
- Improve defect sorting efficiencies prior to colour vision grading
- Sensors & sensor networks for crop monitoring, improved field efficiencies
- Automatic labelling, pallet stacking and product tracking

Survey result highlights – growers only (11)

Responses to Q4 indicated that there was a general sense that automation and robotics use in agriculture would continue to increase:

- Better GPS use, more precise fertiliser and spray application, inter-row spraying using sensors, autonomous machines
- Eventually automated fruit picking, with perhaps more scope in tree crops initially
- Continued slow uptake of the technology with a lot of failures, not many successes - will come down to what people can afford

Responses to the aspirational Q 10 “If there was one other thing you could automate what could it be” fell into three broad areas:

- Packing line processes including automatic box fillers, defect sorting, automatic pallet stacking to grade; automated box/tray stacking; field to the box data collection
- More targeted, strategic weed spraying; zonal spraying (fungicides); autonomous spray rigs, imaging to ID disease issues (based on VRT project experience)
- Automated harvesting and planting, maturity testing (mango), capsicum harvest similar to carrots, that is: mechanise

Some attempts have been made to automate planting and harvesting operations with little success despite substantial investments in time and money – cost, inability to get the technology to do the job and lack of equipment/software flexibility (IP related) seem to be the main issues. Automatic pallet stackers while available are not widely used – one is no longer in operation as it could not cope with the wet environment. A new defect sorter while reducing labour inputs substantially cannot grade out some major defects effectively.

Review meeting and end of project survey

Rationalisation of the vegetable industry continues with some growers exiting the industry, larger growers expanding production and most looking to diversify into other enterprises and markets with a keen interest in getting into or expanding on exports. Water is a limiting factor in Bowen and Gumlu.

Bundaberg

This region grows a diverse range of fruits, vegetables, nuts and herbs. It is estimated to have an annual farm gate value of more than $500 million, injects over $1 billion into the local economy and employs over 5000 people across 30 different commodities peak season.

- Massive increase in tree crops over the last 20 years with of 6500 ha macadamia and 1930 ha avocado plantings now in full production
- Year round vegetable production often grown in rotation with sugar cane
- Traditional gourmet tomato production has declined. There has been an increase in specialty lines such as cherry tomato, snacking cucumber, baby capsicum, ginger, fresh and processing chilli, greenhouse production as well as strawberries and blueberries. The region is the main national supplier of sweet potato
- The region has a secure source of water via the Burnett Water supply scheme

Priorities from forums

(13 people representing 6 grower enterprises, 2 agricultural supplier firms (agronomists), and 1 engineering firm)

High impact/easy:

- Infra-red vision to identify crop health – more targeted protected sprays/nutrition (11 votes); Selective spraying of weeds/diseases/nutrients in crop (2 votes); Chloropyll assessments (vision, sensing)(1 vote); Early detection of pest/disease symptoms (1 vote); In crop weed, bug, disease, plant health/stress checking (1 vote)
- Adapt platform to suit specific industry and type of operation eg weeding, chemical application, bug checking, harvesting – needs to be all terrain, variable speed – weed seeker type technology + AgBot 2 + robotics/GPS/autonomously guided operation (10 votes)
- Camera technology for weed control in a high density crop (6 votes); Infra-red detection of weeds using existing precision tractor and machinery (2 votes); (automated) Inter-row spraying between plastic (2 votes)
- 3D mapping of trees in tunnels for pruning architechture/light diffusion measurements for pruning strategies (5 votes)
- Identify ripe harvestable fruit and mark (for later harvest by human) – brix, colour/size, other quality/ripeness indicators (2 votes)
- (Harvesting aid) recessed circular saw to cut stem off, like they use in the timber industry (2 votes)
- Macro-pest management and deterrent eg duck problem in strawberries and baby lettuce, flying foxes (2 votes)
- One vote each - (Automated) levelling of fruit (watermelon) bins (for stacking); Autonomous fruit fly baiting/ biological control releases/ distribution of predatory insects; Yield evaluation for avocado to improve estimates for marketing; Monitor crop water status to facilitate precision irrigation

High impact/difficult

- Identify harvestable (ripe) fruit, cut and lift onto a conveyor (2 votes)
- Automate sweet potato packing into cartons – vast difference in shape, size and shape (1 vote)

Ideas from farm visits

Six farm visits including four packing sheds and one processor – zucchini, chilli, sweet potato, pumpkin, melons, ginger, blueberries and speciality capsicum, tomato and cucumber.

- Tools to support training and simplify decision-making of unskilled staff, eg by automating grading to size, it is easier to train staff to pattern pack product as there is only one decision to make. Is it possible to speed up training of people for pruning or picking using videos or simulators?
- Shed efficiencies – into and out of sorting/grading area: defect sorting, stacking pallets to grade, redesign of movement, limited storage space
- Sensor networks to assist with crop management eg salinity problems, crop health, fruit maturity
- Automated weed control – inter and in row; Automated harvesting

Automated zucchini harvesting, blueberry pruning and harvesting, ginger cutting for seed and market while very labour intensive were seen as too difficult at this stage.

Survey result highlights – growers only (9)

Most growers said that labour costs will drive future industry innovation however a third of growers interviewed said that they did not see a lot happening with automation and robotics in the next two or three years. Two growers mentioned the following as potential areas of innovation in the short term:

- Precision application of chemicals by sensing technology to improve crop management
- Automated herbicide application with GPS and hooded sprayer

There was a general sense that more needed to happen with automation and robotics to deal with labour costs:

"Sky is the limit if industry, researchers and developers linked up".

Responses to the aspirational Q10 "If there was one other thing you could automate what would it be" included:

- Automated harvesting (5) and more packing shed automation (4)
- Automated weed control (3) and automated pruning (2)

Review meeting and end of project survey

As with North Queensland, there has been a trend toward diversifying into fruit crops.

Lockyer/Fassifern Valleys

This region in South East Queensland is a major cool season supplier of lettuce, cauliflowers, broccoli, cabbage, carrots, onion, potato, baby leaf salad and other leafy and bunching vegetable lines as well as beans, sweet corn, tomato, capsicum, melons and pumpkins over summer. Vegetable production was valued at around $230 Million in 2010/11 with 12% of locals employed in the agriculture sector in addition to casual seasonal workers. This winter vegetable production area is complemented by the nearby production regions on the eastern escarpment of the Darling Downs and in the Granite Belt.

- Major national suppliers of corn, green beans, lettuce and carrots have their home base in this region
- Cool season vegetables are generally grown with overhead irrigation, summer crops with plastic mulch/trickle irrigation systems (excluding direct seeded crops).

Priorities from forums

(14 people representing 9 grower enterprises and 2 engineering firms)

A good cross section of growers was achieved both in the range of crops grown and varied enterprise size. Several of the largest operations were represented at forums. Due to the mid-May timing of forums – the start of the winter harvesting season - only one of the growers interviewed for the survey was able to attend the forums.

High impact/easy:

- Weed control including inter/in row spot spraying/weed eradication based on weed detection and identification using small autonomous platforms/robots (9 votes)

- Chasing ducks out of paddock and crop (4 votes)
- Guidance in crop for mechanical weeding and harvest equipment (2 votes)
- Reliability - day to day - of automation equipment in a dirty, dusty, wet environment (2 votes)
- Airport security screening set up – sweet corn cob (in leaf) defect detection (2 votes)
- Crop quality checking through camera in real time (1 vote)
- Greenseeker - we have GPS - we have IPad in tractor - why can't we have on-the-spot analysing? (1 vote)
- Spot problem in crop by heat, verify then then control problem spot (1 vote)
- Radio frequency or GPS tracking of harvest produce / containers from field to shelf (1 vote)

High impact/difficult

- Crop monitoring for maturity and head quality in lettuce, cabbage, Chinese cabbage (5 votes)
- Ripeness detection and selective harvesting of seedless melon (5 votes)
- Selective harvesting of headed crops by size (eg. cabbage, lettuce, broccoli) (3 votes)
- Vision all vegetables and mass sizing and weight (3 votes)
- Yield information (maturity ie kg per ha ready to pick) in tomato, lettuce (2 votes)
- Picking and grading of broccoli (1 vote)
- Detection of disease on fruit or vegetables in field (3 votes); detection, ID and management of disease or other problem infield (1 vote)

Low impact/easy

- Bird scattering (3 votes)
- Ripe fruit detection (3 votes)

Variations of these two ideas also appear under 'high impact' which could reflect a difference of opinion on whether these ideas are low or high impact or it could be due to time constraints to re-organise ideas into the impact vs ease matrix at the forum.

Ideas from farm visits

Three farm visits – baby leaf salad, lettuce, broccoli, cauliflower, cabbage

- A number of local growers described machines they had purchased that were not supported locally (parts and service) or did not perform as promised. MARS solutions need to operate in a dirty dusty wet environment on range of soil types.
- With increasing casual labour, need to support staff in decision making – what to harvest, when to harvest (is it ripe or mature?). How can we assist our staff to do a more consistent high quality job – this has benefits right through the supply chain
- Interest in sensors for predicting or early warning of disease or pest outbreaks – how do we monitor weather conditions that are favourable to pest and disease occurring?
- Product ownership and tracking – both on farm and in the transport system – how do growers ensure product is looked after on farm and in the transport system?
- Is there a better way to predict crop harvest date or maturity so as to better schedule labour needs?

Survey result highlights – growers only (6)

Growers thought that automation would progress however there may not be much change in the short-term. Something useable specifically for weeding was seen as attractive with one grower calculating that they spent $30,000 on weed control per year. Growers saw the initial step being machine assisted operations not full robotics as they believed the latter would be too expensive and unreliable at this stage.

A real issue for baby leaf salad producers is ground hygiene. They have zero tolerance for foreign objects in field as any plastics, weeds, trickle tape off cuts and other rubbish blown in from nearby roads are a high risk for market rejection. Removal of these foreign objects from fields prior to planting and at harvest through visual inspections is a high cost, labour intensive exercise. Another major cost issue is bird or animal damage, usually overnight, causing significant product losses and risk of faeces contamination (food safety issue).

Several growers have attempted to automate part or all of their harvesting operation. We know of one expensive piece of harvesting equipment sitting in a paddock which is unworkable. Another grower has had to make major adjustments to an auto buncher/washer they purchased which was unable to be adjusted for their required bunch size and has specialist electric componentry that is not supported locally or easily retro fitted. This is an example of an all too common problem – specialist equipment purchased to address a specific on farm problem but once installed found to lack performance and support resulting in a poor (often expensive) outcome.

Review meeting and end of project survey

As in the other two regions, growers are looking to diversify to spread risks and consolidate to fine tune operations as much as possible.

Emerging industry priorities

The farm visits, forums and industry surveys enabled collection of opinions and thoughts from a wide cross-section of vegetable growers and industry about automation needs and current experience in three main vegetable production regions of Queensland. This created an abundance of ideas and information with some common themes emerging. These ‘emerging industry priorities’ were categorised into broad theme areas based on the prioritisation process undertaken at regional forums, observations made during farm visits and survey results.

Automated crop management

Including weeds, pests, disease, disorders, irrigation, nutrition (and crop forecasting/ scheduling, maturity assessment – addressed under robotic harvesting below)

Autonomous weed management

Weed control including inter/in row spot spraying/weed eradication based on weed detection and identification using small autonomous platforms/robots and various vision systems and sensing technologies

More efficient weed management is a priority across all three regions with a range of potential ideas and methods to automate this task receiving a high percentage of votes at the end of regional forums. This priority was categorised as high impact/easy with work already underway as

autonomous spot spraying of weeds is the first target task for QUT's AgBot 2, ACFR's Ladybird and RIPPA the weed zipper and SWARM farms.

Growers and industry could see that some headway could be made in this area in the short term. Automatic weed management also featured strongly in the initial grower surveys (aspirational Q10). While the topic came up during farm visits, it was not one of the main areas of discussion. On all farms visited, tasks requiring a high labour input (harvesting, packing shed operations) tended to be the main focus of discussion between farm business owners and visiting researchers.

Weed control is a continuous and therefore costly operation in vegetable production systems with industry desiring a more strategic, targeted and in some respects "set and forget" approach (autonomous). For example, one grower stated that their (national) operation spends $2 million on labour costs annually to control weeds.

Autonomous all purpose, adaptable platforms

The Agbot 2 and Ladybird captured the imagination of growers and industry. The idea of an autonomous platform that was flexible, adaptable and suitable for a range of tasks across various terrains and farming operations was attractive to industry. An adaptable platform with 'plug and play' interchangeable modules (spray, soil test, crop assess, crop inspection) was a concept that interested growers. There was an understanding that these types of 'robots' may still be some time off in the future, however a step by step approach using existing platforms (which included current spray equipment) to test, develop and implement 'modules' of new technology might bring early benefits.

Automated crop health monitoring for strategic, targeted crop management

During forums, participants discussed the potential impact that various vision systems, imaging and sensor technologies could have on improving efficiency of field operations and better managing field production risks - particularly when combined with autonomous platforms. Industry priorities involved real time early problem identification, monitoring of soil and crop conditions and more targeted, strategic management responses for example, spraying only a part of the crop or specific plant parts. The potential of wireless sensor networks to improve soil and crop monitoring came up during several farm visits and precision application of chemicals to improve pest and disease management was mentioned a number of times during grower surveys.

What next to progress these priorities?

- Encourage involvement of a wide range of potential end users in future development of autonomous platforms particularly with regards to flexibility, adaptability and modular aspects for future successful commercialisation. Keep regional industry informed on progress with the AgBot2 and RIPPA and support further efforts to have these platforms (with weed detection and targeted weed eradiation modules) demonstrated regionally. The RIPPA was on display at the Gatton Horticultural Field days in July 2016, the AgBot 2 was launched at Bundaberg in October 2016. Both have featured at several industry conferences and trial work in Queensland has commenced.
- Support efforts to resource development and on farm testing of vision, imaging and sensor technologies that can improve crop health monitoring, early problem detection and strategic, targeted responses to problems identified.

- The DAF/QUT/CSIRO project collaboration *VG15024 Vision systems, sensing and sensor networks to manage risks and increase productivity in vegetable production systems* will progress R&D on automated crop health monitoring - specifically the component focusing on the d*evelopment of pest, disease, disorder and stress management tools* using hyperspectral imaging (early problem identification) and wireless sensor networks (micro-climate monitoring).

Managing vertebrate pests in vegetable crops – virtual fencing in mixed farming enterprises

Vertebrate pests can be an intractable and significant problem for particular crops, on some farms in all production regions. Some pests are seasonal, others attack only at night. Birds (eg ducks in baby leaf, strawberries) and wallabies (tomato) were seen as particularly troublesome however wild pigs (North Queensland) and flying foxes (fruit) also got a mention. Birds along with ground contaminants (plastics, rubbish) are major problems for baby leaf salad growers who can suffer large production losses overnight complicated by product contamination (faeces) and inability to supply.

A number of growers in North Queensland run a mixed farming enterprise and the concept of sensor driven "virtual fencing" of cattle had great appeal and led to some brainstorming around how this technology might assist with managing pests such as wallabies.

Wireless sensor networks have the potential to provide the core of an effective management system for vertebrate pests especially when combined with autonomous ground and/or aerial platforms and in depth knowledge/experience of animal behaviour.

What next to progress this priority?

- Due to the immediacy of the issue, availability of component technologies, interested grower co-operators and expertise of CSIRO staff, a small wireless sensor network to detect and deter bird in Baby leaf lettuce was built and deployed in Gatton for prototype testing as part of the project during 2016. More work is planned for 2017 in a small DAF funded project. CSIRO have patented the concept and are in discussion with Hort Innovation, industry and the project team to resource further on farm R&D in this area. Appendix III describes this work in more detail.
- The start-up company Agersens is currently working towards commerialising virtual fencing for the beef, dairy and sheep industry.

Robotic harvesting of tropical and sub-tropical horticulture crops

Step by step – overlaps with automated crop management: crop forecasting, maturity assessments as well as vision systems, sensing, imaging, autonomous platforms, manipulators and grippers

There was a real sense that harvesting was THE priority for automation and robotics however growers also demonstrated an understanding that to achieve robotic harvesting would take time and a significant investment of R&D resources. There was some questioning on whether robotic harvesting was the best option for all crops (field grown capsicum may be more suited to mechanical once over harvesting) and that some crops were 'too hard' to be considered at this stage (field grown eggplant, zucchini, perhaps also tomato). In contrast, robotic harvesting of mango was seen as a real possibility in North Queensland.

Automated harvesting as such did not get a high number of votes at the industry forums probably because it was seen as too difficult or too far into the future however aspects of crop management that represent steps towards automated harvesting did receive a significant number of votes. Some of the terms forum participants used included crop forecasting/yield evaluation, maturity/quality assessment/monitoring, product sizing/selection based on vision, imaging and sensing technology. Automated harvesting was the top aspirational response to Q10 during initial grower interviews and was a topic of discussion during most farm visits.

What next to progress this priority?

- QUT have made good progress towards solving the 'detect and detach' problem through their trial work in greenhouse and field grown capsicum crops as part of the DAF funded SIFR program. Several other R&D groups in Europe and elsewhere are working on locating and then detaching fruit from plants using various methods. New manipulator and gripper technology demonstrated at the regional forums illustrated that this problem may not be insurmountable providing product can be located reliably in the crop canopy.
- QUT are in discussions with two growers to develop collaborations to progress robotic harvesting in mangoes. This can be attributed directly to this project.
- The DAF/QUT/CSIRO project collaboration *VG15024 Vision systems, sensing and sensor networks to manage risks and increase productivity in vegetable production systems* will help progress R&D for robotic harvesting - specifically the component focusing on the *Development of vision systems for rapid assessment of fruit quantity and quality in greenhouse and field grown capsicum crops.*

Sensing and sensor networks for horticulture – improving field productivity

Vertebrate pest management/virtual fencing, (environmental monitoring for) crop health, soil monitoring, forecasting/scheduling, maturity sensing

The sensing and sensor networks technology created much interest at forums and at several farm visits. It is potentially a part solution to a number of production issues and provides opportunities to improve efficiencies, crop uniformity and better manage risks. The technology has application across a range of field, shed and value chain situations.

What can sensors measure? How can they be applied to improve productivity?

Some examples are:

Compact, robust, affordable "sensor" weather stations could allow multiple units to be linked and deployed across a farm. This would allow real time climate, environmental and soil monitoring. Such a system could provide in-crop micro-climate monitoring (air and soil) to potentially forecast disease and pest problems, track moisture and nutrient levels or detect vertebrate pests. It could support variable rate technology (VRT) systems by providing valuable, real time data for better decision-making.

Sensor/imaging technologies and networks have application for quality/ripeness monitoring for maturity assessment (for selective and/or robotic harvesting), tracking harvested product from field to shelfing technologies and cool chain management along the value chain.

Some of this technology is already in use in agriculture. Growers and industry are also already familiar with technologies such as GPS auto-steer, NDVI, load cell yield monitoring, irrigation scheduling and through their everyday interactions with the 'internet of things' – their mobile phone, wireless mouse, Ipad and so on. Wireless sensor networks seem a good fit with Precision Agriculture and VRT development and implementation. The key will be the cost and ability to manage and interpret huge data sets.

What next to progress this priority?

Potential application of sensing and sensor networks technology links in with several other identified industry priorities:

- Automated crop management such as in crop environmental monitoring (including soil)
- Vertebrate pest management systems and virtual fencing
- Quality/ripeness sensing – maturity assessment, selective &/or robotic harvesting
- Increased packing shed efficiency such as tracking harvested product from field to shed to shelf

As described earlier, a prototype wireless sensor network has been deployed for vertebrate pest management in VG13113 and a small scale network for environmental monitoring has been deployed in glasshouse pot trials for VG15024. A large-scale deployment for in-crop environmental monitoring is planned for later in this project.

Increased packing shed efficiency

Application of automation, robotics and sensing technologies to improve packing shed operations did not come out strongly at forums. In fact on a number of occasions during farm visits and also at forums there was discussion around what was and what was not already available off-the-shelf.

Why then are these technologies not more widely used?

A desire to automate various tasks around the packing shed made up a quarter of aspirational responses for Q10 from growers during survey interviews. Growers, researchers and project team members also discussed opportunities for improving these operations during farm visits to packing sheds. The key driver is labour. The main areas where improvements are needed are prior to product entering the grading lines – specifically the effort needed to grade out defects – and processes at the other end of the grading line – specifically carton/bin stacking, carton/product tracking and palletising into a number of different product grades.

There are also opportunities for simplifying packing decisions: a real bonus when farming businesses are often dependent on unskilled labour and suffer high staff turn-over. Simplified and therefore better packing decisions based on technology would reduce training needs and reduce the risk of poor pack outs. Reduced product variation, improved packing consistency and clear product specifications enable the business to market more effectively.

Increased packing line efficiency – defect sorting

During farm visits, it was obvious that sorting out defect product early is an area where large gains might be made perhaps even before product arrives at the packing shed. One comment was that better crop management to reduce in-crop product variability and defects was a good starting point (relates to Automated crop management priority). Growers expressed a desire to half the number of staff required on sorting tables for the laborious task of removing defect product prior to grading. Some tomato growers had installed dedicated electronic 'blemisher' machines which reduced labour inputs technology was still unable to reliably grade out some common defects. There was a sense that future vision and sensing technologies could further streamline packing line efficiencies and by the end of the project some significant improvements had been made in this area.

Increased packing shed efficiency – automatic palletising, product/carton tracking

From comments made, it appears that automated palletisers are used by a small number of vegetable growers with varying levels of success. At the initial interviews, one grower mentioned that their palletiser was now parked in the shed as it could not cope with the wet environment. Other limitations are the space available in a packing shed for the palletising operation and the number of grades into which product needs to be packed to satisfy market requirements (up to 24 grades in one instance).

What next to progress these priorities?

- Through the Lean case studies, review meetings and end of project survey interviews, we know that progress has been made in this area since May 2015. The equipment is improving, existing graders and defect sorters (blemishers) are being re-calibrated with good results and several growers have invested in this technology in the past year or two.

- Since 2015, several Lockyer growers have invested in pallet wrapper equipment to secure produce on pallets so it does not move in transit to markets. This also reduces staff handling times and makes truck loading more efficient. In North Queensland, vegetable growers are organizing a trip to South Johnstone to investigate use of automatic pallet stackers in the banana industry after a visit by banana growers to the Bowen district in 2016.

- Participation in the project led to one grower re-assessing automated grading machines and colour defect sorting. Another grower asked the manufacturer to recalibrate equipment to better grade product to different market specifications. A third grower revisited harvesting procedures to reduce potential yield loss and wastage through cutting immature product (too small) and oversize product coming into the packing shed.

- An in-depth review of technologies already available off-the shelf and their application and suitability with regards to vegetable packing sheds is needed. This work is outside the scope of this current project however we encourage industry to look for ways of funding this work. This type of study needs to move beyond the desk top to include discussions with growers, local engineering firms, machine developers and researchers. This could be achieved by on site assessment of regional packing sheds to determine what specifically is required and how, if at all, existing off-the shelf technologies could be adapted to address these requirements.

Challenges, constraints and opportunities

Automation equipment for horticultural application needs to be fit for purpose, robust, dependable and affordable. Complex high tech machines need to be supported locally with specialist componentry (e.g. cameras, manipulators, guidance modules) that are easily removed, replaced and shipped off for specialist repair.

As flagged in the regional summaries, several growers have attempted to automate part or all of their planting and/or harvesting operation. We know of some expensive pieces of equipment sitting in paddocks or sheds that are not used despite a significant investment of time and money. Other specialist equipment either required extensive adjustments by the grower before it could perform the task for which it was purchased or cannot perform the task to the level expected/required. There was however also an example where collaboration between a specialist machine supplier and a local engineering firm resulted in a modified grading line that met grower expectations.

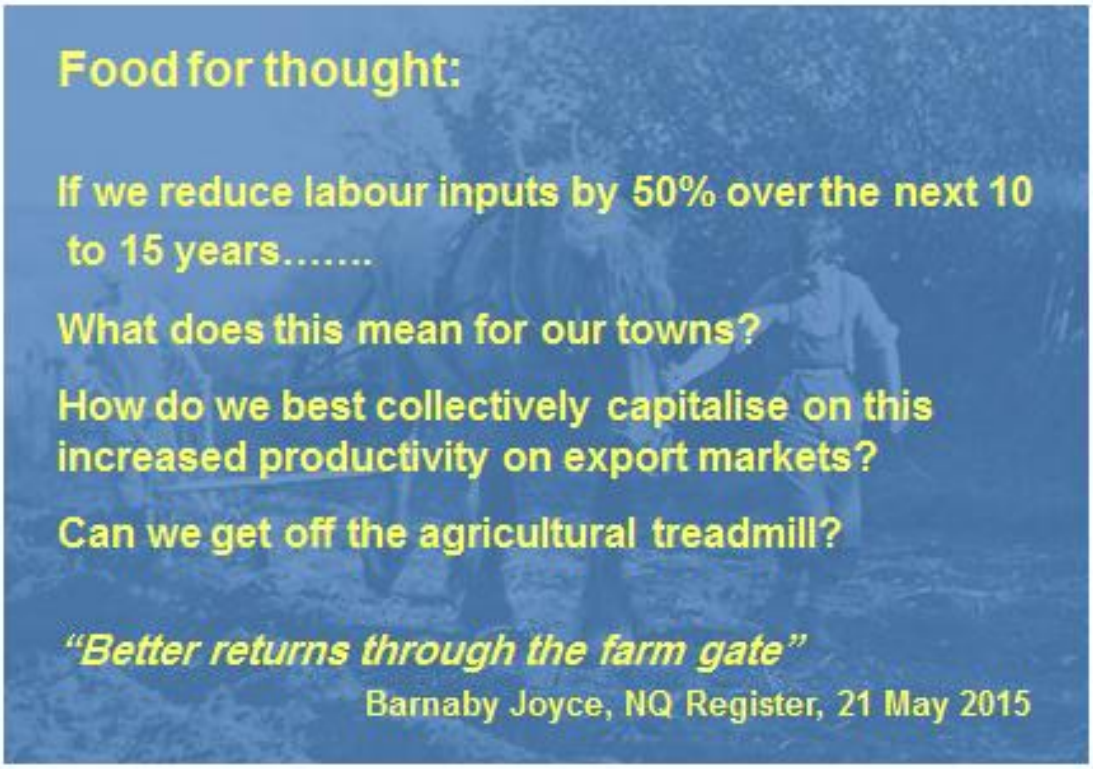
There is latent innovation capacity within growing regions already – engineering firms, consultants, agronomists and growers themselves (many who have trade or degree level engineering, agricultural or business qualifications). Local engineering firms generally have many years' experience in custom building or modifying machinery and equipment to perform specific tasks for vegetable production systems. This expertise is becoming increasingly sophisticated. Agronomists and consultants have an excellent understanding of the industry, productions systems and experience in developing and implementing new technology with growers. They are digitally literate and are bringing growers along with them. Two have bought UAVs to for trial with their grower clients.

Some questions to consider:

- What potential is there for technologies or components of automation and robotics technologies to be regionally manufactured, serviced and repaired?
- What opportunities are there for greater in-built flexibility so that technology is more easily adapted to different farming systems – hardware and software?
- How might greater technology flexibility/adaptability be achieved while protecting the intellectual property (IP) of technology developers?

Challenges, constraints and opportunities for commercialising and implementing automation, robotics and sensing technologies for vegetable production systems are discussed in more detail in Appendix IV. It includes example Return on Investment (ROI) and payback calculations for several technology/cropping combinations.

A final word


Food for thought:
If we reduce labour inputs by 50% over the next 10 to 15 years…….
What does this mean for our towns?
How do we best collectively capitalise on this increased productivity on export markets?
Can we get off the agricultural treadmill?
"Better returns through the farm gate"
Barnaby Joyce, NQ Register, 21 May 2015
Department of Agriculture and Fisheries

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We would like to express our thanks to growers for hosting us on their farms, allowing us into their packing sheds, participating at forums, review meetings and surveys and freely sharing information and ideas. Contributions made by owners/managers/staff of local engineering firms, consultants and agronomists as well as researchers from Central Queensland University (CQU) added another perspective to forum discussions and we thank them for their input.

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Attachment I: Survey questions with summarised results

The questionnaire responses are divided into eight sections:

- General questions on demographics, education and experience of respondents
- Production, markets and future plans to provide an overview of growers interviewed
- General questions about their view of the vegetable industry and its future
- Specific questions on automation, robotics and sensing within the context of the vegetable industry and their business operations
- Questions about awareness, attitudes, aspirations, involvement and understanding of automation, robotics and sensing including sources of information
- Staying in touch and effectiveness of the project newsletter
- Specific impacts the project may have had on business operations
- Consolidating industry priorities

Each of these sections contains summarised results from start and end of project interviews with comparisons and contrasts made as appropriate between (i) grower and industry responses and (ii) changes evident between the two years. For ease of reading, the questions are not necessarily presented in the order they were asked.

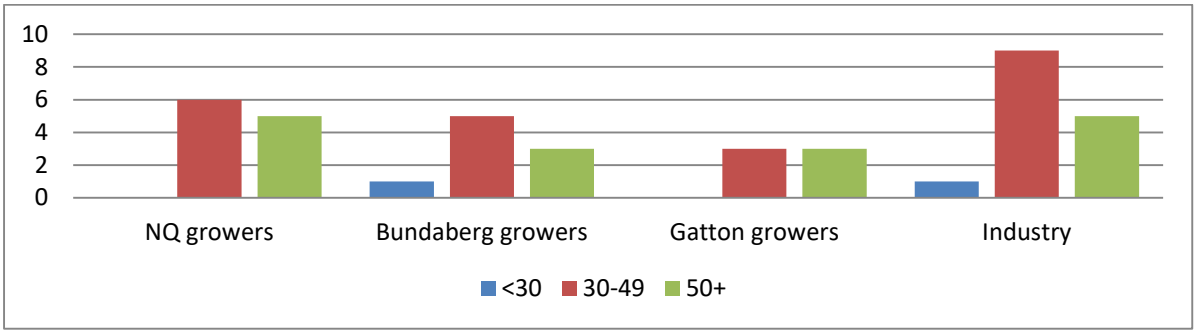
To reiterate, the selection process for grower and industry interviews was not random so **data cannot be statistically analysed** or seen as representative of the broader Queensland vegetable industry. To achieve survey aims, we selected interviewees based on crops grown, size of farm, markets targeted and our perceived assessment of an individual's interest in automation and robotics technology and capacity to implement innovations.

Information from interviews will contribute to baseline data for *VG15024 Vision systems, sensors and sensor networks to manage risk and increase productivity in vegetable production systems*.

General questions on demographics, education and experience

Start of project

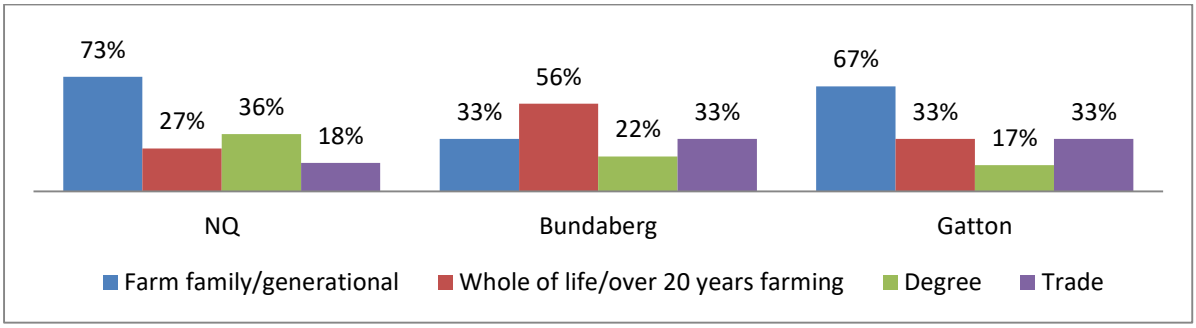
Age of people interviewed – growers and industry



Growers:

Four female (all in Bowen) and 22 male – 24 businesses

Background - how long in Agriculture? Education?



Industry

Five female (all in Bowen) and 10 male

Five engineers/fabricators; 5 consultants/agronomists;

One DAF researcher; one DAF agribusiness development officer, one industry development officer, one workforce development officer, one regional development officer

Most have either a diploma or degree in agriculture, engineering or business and a background working in agriculture in some instances for many years depending on age. Respondents provide support on a local or regional basis, across horticulture industries in that region and also other agricultural enterprises such as sugar cane and broad acre crops.

In summary – growers and industry

The majority of people interviewed at the start of the project were in the 30 to 49 age group and had trade, diploma or degree qualifications in agriculture, mechanics/engineering or business. Most were either from farming families or had many years' experience in agriculture (depending on age). For growers, a generational change is occurring with sons and daughters taking on the business and succession plans in place or already executed.

Growers - production, markets and future plans

Main crops grown - number of times mentioned

North Queensland

5 tomato, 5 capsicum, 2 rockmelon/honeydew; 2 watermelon, 1 cucumber, 1 zucchini, 3 pumpkin, 2 bean, 1 sweet corn, 1 sweetpotato, 1 potato/brassicas/celery (south) + 5 mango, 3 cattle + seedling nursery (capsicum, chilli, tomato, eggplant, herbs)

Bundaberg

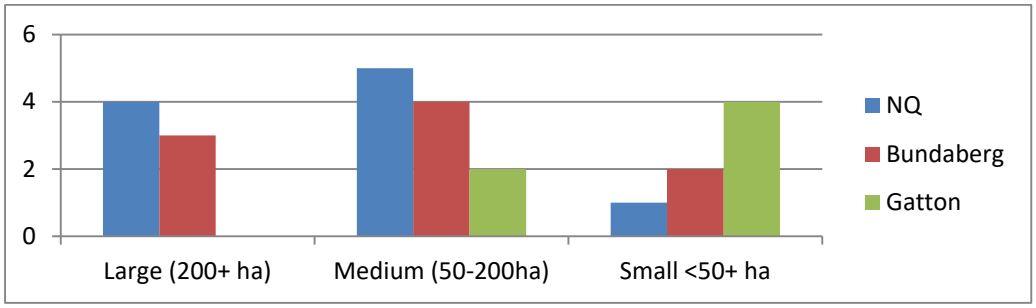
3 watermelon, rockmelon + 2 pumpkin (3 grow cane); 1 sweetpotato, 1 capsicum, 1 chilli, 2 zucchini, 2 cucumber, 1 eggplant, 1 beans (handpicked), 1 snacking tomato, 1 babyleaf salad, 1 herbs, 1 blueberry

Gatton

4 brassicas, 2 shallots, 1 each of baby leaf, lettuce, spinach, herbs, sweetpotato, potato, capsicum, carrots, beetroot, Lucerne

Total area of vegetables grown

Note that for Bundaberg "small" includes a large greenhouse enterprise



Number of staff employed

Permanent at least 550 and casual peak season at least 2100

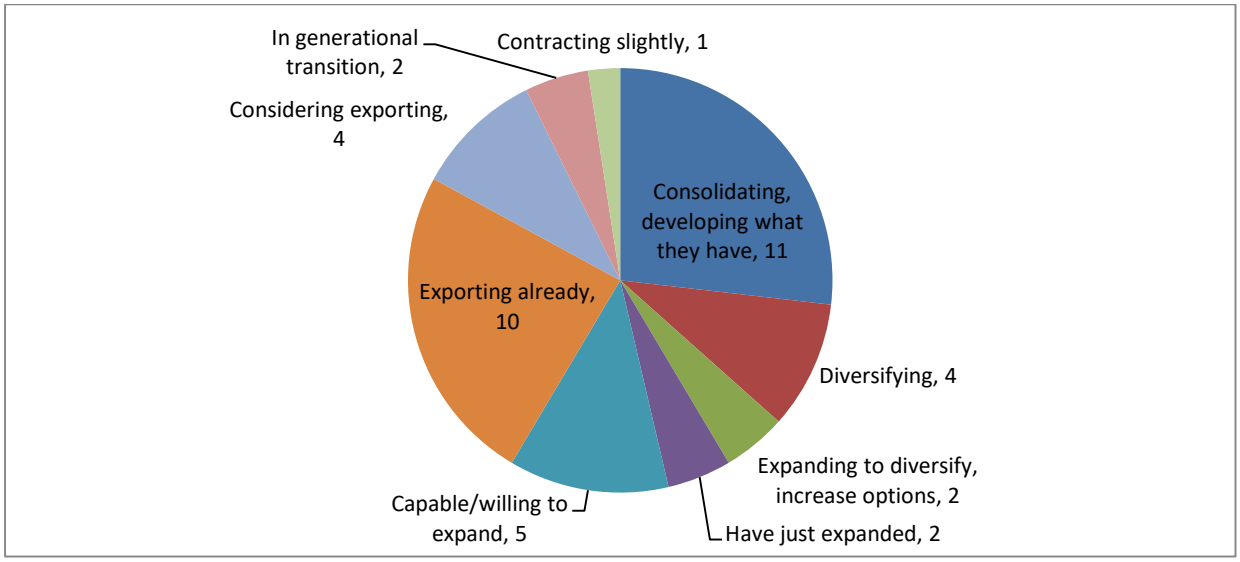
Main markets supplied

A wide range of marketing options were represented.

Central markets on the eastern seaboard – Brisbane, Sydney, Melbourne, Adelaide, New Castle – also Tasmania; Chain stores – Woolworths, Coles, IGA, Aldi; Pre-packs and processing; Food service sector/providores; Regional and local markets. A range of Quality Assurance systems are in place including Freshcare (most common), HACCP, SQF2000, Woolworth and Coles Vendor and Environmental add-ons.

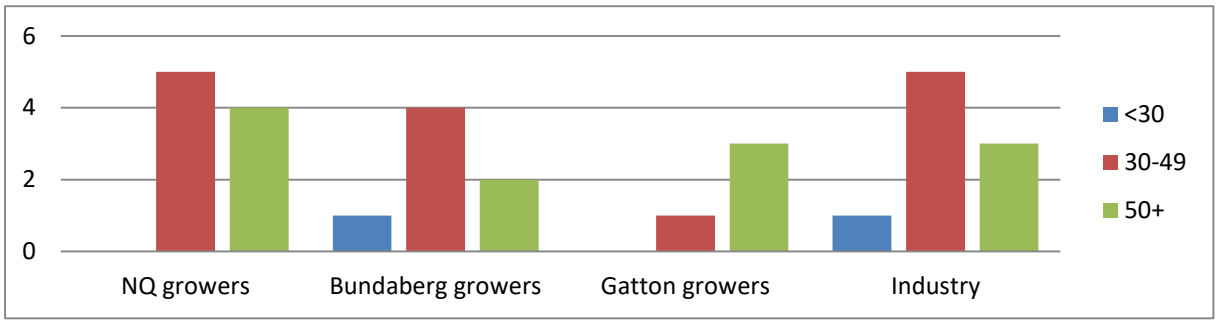
The impression given was that each enterprise had carved out a 'market niche basket' to which they grow and pack according to suitability for their business, as opportunities arise and to spread risk across several key markets. A number of North Queensland and Bundaberg growers interviewed are already exporting while several other growers were interested in developing export markets for their business or had the capacity to expand if market were available (see diagram below).

What plans have you got for the next 2 to 3 years?



End of project

Age of people interviewed – growers and industry



Growers

Two female (Bowen) and 19 male – 18 businesses

Two growers in Bundaberg, two growers in Bowen and three growers in Gatton were not interviewed (too close to Christmas). They will be contacted for VG15024 baseline data interviews in early in 2017. In Bowen, one grower has exited the horticultural industry.

There has been a trend toward diversifying into fruit crops with two growers interviewed at the start of the project no longer growing vegetables (expanding mango production) and one grower moving from vegetables into tree crops (macadamia, avocado).

Industry

Three female (all in Bowen) and 6 male

Three engineers/fabricators; two consultants/agronomists

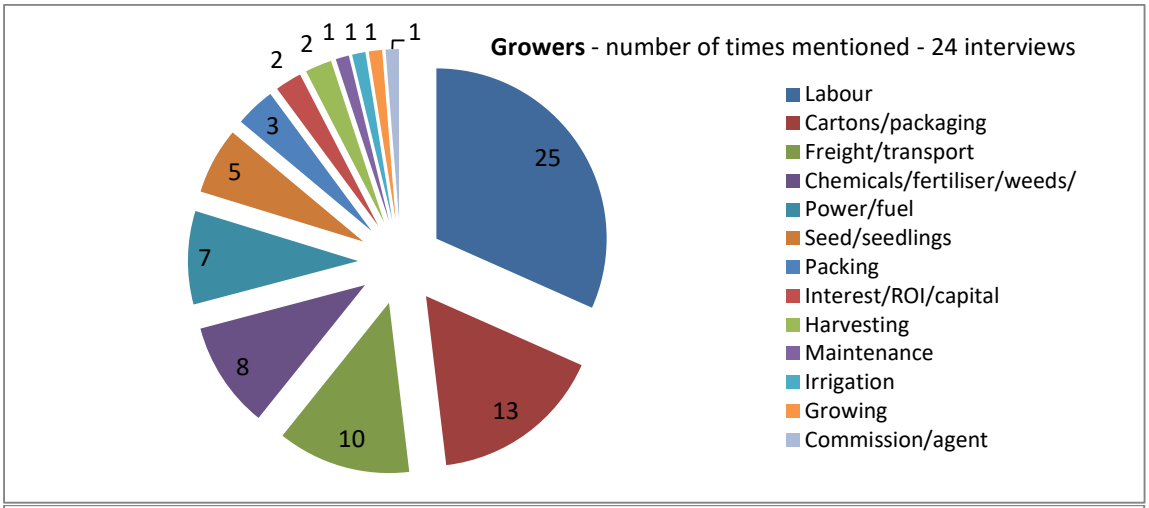
Plus 1 DAF researcher; 1 DAF agribusiness development officer, 1 industry development officer, 1 one workforce development officer – all in Bowen

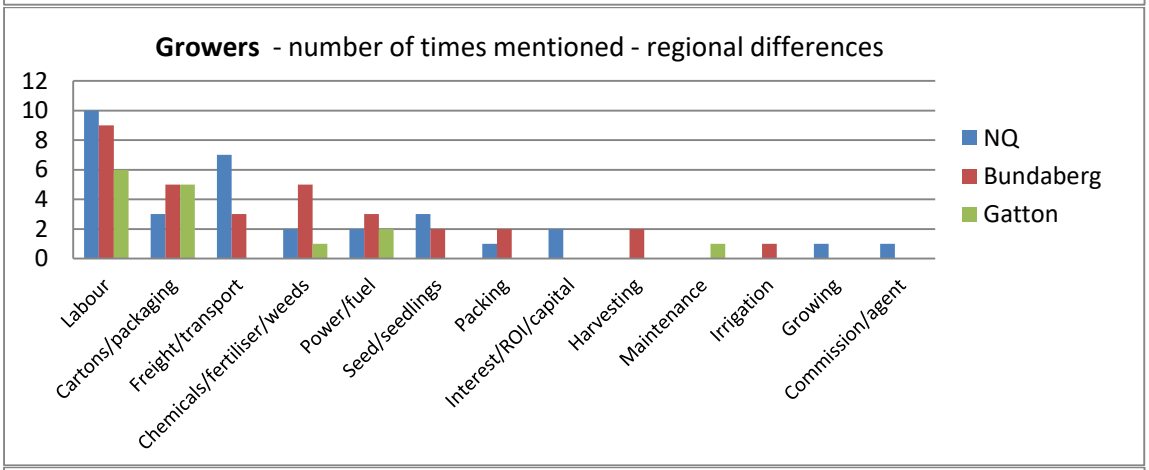
The vegetable industry and its future

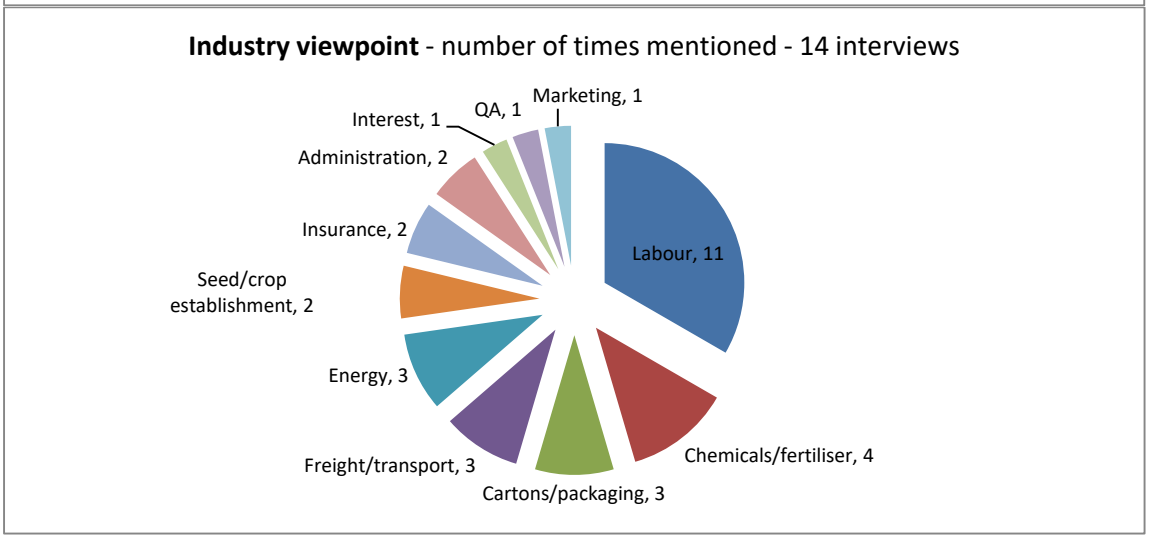
Start of project

Q1: What are your three biggest production/business costs?

Labour is by far the most important production/business cost for growers interviewed, followed by packaging costs and in the case of North Queensland, freight costs, as might be expected. This is reflected in industry responses to this question.

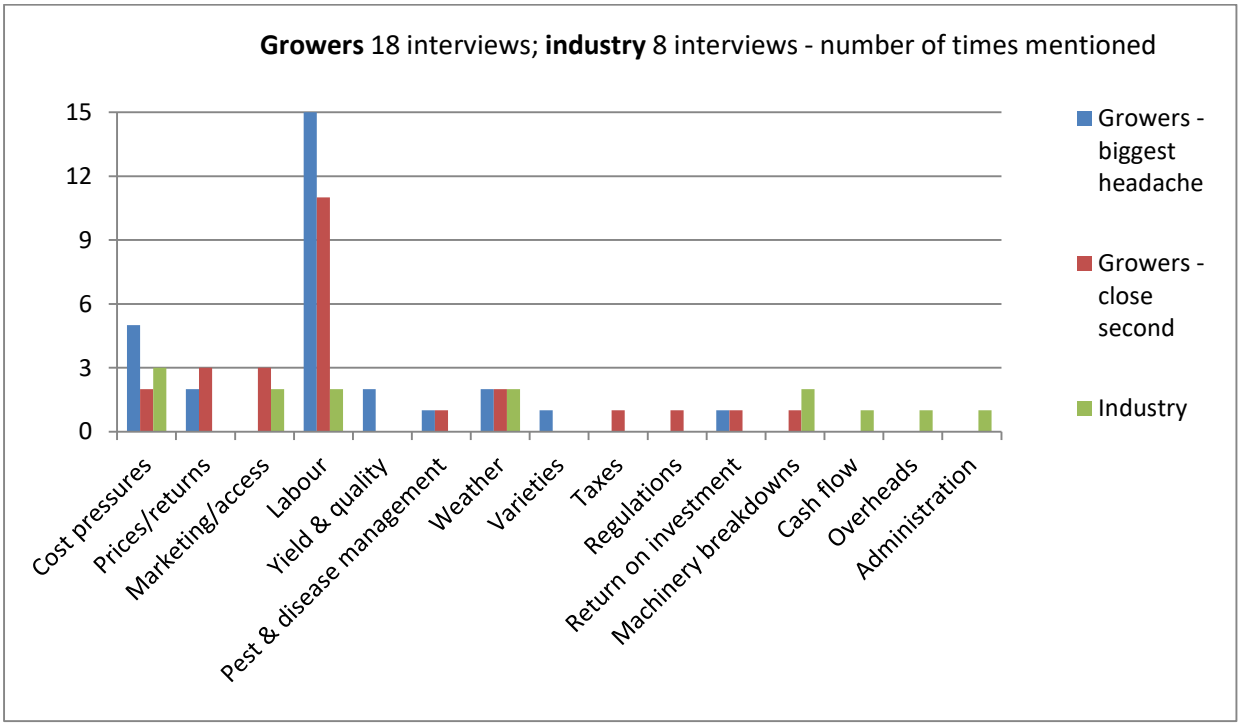






End of project

Q2 What gives you the biggest headaches when it comes to running your business profitably? What comes in a close second?



Specific grower comments include:

- Cost pressures and prices/returns - input costs always rising while returns stay the same, margins too thin. Ensuring what we grow makes us a profit. Getting a return on capital.
- Accessing and keeping markets/exports. Lack of market transparency – resale of product
- Labour – increasing cost; coordinating, managing and hiring large numbers of staff, dealing with personal issues; availability and access to skilled, trained, experienced and reliable people that can do the job well – the impact of the backpacker tax was mentioned by several people.
- Weather, pest and disease management and varieties are interlinked and impact on quality and yields.

Specific industry comments include problems with saturated markets, returns and market transparency, high input costs, impact of weather on quality and yields, labour supply and reliability and machine reliability, breakdowns and parts.

Q 2a. Is labour still important?

As the graph illustrates, the answer to this question was a resounding YES for both growers and industry for all the reasons mentioned earlier. It is still the largest single cost. While cost per unit cannot be reduced, businesses can do something about the number of labour units required.

Only one grower who had stopped growing vegetables and diversified into tree crops disagreed, with canopy management and chemicals more important than labour in mango.

Growers Q1 Have you made any major changes to your operation over the last two years?

- Improving grading lines – modifying equipment by incorporating new module and software to sort for defects; improving existing grader; purchased, improved or extended packing line (vision grader, blemisher/defect sorter);
- Improved pallet stacking in field and installed automated pallet wrapper in packing shed – saves material, easier for staff as less skill required
- Automated irrigation system on one farm to save time in pipe moving
- Expanded use of GPS, VRT, yield monitors and soil/crop mapping, another is incorporating drones and EM (electromagnetic) mapping into farm operation
- Imported new harvester and changed bed width to accommodate
- Two growers have entirely changed their marketing strategy to manage risks/ reduce environmental impacts; one has stopped growing a product line (too difficult), another has extended pre pack lines
- Two have stopped growing vegetables and expanded into mango, another is moving from vegetables into high density macadamia and avocado with a view to future automation, a third has exited the horticulture industry altogether

Industry Q 1. What major changes have there been in the vegetable industry over the last 2 years?

Industry rationalisation continues. The next generation of farmers are is coming through and are open to new ideas, technology and how to apply these. Specific changes mentioned were:

- Precision agriculture, GPS guidance and software, yield monitors, crop sensors to predict yields
- Focus on automation and streamlining processes to increase efficiencies and reduce labour, increased staff training
- Awareness of land management issues and possible impact on farming practices
- Interest in finding other markets and diversifying into other crops
- Peak bodies trying to improve communication which at present is very southern driven

Q1a What is driving these changes?

- Cost pressures and the need to retain margins and find efficiencies – save time, reduce number and skill requirements of staff, increase grading accuracy.
- Better water efficiency, minimising inputs while maximising yields, reducing environmental impacts
- More flexible management, diversifying and differentiating to better manage financial and market risks

Industry interviews reflected these drivers of change: need to be sustainable, competitive, keep up; decreasing margins, oversupplied domestic markets; increasing cost of inputs, labour issues including the backpacker tax and its impact on labour supply. Also mentioned were: the publics' perception of farm impacts on the Great Barrier Reef, the media filtering into growers thinking; a disconnect between corporate (peak bodies) and Agriculture.

Q1b Are they giving the results you/the industry are looking for?

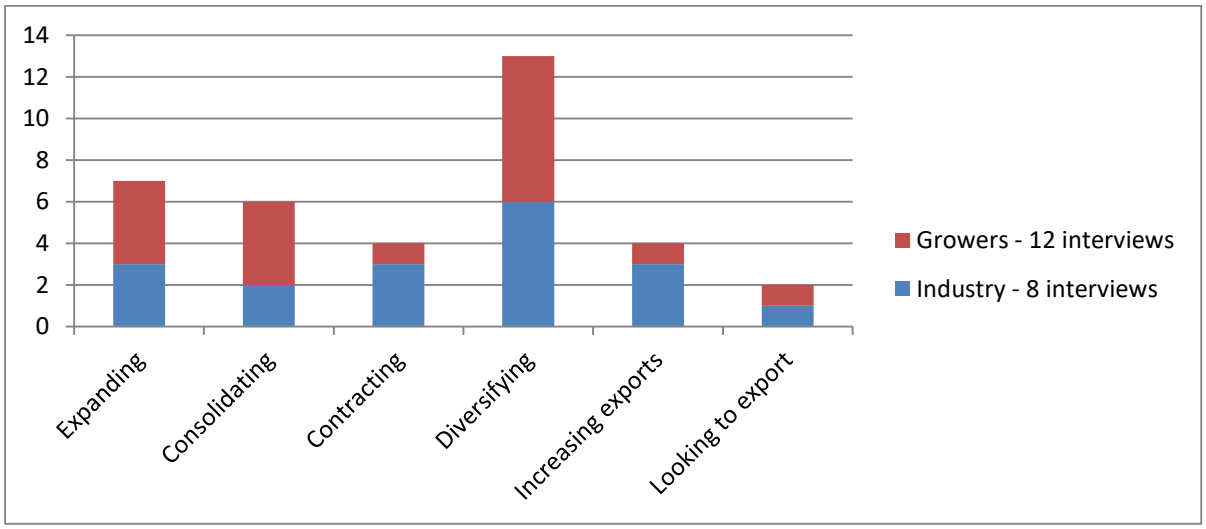
For some growers it is too early to say. The majority said that they are giving the results they were looking for. Industry also thought that it was too early to see results of developing land, technology, increased staff training and the impact of the National vegetable extension network.

Automation and robotics were seen as a long way off by some. There is a need to demonstrate technology benefits, for example yield monitors, with some growers measuring results of changes implemented better than others, essential for staying in the industry and making a profit according to one consultant. Fabricators (local engineering firms) tend to modify equipment to specific requests which usually has the desired results.

Q 3. What are your plans for the next 2 to 3 years?

Growers continue to look for ways to improve efficiencies, keep costs down and stay profitable by streamlining and reducing labour inputs, mechanising, improving existing equipment and investing capital where this makes economic sense. They are keen to continue to innovate and are open to any improvements where gains can be made including step and wholesale changes in the farming system and marketing strategies. Growers are actively looking for opportunities to better manage profit and market risks. Strategies mentioned include leasing, contract growing, diversifying, exporting, adding value to lines, for example through prepack or changing product lines.

Q3a Would you say you are: expanding - consolidating - contracting – diversifying - increasing exports or looking to export?



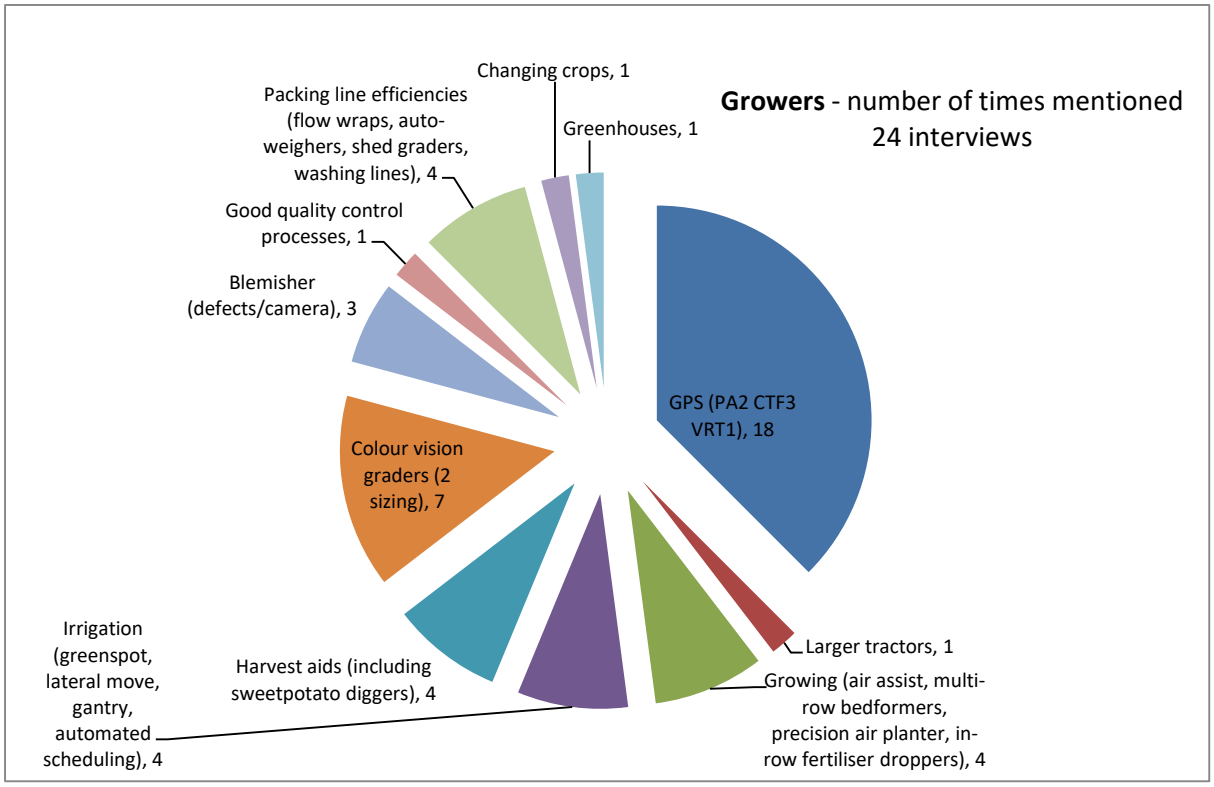
This is a change from two years ago (see graph on page 38) in that growers appear to be more focused on diversifying their business to spread risks with some moving out of vegetables into tree crops, consolidating existing operations to fine tune and add value or cautiously expanding. Exports are part of this diversification and risk management process for some.

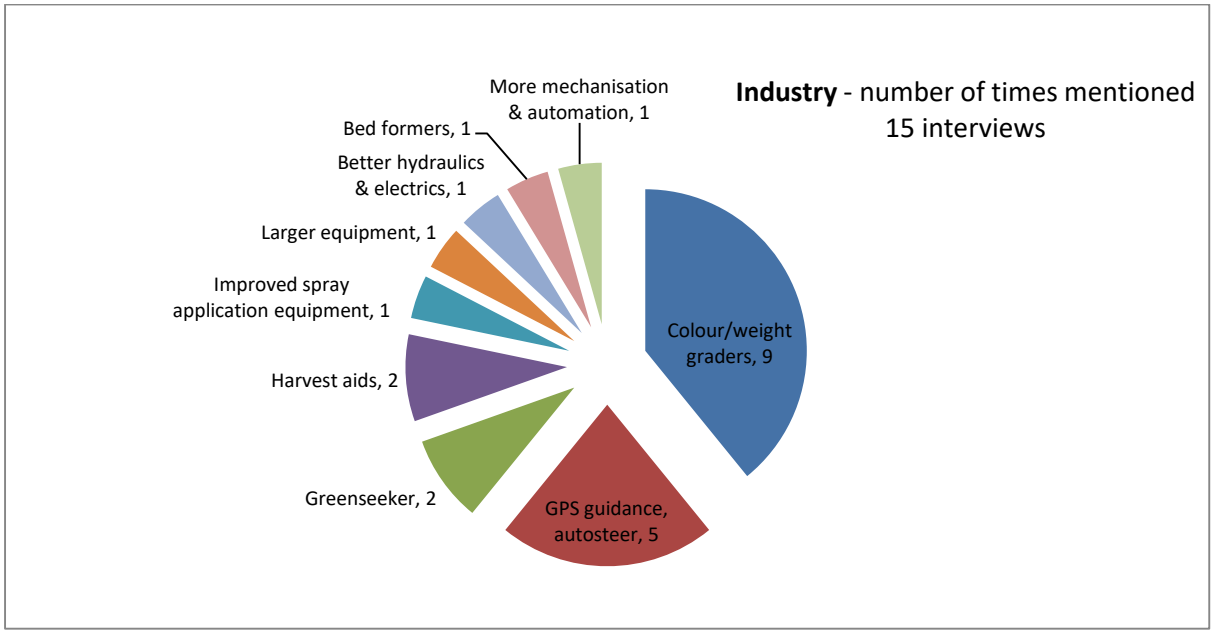
Industry thought that the vegetable industry was contracting and diversifying into other crops, especially tree crops as these had better export potential, that the industry would continue to rationalise due to cost pressures (not only labour) to stay competitive with smaller growers continuing to move out of the industry. Mechanisation and automation would continue to increase. There were also comments about farming smarter to better manage soils, water and energy.

Specific questions on automation, robotics and sensing

Start of project

Q2: What major changes in mechanisation and automation have there been in the district over the past five to ten years?





As the two contrasting graphs show, there is some difference between grower and industry viewpoints. Growers focused on changes in field operations such as GPS while industry found packing shed improvements such as colour sorters as the more memorable, perhaps a reflection of the part of industry interviewed.

Growers Q3: How has your system changed over time?

This question included a number of prompts to explore how and why decisions to change the system were made and whether the changes gave the expected results. It is specific to individual operations, confidential and therefore not for the public domain.

In general terms, changes are driven by the need to continue to improve, find efficiencies and increase productivity in a highly competitive marketplace. The process is on-going and is essential for staying in business. However there was no evidence from the terminology that growers used to describe their continuous improvement process, that formalised process flow analysis tools/concepts from the manufacturing industry were widely used.

This question was not included in the industry interviews.

End of project

Growers Q4 How do you see automation, robotics and sensing fitting into your future farming operation?

Most growers said that these technologies were important for future productivity gains with slow uptake as technology becomes fit for purpose and affordable. There was some impatience with the speed of research progress and commercialisation evident during interviews. Two growers described the changes they had already made to their farming system to better accommodate future automation and robotics technology. Some other comments included:

- Too far off at present to be of benefit in the short term (for smaller operators in current price environment)
- More automation in packing lines (washers, sorters, graders, bunchers, packing, prepacks, palletising) than field as it is a more controlled environment (level floor, no mud or rain)
- UAVs/Drones for surveillance to pick up problem trees (termites, disease, poor health, scale host trees), biomass mapping and to fly in parasitoids - possibly though fly over contract services; aerial mapping (helps with IPM)
- Inter row weed spraying – only seen on line and at meetings; searching for a platform

Industry Q 4. How do you see automation, robotics and sensing fitting into future farming?

Industry thought that automation in packing sheds for example colour grading/sorting had been happening for some time and that there had been huge changes over the last 10 to 15 years and this would continue. Significant reduction of labour inputs has happened already. Investment in these technologies requires large volumes to justify.

Changes are only just starting in the field for example GPS for harvest aids and other operations, auto steer tractors, drones. It takes a long time for these innovations to filter through and become affordable. While the research might be done, most technologies are still a long way from commercialisation. The next step is the hardest and tree crops and protected cropping systems may be better suited. Old technologies are not being used to advantage for example, soil monitoring, water scheduling through sensors and VRT.

Start of project

Q4: What do you see happening in the industry over the next two or three years?

With regards to automation & robotics - what do you think is driving these changes?

North Queensland growers thought (and hoped) that automation and robotics use in agriculture would continue to increase:

- Better GPS use, more precise fertiliser and spray application, inter-row spraying using sensors, autonomous machines
- Eventually automated fruit picking, with perhaps more scope in tree crops initially
- Continued slow uptake of the technology with plenty of failures, not many successes. It will come down to what people can afford

In Bundaberg, most growers said that labour costs will drive future industry innovation however a third of growers interviewed said that they did not see a lot happening with automation and robotics in the next two or three years. Two growers mentioned the following as potential areas of innovation in the short term:

- Precision application of chemicals by sensing technology to improve crop management
- Automated herbicide application with GPS and hooded sprayer

There was a general sense that more needed to happen with automation and robotics to deal with labour costs:

"Sky is the limit if industry, researchers and developers linked up".

Lockyer Valley growers thought that automation would progress however half the growers interviewed thought that there would not be much change in the next two or three years.

Overall, growers said that cost pressures especially labour were the main drivers for automation and robotics. Pests (including vertebrate pests), disease and weed management were mentioned as potential drivers for increased automation and robotics.

"It is all about the dollars"

It was obvious that economies of scale with limited marketing options were driving changes with one grower stating that farming had become industrialised. The issue of quality was raised with a distinction made between what might be possible for crops grown for processing and those grown for the fresh market.

Industry respondents thought that systematic improvements for efficiency gains would continue, that there would be more real time data collection, more crop monitoring, increased use of Precision Agriculture and variable rate technology and that the cost: benefit of more machinery would be looked at. The drivers were the need to stay competitive especially for accessing global markets, the cost prize squeeze for price takers in the market place and the need to continue to reduce labour inputs.

End of project

Q6 Have you seen any major changes in automation & robotics over the last two years?

Seven growers responded NO qualified with no major changes (five respondents) and the following comments:

A few articles in the paper and rural weekly; more incremental improvements; every year getting closer to being implemented and more affordable, for example autopilot and irrigation; still getting worked on; researchers unconnected and not getting stuff on the ground

Three growers responded YES with the following comments:

Heard of changes - focusing on where the biggest costs are to drive change; working in partnership with university for better crop monitoring system; project and excitement generated has helped drive changes

Other responses included:

A lot of attempts – research on right track - need to build capability and capacity of tech industry; have read about this - definitely more in sheds (blemish sorters, automatic stackers); more people moving into VRT, GPS, auto steer, mapping, embracing technology and getting past fear factor; a lot more concepts such as platforms - how will they work in the field?; Blemisher (defect sorter) even better than we thought – can IR measure internal quality?

Industry thought that growers were becoming more aware, open and thinking outside the square and that government was increasingly investing in this area of R&D. However not much has happened on farm as yet. There have been refinements in sheds – packing lines, colour grading, defect sorting – with an increase in the quality and reliability of electronics. Equipment has become more user-friendly and requires less maintenance. In the field, GPS is the most advanced, SWARM farms the most commercially oriented and there is an interest in drones with two agronomists recently having bought this technology for trialling with their growers.

The paperless office is becoming a reality with people in key roles more tech savy, records stored and accessed digitally (even by older farmers) and mobile phones being used to turn irrigation on and off. Possibly this change has happened over the past two years as digital technology has become widespread in our daily lives.

"Skills have changed - ability to drive a tractor straight vs operating a smart phone"

6a What do you think will happen over the next 3 to 5 years?

Automation in packing sheds will continue to increase and improve. In field, automation and robotics will continue to take gradual steps forward as technology improves, becomes more user-friendly and affordable, for example automated inter row weed management, targeted spray application for pests and diseases; GPS, VRT and crop/soil mapping. However:

"Robotic harvesting is still a long way of - my kids might see it"

There was a sense (not only in responses to this question) that looking after the environment and profitability were not mutually exclusive and that automation and robotics could assist with this. In the future, farming would be more reliant on automation and robotics.

Closer liaison between researchers and farmers was needed. Areas where R&D was located would be the first to try out the new technologies. Farms will get bigger with more corporate dollars invested and there will be a race to take up proven technology as it becomes available.

Industry hopes that theory will make it into practice and that a lot of dollars will be spent with some results. More funding for collaboration between growers and universities could help to bring young people into the industry. Much could be improved but this needs time for example, GPS to improve accuracy. Drones are a part of this. Farms will get bigger and there will be fewer growers.

6b What do you think is driving these changes?

Input costs in particular labour, financial and time pressures and the need to stay competitive were given as the main drivers for change. Sustainability also featured particularly with growers farming adjacent to the Great Barrier Reef.

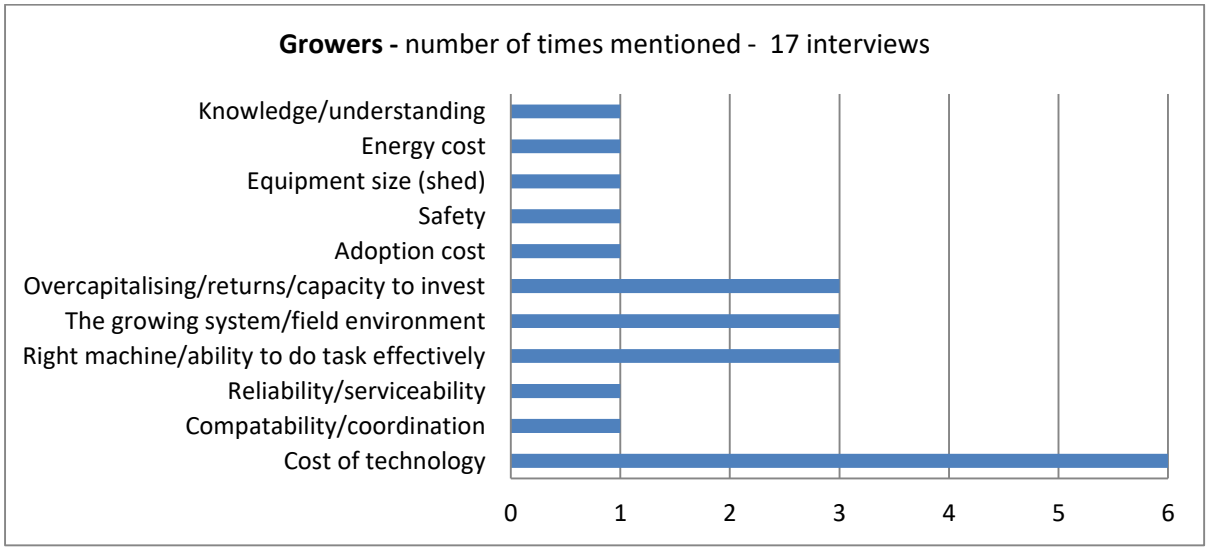
There was greater interest in automation, robotics and sensing as it became more practical and effective.

"It will be commonplace for the next generation"

Publicity about the technologies, more digital technology generally, this project and having people in the regions were also mentioned. Thought was given to what skills will be needed - technical people to service and support technology. Some comments from industry included

- Governments and R&D corporations were investing and driving the changes not industry
- Labour costs is the driver as it is in all businesses
- The need to stay in front of the competition, need for sustainability (soil, water, energy) while feeding an increasing global population
- Crop sensing – how to predict pests and disease movement

6c. What are some of the constraints to greater automation of the vegetable industry?



Industry responses reflected those from growers:

- Cost of technology and the need for high volumes to bring down capital costs
- Technology gaps – complexity of tasks, reliability, ability of equipment to operate in difficult and variable field environment, will still need human input, the technology needed has not been invented yet
- Valley of death – the problem of getting inventions to market – lack of knowledge, dollars, poor advice and information sources
- Knowledge, understanding and attitude to unfamiliar technology, time needed to understand data management and learn how to manage new technology. However automation in other areas of our lives may help to overcome this.

Awareness, attitudes, aspirations, involvement and understanding

Start and end of project

Q5: How do you feel about increased mechanisation and automation of vegetable production?

In the initial survey, the response to this question was overwhelmingly positive for both growers and industry with only one strong negative however several people talked about the pros and cons of replacing people with machines from a social/community perspective: fewer but higher skilled jobs available in regional areas. This was seen as a positive that outweighed any negatives. A hope was expressed that higher skilled jobs might help to retain/bring back/attract young people into the regions.

In the end of project interviews, growers and industry were even more positive about automation than they were two years ago. Words used had changed to include:

- Exciting, awesome, love idea of it, passionate about it
- Integral and way of the future, inevitable, necessary especially with regards to reducing labour inputs, remaining viable, competitive and sustainable.

And that it seems to taking a long time to get there. There was the hope that greater automation would result in better, more interesting jobs and opportunities for young people. However, one person wondered what people would do when there were even less jobs in the regions than there are now.

End Q5a Is that a change from 2 years ago?

Most said that their feelings about automation had not changed: can see benefits as I learn more; will keep us viable; always looking to innovate, achieve efficiencies. One was not sure (need capital), another was now more certain about the need to automate. Two growers said that their feelings about automation had changed as the technology improved and looked more achievable.

Most industry people also said that their feelings had not changed. One said that it reinforced thinking, another that they would like more grower commitment to test new technologies and systems.

Start Q6: Can you give me some examples of what automation & robotics technologies you have heard about recently?

At project start, this question was asked as an open question followed by a prompt about ACFR's Ladybird and UAVs as both technologies had been widely reported in the media. Of the 26 growers interviewed:

- The Ladybird was mentioned 6 times by name, the AgBot 2 twice (in Bundaberg), Drones 4 times and Swarm farms once
- Research on managing weeds with automation/robotics was mentioned 5 times
- Robotic harvesting/picking: strawberries 3 capsicum & chilli 2 kiwifruit 1 mango 1 – with the exception of once (Bundaberg) these were mentioned in Bowen

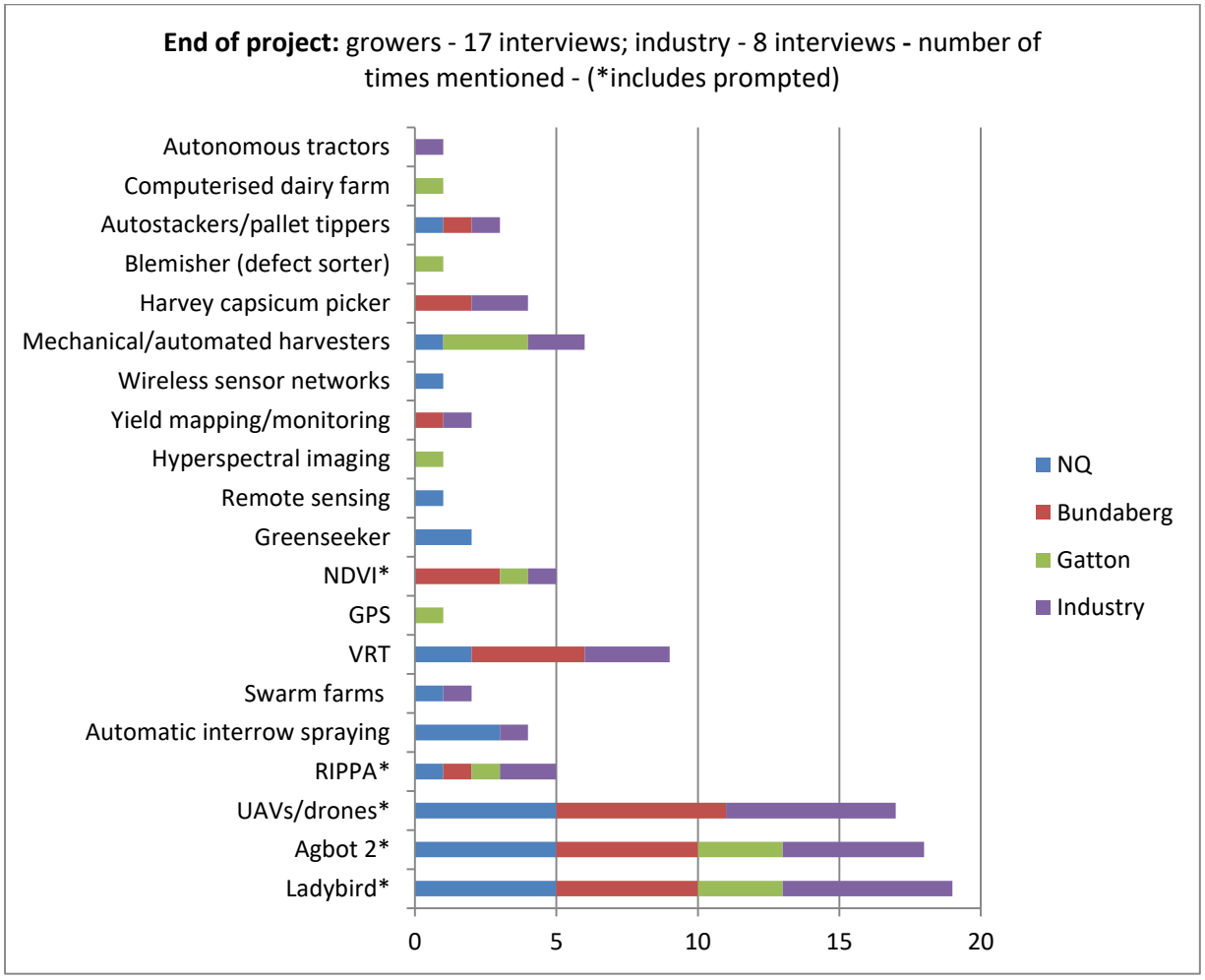
- Self-driving or “Buddy” tractors were mentioned 6 times (seen on overseas trip by two Gatton growers)
- Automated pallet stackers 3 various grading/weighing equipment 3 (not in Gatton)
- Sensing technology 4 - includes dry matter testing, facial recognition
- Auto irrigation 1

Of the 15 industry people interviewed UAVs/drones were mentioned 6 times, the Ladybird 4 times, various robotic harvesting research 4 times and VRT twice. For the packing shed, automated palletising and volume pack box fillers were mentioned. For field operations, EM surveys, autonomous tractors, automated planters, crop mapping, Greenseeker, remote sensing and work to develop varieties better suited to automation (broccoli) were mentioned.

These results show that growers and industry now have a better awareness of specific automation and robotics technologies under development for the vegetable industry than they did two years ago.

This question was again asked during the end of project interviews. As the graph below shows, growers and industry now have a better awareness of specific automation and robotics technologies under development for the vegetable industry than they did two years ago.

End Q7 What are some of the Automation & Robotics technologies you have heard about over the last year or two?



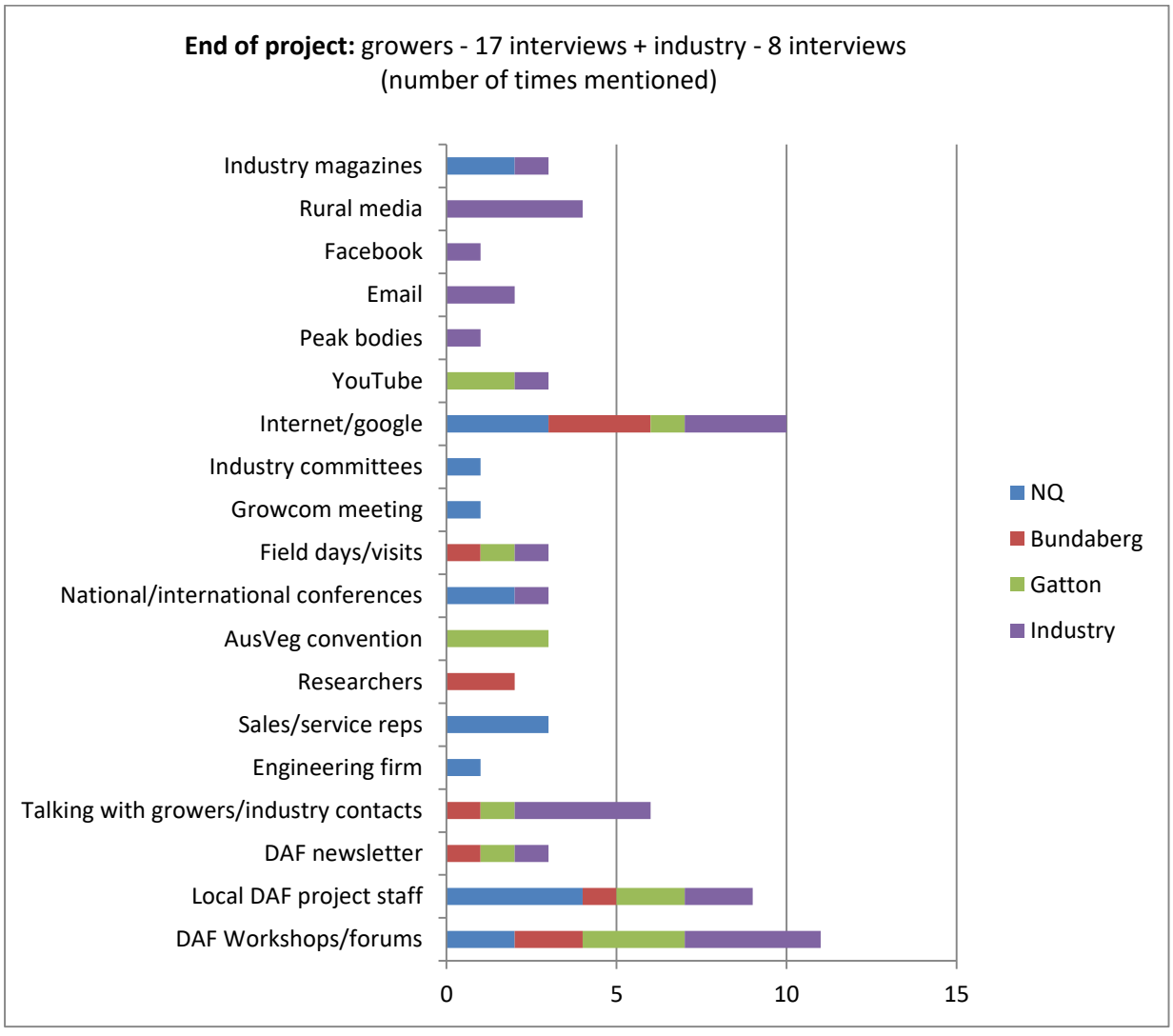
How did you hear about these technologies?

We asked this question at the start and end of project interviews to determine if our project had had an impact on grower and industry awareness of different automation and robotics technologies.

In the initial interviews, a range of responses were received to this question. Industry magazines, the internet and in particular YouTube were mentioned by several growers. Other sources of information on robotics and automation included field days, workshops, radio, Landline, word of mouth, industry contacts including industry organisations, membership of committees/boards. Two growers mentioned direct contact with researchers. Two growers said that you needed to research the information yourself.

Industry mentioned AusVeg, Growcom, newsletter, magazines, the internet, YouTube, the University of Sydney, suppliers and other contacts, talking and listening to people including local DAF staff.

The same question was asked two years later. As the graph below shows, the project has contributed to increased awareness of automation, robotics and sensing technologies currently under development along with a range of other information and communication activities. The internet in particular is becoming a more important source of information for growers and one-on-one communication remains important.



Start Q7/End Q 8: What do you think is the difference between mechanisation, automation and robotics?

The purpose of this question was to get a sense of what growers and industry understood these three different terms to mean. Some example responses were:

Mechanisation: need human eg transplanter (aid)
Automation: fully automate + human
Robotics: computer + no people

Mechanisation: machine assisted process
Automation: reducing people needed
Robotics: machine does the task

Mechanisation: motors, belts
Automation: someone doesn't have to pull levers
Robotics: more about the variables

Mechanisation: machine replacing a person
Automation: more repetitive
Robotics: can vary what it is doing

Mechanisation: human to machinery to complete a task
Automation: does it imply that there is some type of computerised control for the task?
Robotics: more advanced form of automation to replace a human – probably lots of overlap

Mechanisation: transition from hand to machine – still manually operated
Automation: transition from manually controlled to mechanically or electronically controlled
Robotics: minimal human content

A national automation and robotics equipment developer suggested that automation was about hard tooling, simple, fast work while robotics involved more complex, flexible, lengthier tasks.

The same question was asked two years later. There were no obvious differences in responses however growers appeared more comfortable answering the question and several said that they had a good understanding of the different terms.

Do these terms mean anything to you?

This question was only asked at end of project interviews to gather baseline data for VG15024.

Visions systems?

Growers: all said yes and most provided examples of colour cameras in graders/defect sorters or greenseeker technology.

Industry: all said yes with some examples provided - cameras, satellites, graders, NDVI?

Hyperspectral imaging?

Growers: Most said yes with several comments about more complicated cameras (to detect plant health), outside visible light, to do with infrared; two growers said No.

Industry: Four said yes - wavelengths, aerial images? NDVI; three said no

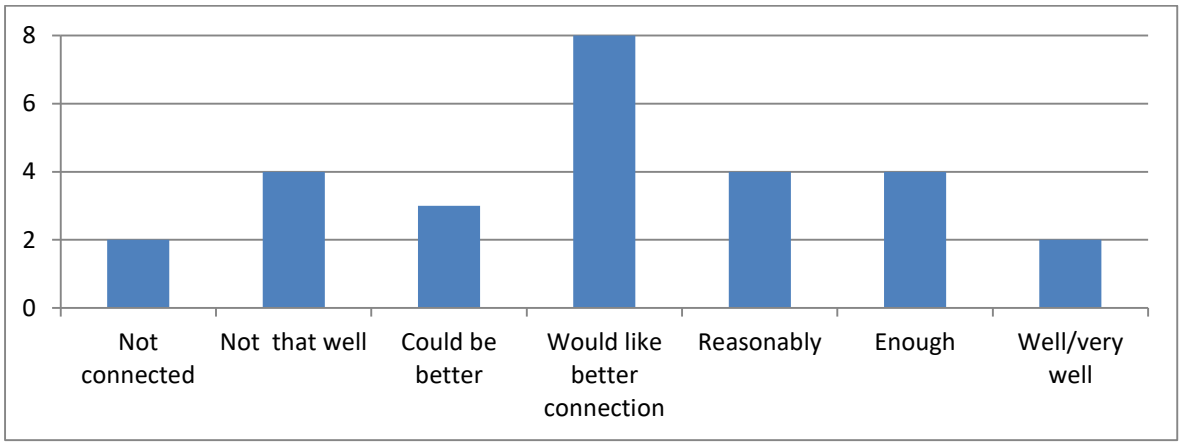
Wireless sensor networks?

Growers: All but one said yes with automated irrigation, soil probes, cool room alarms given as examples.

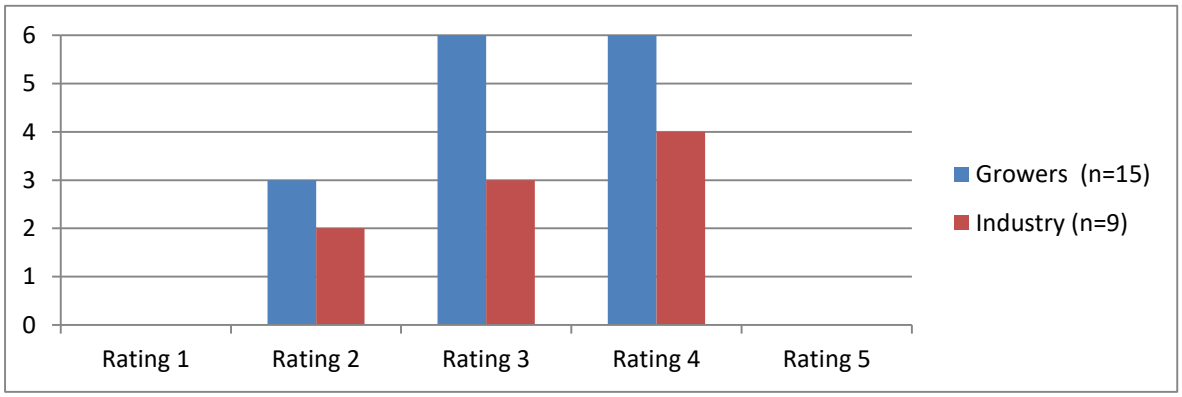
Industry: Five said yes - remote/wireless signal/sensing, turn pumps on & off, QFF traps, biosecurity; one said a bit; one said no

Start Q8: How well connected do you feel you are with what is happening in automation and robotics in the vegetable industry?

Responses were difficult to categorise. A very loose interpretation of grower results from initial interviews is presented in the graph below. The question was revised for the end of project interviews.



End Q9 On a scale of 1 to 5 how well connected do you feel you are with what is happening in automation & robotics in the vegetable industry?



Are you happy with that level of connection?

Most growers were happy with their level of connection, two said they would like more connection with researchers, one would like more information. Compared to two years ago, this suggests that there has been an improvement in how well connected and informed growers feel about progress in automation and robotics research in the vegetable industry.

For industry, three were happy with their level of connection, four would like to be more involved and connected. These responses did not always correspond to the level of connection they felt they already had. One person said that it was difficult to understand what was actually going on and that this applied to growers as well. It needs simplification.

Start Q9/ End Q10: Do you think that your level of involvement with automation & robotics has changed over the past two years? End Q10

This question was designed for the end of project evaluation.

Most growers were happy with their level of connection, two said they would like more connection with researchers, one would like more information. Compared to two years ago, this suggests that there has been an improvement in how well connected and informed growers feel about progress in automation and robotics research in the vegetable industry.

For industry, three were happy with their level of connection, four would like to be more involved and connected. These responses did not always correspond to the level of connection they felt they already had. One person said that it was difficult to understand what was actually going on and that this applied to growers as well. It needs simplification.

Seven growers said that they now felt more involved. Comments included: more awareness, can see the possibilities, has fuelled interest, appreciation of DAF workshops and involvement in trials, more engaged and what the technology is evolving in to.

Five growers did not feel more involved. One grower said that interest had increased, another mentioned time and cost constraints and a third that they were focusing on mechanisation not robotics or automation. One grower said Not sure, the information is out there if you want to find it.

For industry, five said Yes with comments including: growers rely on us, can't be left behind, DAF workshops, grower discussions. Four said No with comments including researchers operate at different level despite us providing feedback on design ideas; growers less interested in new technology in poor years as they can't do anything about it.

End Q11 Would you like more input on what R&D is happening on automation & robotics?

Growers

Yes 12: Project activities were seen as important for informing and involving growers and providing an avenue for growers, who are time poor, to have input on R&D directions and investment. Some like to go to meetings, other prefer to have private input. The importance of connecting with researchers and involvement in technology development in order to fast track research to commercialisation were mentioned several times.

No 4: Comments included - have had plenty of opportunity, other things are more important, would like to be kept up to date.

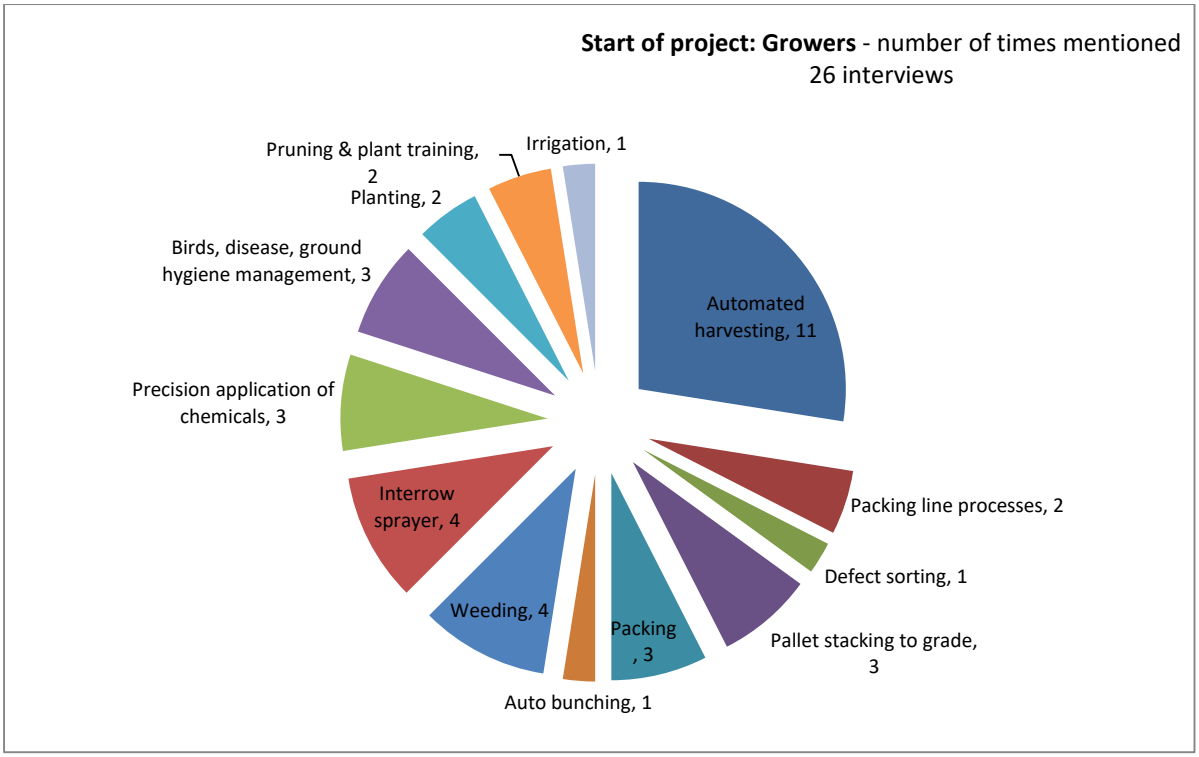
Industry

Yes 5, No 2 and Not sure 1.

Comments included: too busy but want to contribute, have more input on how technology is applied, provide on ground experience and field perspective and look for technology with immediate benefits in the short term or of high impact over time.) Would like involvement in prototypes development and trials as local people have established trust with growers, are better able to provide after sales service and have a stake in the technology working as they live locally.

Start and end of project

Start Q10/End Q13: If there was one (other) thing you could automate on your farm what would it be?



Engineers wanted to see further improvements in packing sheds and also harvesting efficiencies. Consultants/agronomist were looking for more efficient ways to monitor, assess and manage crops and better ways to apply management strategies such as pesticides and parasitoids.

The same question was asked again two years later:

- Automated/robotic harvesting or aids to harvesting were still a priority although growers understood that this technology was still some way from realisation.
- Five growers said automated weed management with one stating that he would like to trial a customised Bot within 12 months.
- Disease identification, nutrient and irrigation management were mentioned alongside platforms to apply foliar fungicides, automated bait spraying for Queensland Fruit Fly, robotic scouting, drones and satellite imagery to better manage crops.
- Automated planting was a priority for two growers which is a change from two years ago. Planting has not been a focus during other project activities.

- In the packing shed, all tasks including automated dipping (for pest and disease control), palletising, labelling, better defect sorting, (capsicum are not round so do not rotate) and packing were listed.

Industry would like to see further improvements in the packing shed with robotic pallet stacking seen as achievable in the short term. Agronomists were looking at ways to automate pest and disease assessments. Silverleaf whitefly and powdery mildew were given as examples. Driverless picking aids were mentioned with automated harvesting the dream.

No major changes in grower or industry aspirations are apparent over the two years.

Keeping informed - staying in touch

Start of project

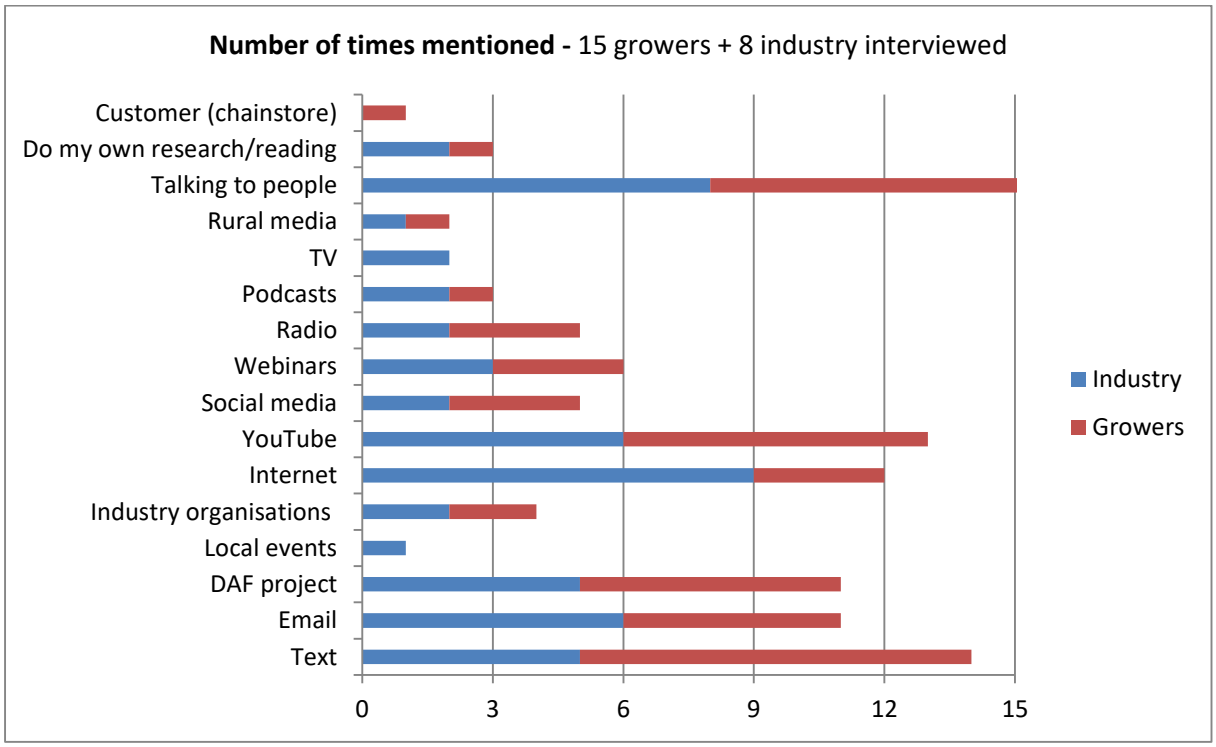
Without exception, email and mobile phone (and sometimes SMS) were the best methods for keeping in touch with growers and industry about what was happening in the project.

End of project

Detailed questions to explore options for better communicating with growers and industry were developed for the end of project interviews. It included a 'market survey' for the project newsletter.

End Q12 How do you keep up to date with what's happening in automation & robotics?

We followed this question with prompts about other sources of information such as radio, podcasts, YouTube, social media, webinars so results below are fairly exhaustive.



As the graph shows, text and email continue to be important tools for keeping up to date. The internet and YouTube are as important with industry and increasingly growers actively searching for

specific information. Talking with people including other growers, local consultants, engineers and managers and key staff in the business top the list.

The project has had an impact (DAF workshops, newsletters and team members). Industry contacts mentioned included local organisations, Growcom and Hort Innovation. Few use social media (facebook – private only, twitter – too limited). Radio, podcasts and TV did not rate highly for most.

Growers but also industry people are inundated with information. Finding useful information amongst a plethora of other information is a problem for all. The need to check the range of platforms to inform growers was mentioned by an industry person. Hard copy, snail mail and fax were mentioned two or three times during interviews as a means for overcoming electronic information overload.

There is no easy answer. It is a question of where to invest and for what impact. Texts need to be personal, selective, well targeted and are good for reminders. Emails need a good header that draws people's attention. Electronic media is often filtered usually as it first comes into the business (wife, office staff). Electronic filtering and use of key words was mentioned by one consultant. Several growers have given us their personal emails for direct contact.

End Q12a Participation in project activities

	Survey - start	Survey - end	Farm visits	Forum 1	Forum 2	Review meeting	Enterprises engaged
NQ growers	11	7	6	6	3	6	18
Bundaberg growers	9	6	6	7	2	1	11
Gatton growers	6	4	3	8	7	4	14
Agronomists/consultants	4	2	0	2	4	6	5
Engineering firms	5	3	0	5	2	0	5
DAF/BGGA/BFVG	5	4	0	12	10	6	6
Totals	**40**	**26**	**15**	**40**	**28**	**23**	**59**
Presenters DAF/CSIRO/QUT/ACFR	0	0	8	9	9	7	3
TOTAL	**40**	**26**	**23**	**49**	**37**	**30**	**62**

End Q12b Newsletter effectiveness

We took the last two editions of the project newsletter (May and Sept 2016) to interviews to check on effectiveness of format and distribution method.

Format

No major changed are needed in the format of the two page 'QLD Veg Automation Update' with comments including good overview, short and concise, easy to read, not too much, has key things, web links important, blue boxing good. Headings are important as growers scan the newsletter much as they would a newspaper. Pictures need to be interesting, relevant, perhaps larger, on the front page and draw the eye.

Distribution

Effectiveness of distribution varied with region. In the Gatton, growers had not seen the September 2016 edition which was sent out via Lockyer Valley Growers for the first time. They had seen earlier editions emailed by the local project team member.

In Bowen, the response was mixed with some having seen the September edition, others not. Reasons given were filtering out in the office, dropping of BGGA email list, getting lost in other information. It appears that distribution through BGGA is only partly effective. Two growers said that the newsletter needed to go to their private email (which they supplied).

In Bundaberg, distribution through BFVG is very effective. It is emailed to growers and also placed on the BFVG website.

Most industry people had seen the September edition. Two had only seen earlier editions as they are not on the local industry organisation email list. This was not an issue in Bundaberg where newsletters can be accessed via the BFVG website.

We will incorporate suggestions for further improving the format of the newsletter in future editions developed for VG15024. Distribution in Gatton and Bowen requires some rethinking. Direct emails from the project team especially to industry are an option as is making newsletter available via the BGGA, Lockyer Valley Growers or DAF websites.

In summary – communicating with growers and industry

Recognise the problem of information overload and limitations of different distributions tools. Avoid contributing to the problem, hard filter information prior to sending and use concise descriptive headers for emails. Get project information onto websites so interested can find it when searching for information. Don't underestimate impact of word of mouth (diffusion of innovations theory). Webinars have great potential as a means of better linking up growers, industry and researchers. Social media is not a major tool for keeping up to date at present but that may change in the future.

See also page 50 and 51 "How did you hear about these (automation and robotics) technologies?"

Do you have any other comments you would like to make?

Start of project - some grower responses:

- Keep it simple and the demand is out there for the right machine. Look to automate if the right machine came along;
- Looking for controlled systematic automation;
- Got to get profitability for everyone so they can invest in the latest technology, through the whole supply chain;
- This (automation & robotics) is necessary to manage wages and to cover for possible specialist labour shortages;
- Machine parts/electronics not available "off shelf" here
- Automation changes will be driven from overseas as we don't have big enough population to fund and develop high end equipment in Australia
- Technology needs to be understood & fixable – auto-planter not used due to poor understanding
- Travelling to USA to look at Drones for field assessment and remote treatments;
- Spend $ wisely & productively. General purpose machine - if R&D dollars go to individuals then (outcomes) need to be shared with industry

- Positive that we're (this project is) looking at the area - worry about smaller businesses & ability to afford investment
- Good luck!

Some specifics mentioned:

- Business spends $2 million a year on controlling weeds through labour and chemicals (nationally);
- Looking to upgrade the packing machine to custom pack for the direct market;
- At the moment (need) disease detection and agronomy aids direct to computer;
- Bird damage, weeds big issue
- Test maturity of mango - have machine for dry matter testing;
- Do some more in shed if had $ - it's next on list - packing, washing/grading

Some industry responses:

- A real need for more automation and robotics and how to get growers involved in process
- Will be interested in results – heterogeneous industry
- These are the things we need to promote and make the industry attractive to young people

During the end of project interviews, growers and industry generally had not much to add to what they had discussed with us already.

What impact has the project had on your business?

VG13113 was not designed to have direct impact on farming practices as its prime objective was to better engage growers and industry in the R&D process, raise awareness of automation, robotics and sensing technologies currently under development and explore potential applications of these technologies with growers and industry.

The purpose of including a question on impact was to gather baseline data for the new project VG15024 and explore the question:

"Has closer interaction between researchers, machine developers, growers & other industry stakeholders delivered technology that is more fit-for-purpose and therefore more readily commercialised and adopted?"

Process flow analysis case studies (Lean)

The three grower collaborators who took part in the Lean case studies have made some changes to their operations as a result of taking part in this project activity. It created awareness and highlighted areas that could be addressed. There was frustration at the slow pace of the Lean workshops. Appendix II Lean brief and Lean leaflet provide more detail.

Bringing research into the regions

There is no doubt that growers and industry appreciated hearing about a range of R&D in automation, robotics and automation technology first hand. Providing a forum to question researchers, contribute to discussions on how technologies might be applied on farm, point out potential issues from a practical perspective and have input to the prioritisation were seen as valuable.

Several growers have followed up ideas with researchers after the May 2015 forums and farm visits. One grower has modified and redesigned equipment which had been sitting in the shed for four year. Two or three growers have recalibrated their grading lines for better results. A group of growers is planning to look at an automatic pallet stacker in bananas (after a visit by banana growers to Bowen in 2016). Our project may have indirectly contributed by bringing these issues to the forefront of growers thinking and providing new perspectives.

Commercialising R&D

There is some impatience with the speed of research and inability to make technology available for testing in regional areas. In particular, growers are keen to trial autonomous inter row weeding platforms on their farms. Better links between researchers and end users is seen as essential for achieving commercial outcomes and overcoming problems and constraints early.

Industry responses

The project raised awareness, helps with acceptance and shows progression of a range of research and technology. Growers are talking about the technologies and using the terminology. Webinars were excellent and it was good to have researchers in the regions and on farms. The technology needs physical demonstrations, on ground manufacturing involvement and further local input to get realistic outcomes that will deliver locally. Two agronomists have bought a drone this year for trialling on farm.

Attachment II: Example agenda for the May 2015 industry forums

Automation & Robotics developments in the vegetable industry
GATTON Information meetings
2 pm to 5 pm – Gatton Research Facility, Warrego Highway

Forum One – Monday 11 May 2015

2:00 pm	Expectations & how we will get to a list of priorities for the region David Carey & Sue Heisswolf, QLD Dept Agriculture & Fisheries (DAF)
2:15 pm	Setting the scene – concepts, technology, issues Sue Heisswolf & David Carey
2:45 pm	Tristan Perez and Chris McCool/ Chris Lehnert Queensland University of Technology (QUT) Tristan and Chris will talk about their new AG BOT 2 agricultural robot platform, they will discuss camera vision systems and tell us about their local work on using camera vision to identify and spot spray weeds, show how they are trying to use high tech cameras to "see" capsicum fruit on a plant and develop a gripper capable of harvesting that fruit
4:00 pm	James Underwood Australian Centre for Field Robotics (ACFR) University of Sydney Video presentation on the 'Ladybird' agricultural robot platform
4:15 pm	Potential application of this technology on farm and in packing sheds – sorting out priorities - facilitated session led by Sue Heisswolf & David Carey

Forum Two – Monday 18 May 2015

2:00 pm	Warm up and update on farm visits - Sue Heisswolf & David Carey
2:15 pm	Adrian Bonchis and Phil Valencia - CSIRO Brisbane Adrian and Phil will talk about their capability in automation and robotics; they will touch on work they have done in Unmanned Aerial Vehicles (UAV) planes and helicopters, micro sensors to measure climate variables, moisture probe and weather station technologies as well as autonomous vehicle work they have completed for the mining industry
3:30 pm	Ian Layden & Julie O'Halloran - DAF Ian and Julie will talk about their Variable Rate Technology (VRT) work within the context of Precision Agriculture and "Big Data"
4:00 pm	Bringing it all together – facilitated session led by Sue Heisswolf & David Carey

There is time allocated throughout both forums to ask questions & discuss and think through implications of this technology for your farming operation and the broader vegetable industry.

The second information meeting will build on the first, so please plan to attend both if at all possible.

Attachment III: Consolidating industry priorities

The 'Emerging industry priorities' arising from the May 2015 regional forums and farm visits and start of project surveys were reviewed with growers and industry during the review meetings in autumn 2016. Those growers and industry people who had not attended the review meetings where given an opportunity to contribute during end of project interviews. Participants at the April 2016 Hort Innovation steering committee meeting for VG15024 and VG15003 were also invited to contribute.

The form on pages 60 and 61 was used as the data collection tool. It was formulated from the industry priorities outlined in detail earlier.

Do you agree or disagree that this is an industry priority?

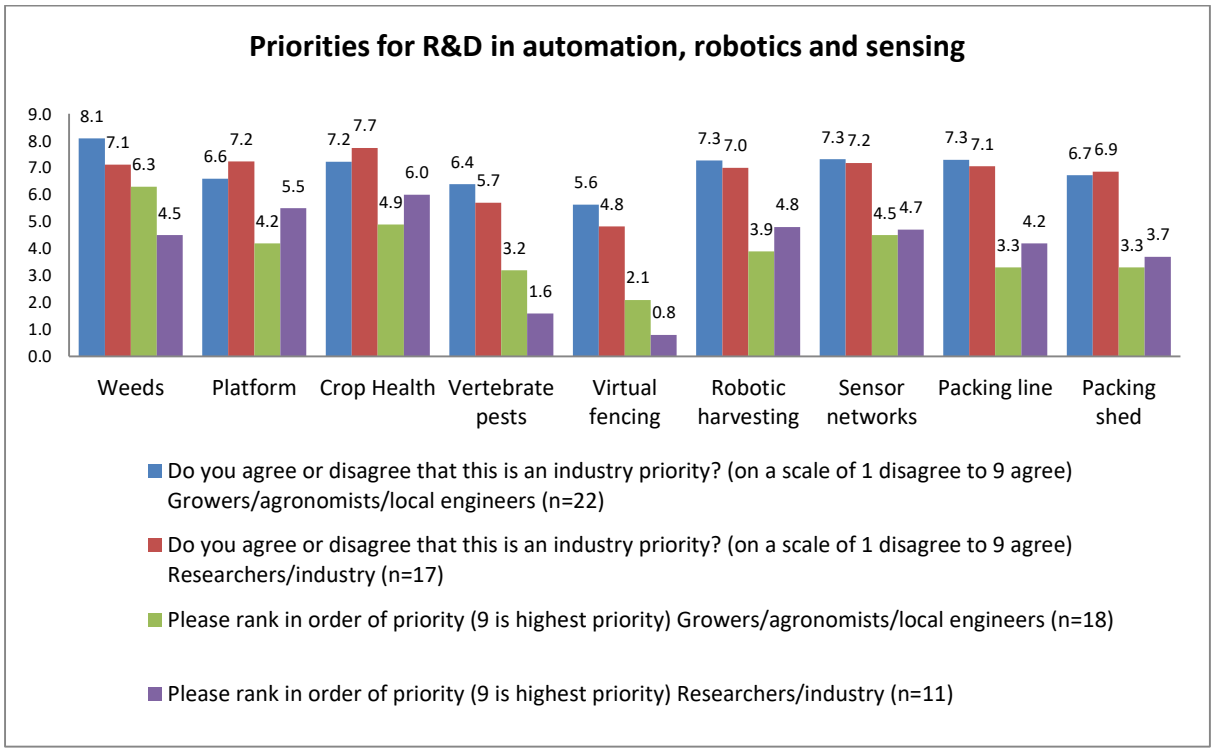
Participants were first asked to think about the importance of different technologies and their on farm application and whether or not they agreed that this was an industry priority on a scale of 1 = disagree to 9 = agree.

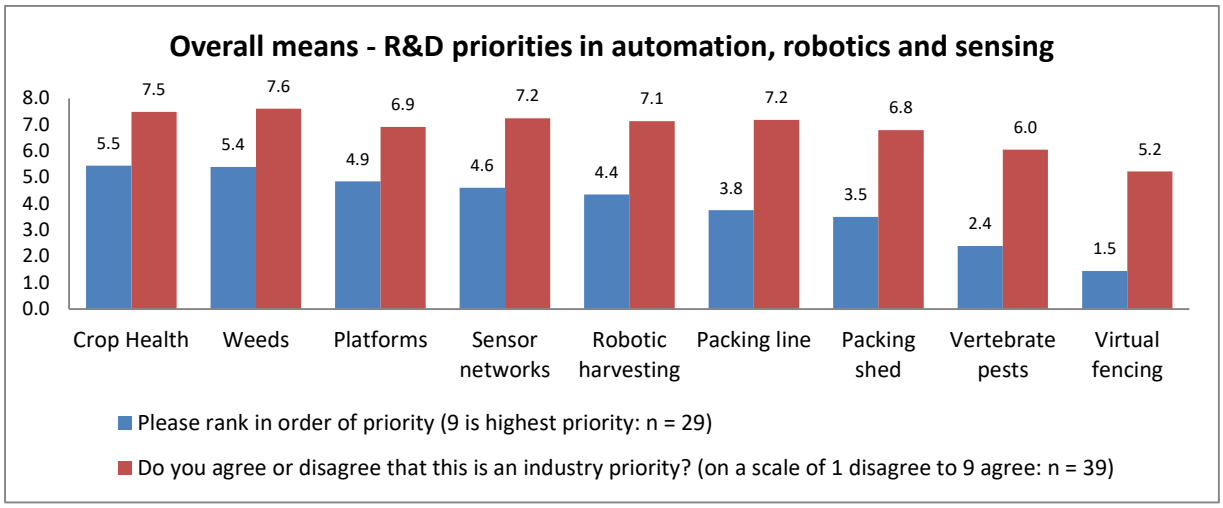
Please rank in order of priority

Once participants had thought through priorities and their importance they were asked to rank priorities from 1 to 9 (blue squares in the form overleaf). For ease of visual presentation, mean ranking for each priority are inverted in graphs below.

The first graph shows the combined means for growers/agronomists/local engineers against the combined means for researchers and other industry staff to illustrate differences between the two groups.

The second graph shows overall means, sorted from the highest ranking to the lowest ranking., followed by a summary of each priority in order of priority.





1 Automated crop health monitoring (ranking 5.5, scale 7.5) for strategic targeted crop management – potential of various vision systems, imaging & sensor technologies to improve efficiency of field operations & better manage production risks

2 Autonomous weed management (ranking 5.4, scale 7.6) – inter/in row spraying/weed eradication based on weed detection and identification using small autonomous platforms/robots and various vision and sensing technologies.

3 Autonomous all purpose, adaptable platforms (ranking 4.9, scale 6.9) – flexible and suitable for a range of tasks across various terrains and farming operations; 'plug and play' interchangeable modules – use existing platforms to test, develop & implement prototypes

4 Sensing and sensor networks (ranking 4.6, scale 7.2) for horticulture – improving field productivity. What can sensors measure? How can they be applied to improve productivity? Examples: environmental/ micro-climate monitoring, quality/ripeness/maturity, vertebrate pest management, virtual fencing, product tracking

5 Robotic harvesting (ranking 4.4, scale 7.1) of tropical and sub-tropical horticulture crops - step by step – overlaps with automated crop management: crop forecasting, maturity assessment; also vision systems, sensing, imaging, autonomous platforms, manipulators and grippers

6 Increased packing line efficiency (ranking 3.8, scale 7.2) – defect sorting before product enters the packing line.

7 Increased packing shed efficiency (ranking 3.5, scale 6.8) – automated/robotic palletising and product tracking.

8 Managing vertebrate pests (ranking 2.4, scale 6.0) in vegetable crops - for example: wallabies in tomato, birds in various crops, ducks in baby leaf and strawberry

9 Virtual fencing (ranking 1.5, scale 5.2) for mixed farming operations - for cattle - based on wireless sensor networks – under CSIRO patent

VG13113 Automation, robotics & sensing for the vegetable industry

Name (optional)……

Grower/Engineer/Consultant/Agronomist/Researcher……..……....

Autonomous weed management

Inter/in-row spot spraying/weed eradication based on weed detection & ID using small autonomous platforms/robots and various vision & sensing technologies

Do you agree or disagree that this is an industry priority?

Agree 9 8 7 6 5 4 3 2 1 Disagree

Comments?

Autonomous all purpose, adaptable platforms

Flexible & suitable for a range of tasks across various terrains & farming operations; 'Plug & play' interchangeable modules - use existing platforms to test, develop & implement prototypes

Do you agree or disagree that this is an industry priority?

Agree 9 8 7 6 5 4 3 2 1 Disagree

Comments?

Automated crop health monitoring for strategic, targeted crop management

Potential of various vision systems, imaging & sensor technologies to improve efficiency of field operations & better manage production risks

Do you agree or disagree that this is an industry priority?

Agree 9 8 7 6 5 4 3 2 1 Disagree

Comments?

Managing vertebrate pests in vegetable crops

For example: wallabies in tomato, birds in various crops, ducks in baby leaf and strawberry

Do you agree or disagree that this is an industry priority?

Agree 9 8 7 6 5 4 3 2 1 Disagree

Comments?

Virtual fencing in mixed farming operations

For cattle - based on wireless sensor networks – under CSIRO patent

Do you agree or disagree that this is an industry priority?

Agree 9 8 7 6 5 4 3 2 1 Disagree

Comments?

Robotic harvesting of tropical and sub-tropical horticulture crops

Step by step – overlaps with automated crop management: crop forecasting, maturity assessment; also vision systems, sensing, imaging, autonomous platforms, manipulators and grippers

Do you agree or disagree that this is an industry priority?

Agree 9 8 7 6 5 4 3 2 1 Disagree

Comments?

Sensors & sensor networks for horticulture

What can sensors measure? How can they be applied to improve productivity?

Examples: environmental/micro-climate monitoring, quality/ripeness/maturity, vertebrate pest management, virtual fencing, product tracking,

Do you agree or disagree that this is an industry priority?

Agree 9 8 7 6 5 4 3 2 1 Disagree

Comments?

Increased packing line efficiency – defect sorting

Do you agree or disagree that this is an industry priority?

Agree 9 8 7 6 5 4 3 2 1 Disagree

Comments?

Increased packing shed efficiency – automatic palletising, product/carton tracking

Do you agree or disagree that this is an industry priority?

Agree 9 8 7 6 5 4 3 2 1 Disagree

Comments?

Process Flow Analysis in Vegetable Production Systems

A component of the HIA/DAF funded project *VG13113 Evaluation of automation and robotics innovations: developing next generation vegetable production systems* is to investigate use of systems analysis concepts and tools with participating vegetable growers.

Objective: Investigate the potential of appropriate process flow/root cause methodology used in other industries (e.g. manufacturing) to analyse and improve field and packing shed efficiencies in vegetable cropping systems.

Rationale: Implementation of automation, robotics and sensing technologies are likely to be expensive therefore any improvements that can be made to field and shed operations prior to considering this investment will be of benefit to vegetable production enterprises.

Principles: Methodology used must take into account and complement systems/protocols for Quality Assurance, Workplace Health & Safety and Environmental Management already in place on farms and in packing sheds.

Training aspect: The work must engage with and utilise local project (DAF) staff in order to bring some capacity/understanding of the methodology, its application to improve existing processes and its potential to increase farm productivity into the targeted production regions.

The brief:

Complete three vegetable enterprise case studies with both field and packing shed operations assessed using process flow analysis concepts & tools. This work to include an 'on the job' training aspect for project team members and a report documenting methodology, outcomes and recommendations for each case study. Expected locations are:

- Gatton – either leafy vegetable or brassica crop
- Bundaberg – possibly capsicum, sweet potato or ginger
- Bowen – most likely tomato

Assessments to be conducted autumn 2016 with reports due by 31 August 2016.

Commitment for each enterprise:

Training and audit assessment – 2 days per site • Based on lean concepts & tools – continuous improvement, value stream mapping, bottlenecks, waste reduction, product & information flows • Enterprise owner(s)/manager(s) plus the local DAF agronomist • Aim would be to minimise time spent in workshop environment in favour of practical application of concepts/tools on farm
Follow up and action plan development – 1 day per site *No more than two weeks after training and audit assessment*
Outcomes: • Prioritised action plan with confidential report • Enterprise must be willing to share learnings with peers & industry

For more information please contact Sue Heisswolf, Bowen Research Facility – 07 4761 4044

Process Flow Analysis in Vegetable Production Systems

Lean Operational Excellence workshops

A component of the HIA/DAF funded project *VG13113 Evaluation of automation and robotics innovations: developing next generation vegetable production systems* was to investigate use of systems analysis concepts and tools with participating vegetable growers.

From the results of the industry survey we conducted with growers and the broader vegetable industry from November 2014 to May 2015, it was clear that enterprises were continuously looking for and putting into place processes, technology and systems to improve field and shed operations. These changes are driven by the need to find efficiencies and increase productivity in a highly competitive marketplace. This striving to improve is ongoing and essential for staying in business. However, the terms that growers used to describe these ongoing business and farm improvements did not reflect the formalised process flow analysis tools/concepts used in other industries such as manufacturing.

Can process flow/root cause analysis used in other industries provide a more systematic approach to further stream line and improve field and packing shed efficiencies in vegetable production system?

To answer this question, we conducted three case studies across Queensland. After a competitive tender process the task was awarded to the Queensland Manufacturing Institute (QMI Solutions) who conducted introductory Lean Operational Excellence workshops in July to August 2016. The grower co-operators were:

- Koorelah Farms in Bowen – tomato
- Holt Farm in Bundaberg – sweetpotato
- Sutton Farm in Gatton – broccolini

The work plan was to conduct training and a business audit assessment over two days per site with the owners/managers, key staff and the local DAF horticulturist followed by a one day review session two to three weeks later to develop a priority action plan for each business.

What is Lean?

Lean is a continuous improvement methodology used in the manufacturing and mining industries to increase productivity by:

- systematically reducing **WASTE**: any activity that absorbs resources without adding value
- improving process **FLOW** by addressing bottlenecks (constraints) in the system

Lean thinking evolved from the Toyota Production System which switched the focus from machines and technology to the flow of product (and information) through the total manufacturing process. It was based on the concept of **PULL** through/just in time manufacturing which provides increased flexibility and capacity to respond to changing customer needs quickly.

For horticulture, Lean offers:

- a systematic method for analysing the business and identifying potential ways of increasing productivity
- a different perspective from QA and HACCP which are risk focused – Lean focuses on identifying constraints and waste in the current production system

The aim of the three case studies was to determine if Lean concepts and tools are of value to the vegetable industry. It was not to conduct a detailed process flow analysis of each business using Lean.

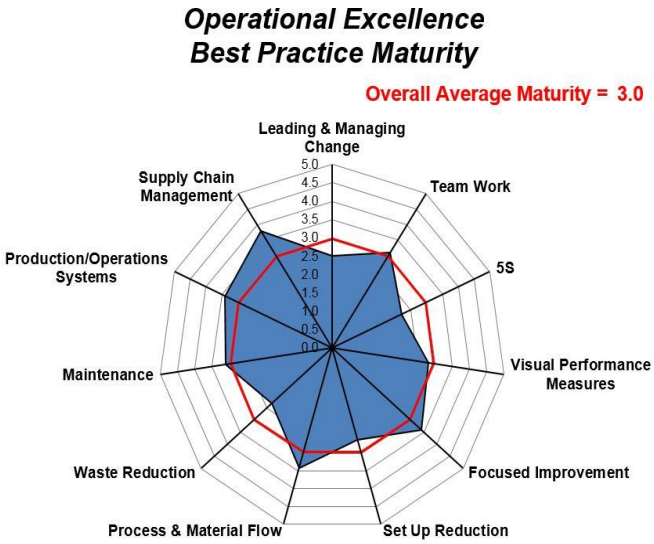
To find out more about Lean go to http://www.lean.org/whatslean/

Tools used in the case studies:

Lean assessment

This is basically a benchmarking tool to assess the business against what are considered good business practices in general (not just agriculture) using various criteria:

- Leading and managing change
- Team work
- 5S housekeeping
- Visual performance measures
- Focused improvement
- Set up reduction
- Process and material flows
- Waste reduction
- Autonomous and effective maintenance
- Production/operation systems
- Supply chain management – plan, source, make, deliver



Participants are asked to rate their business against these criteria using five different levels that describe a range of practices to measure 'business maturity'.

Most growers would be somewhat familiar with this type of audit assessment as it has similarities with some parts of HACCP, Freshcare, Enviroveg, other QA and best practice/ bench marking protocols. The Lean assessment focuses on those components that are considered high impact for increasing efficiency.

The Lean assessment tool used for the case studies provided the spark for some good discussion amongst business owners and their key staff. While useful, the tool needs major modifications to make it more relevant to the horticulture industry.

5S Housekeeping

This was seen as useful tools by participants. It consists of a check sheet for looking over different parts of the business and provided a hands-on practical demonstration of a component of Lean.

Sort – to separate needed equipment, instructions and documents from those that are not needed and removing the unneeded items from the work area.

Set in order – to neatly arrange and identify equipment and instructions for ease of use.

Shine – to conduct a clean-up campaign and helps to spot problems early.

Standardise – to set a routine for conducting the first three S's on a frequent, regular basis to maintain a workplace that is 'tour ready'.

Sustain – to form a habit of following the first four S's and monitoring through routine management walkabouts, audits and team meetings.

None of the above is new and most businesses would use something similar already - though possibly not documented. The value lies in having a tool for looking at a work area with fresh eyes and being more likely to do so, on a regular basis. In the case studies, we used 5S on the machinery shed and specialist packing line. Growers thought 5S could also be applied to field or office operations. Some parts of the check list needs revising to better suit horticulture.

5S Housekeeping Operational Audit

Area: Rhubarb Pack Shed **Assessor:** A. Mann **Date:** 28/7/2016

Read each criteria and rate the degree to which this is done. ***Rating 2: Excellent***, ***Rating 1: Minor Non-conformance***, ***Rating 0: Poor.*** Where there are examples of both good and bad in the area, take the lower score. Record what changes are required to lift the rating and improve the work area.

	Description	Rating			Comments/Required Improvements
Sort – (Everything sorted, only essential materials on hand)		0	1	2	
1	There is no outdated or incorrect information such as drawings or standards in the area		1		Some standards are not current.
2	There are no, components, tools, jigs stored in the area which are not used in this area			2	
3	There are no offcuts, obsolete or damaged components or tools stored in the area			2	
4	All work areas are clear of parts, tools & instructions not being used at this time		1		Some accumulated tools and parts on bench.
5	All tools & equipment have been placed where they belong – rolled, racked and/or packed		1		Most hand tools e.g. spanners are returned to mobile toolbox.
6	The area is free of foreign objects unrelated to the tasks performed in this area			2	
7	Consumables and components do not exceed the documented holding levels		1		The minimum/maximum quantities of consumables not defined. Utilise visual kanban.
Set in Order - (A Place for Everything, Everything in its Place)		0	1	2	
1	All tools, equipment, bins, WIP, consumables etc. stored in the allocated & demarcated place		1		Demarcations for most key areas and tools not defined.
2	Wherever practical colour coding is used to quickly communicate kits, types, correct conditions		1		No colour coding of tools - determine if beneficial.
3	All parts, materials, tools etc stored at point of usage with priority given to the most frequently used			2	
4	All safety equipment is clearly marked, in its place, and clearly accessible		1		Hearing protection at far corner of shed - could be placed in closer proximity to staff operational areas.
5	All tools/jigs stored in readily accessible, clearly labelled shadow boards/demarcated areas	0			No shadowboards for frequently used tools.
6	The area has demarcations for, walkways, bins, storage areas, set-down/collection locations etc.		1		Demarcation for primary walkway. Demarcation required for field bins at bunching.
7	All storage facilities such as shelving, boxes, racking etc. are clearly marked, labelled and neat		1		No labelling for any packing materials or consumables.
Shine – (Everything Clean and maintained)		0	1	2	
1	The floors, walls, windows, and lights are clean and in good condition		1		Lights clean but walls dirty. Clean walls and perhaps painted white to reflect light.
2	Equipment/tools are free from dust, grease, oil leaks, loose parts, graffiti & temporary repairs etc		1		Oil leak/excessive noise evident at intake conveyor.
3	Ancillary areas such as toilets and lunch rooms are clean, well maintained and free of graffiti			2	
4	Sources of contamination/product spillage been eliminated to simplify cleaning requirements		1		Spillage when decanting treatment chemicals from storage drums.
5	All machine gauges are clean and clearly calibrated/marked and easy to read			2	
6	There are appropriate waste bins and are they emptied regularly to prevent overflowing			2	
7	There is easy access to sufficient cleaning materials			2	
Standardise – (Communicate formal Policies and Procedures)		0	1	2	
1	There is a well communicated and accepted Housekeeping Vision		1		Documented and communicated at induction but lacking visual standards.
2	There are visual 5S (housekeeping) standards with photos of what is required and 5S tasks listed		1		More relevant and visual standards would help clearly communicate required condition of all areas & machinery.
3	5S Standards show what tasks are done, where and when they are performed			2	Cleaning tasks/schedule well defined.
4	There are clear visible performance indicators on display for safety, productivity and other KPIs		1		Primary indicator is performance relative to delivery target. However consider, cost, quality, safety & morale KPI's.
5	There are SOPs for handling, storage and disposal of waste, chemicals & dangerous goods			2	
6	Cleaning/housekeeping responsibilities have been communicated to all employees			2	
7	All safety and exit signs clean and clearly visible - there are documented emergency procedures			2	
Sustain – (Committed and Motivated to Ongoing Improvements)		0	1	2	
1	Problem action boards are located in the work place to record issues & opportunities to improve		1		No action boards evident. Consider introducing a 5S storyboard including continuous improvement action list.
2	5S is a regular agenda item for management meetings, office and factory meetings		1		
3	Regular 5S audits are conducted at scheduled intervals as well as ad hoc times		1		No formal 5S audits, but complemented by other quality audits.
4	New employees receive 5S training as part of their induction		1		Ensure a clear understanding of the reason for 5S is communicated, i.e. compliance and constant improvements.
5	5S audit results are recorded on progress charts and displayed in the workplace	0			Audit results not displayed.
6	Senior management are committed to 5S succeeding and provide recognition of achievement		1		
7	5S Before and After pictures, examples or story boards are on display in the business	0			Consider a 'story board' to effectively communicate the journey, measures against targets & improvement actions.

Maximum Score:	70
Achieved Score:	44
Percentage Score:	**62.9%**

DOWNTIME – waste hunt

This is a method for looking at a process to identify opportunities for reducing waste – any activity that absorbs resources but does not add value from a customer's point of view.

Defects and rework – imperfect product is delivered to the next process – for example, poor quality fruit enters the packing line, overwhelms the defect sorting and colour grading processes resulting in out of spec product which needs repacking.

Overproduction – processing more than what is required by the next process.

Waiting – idle time created when waiting for resources or materials – where is the bottleneck?

Non-use of employee talents – wasting or not making the most of people's abilities and talents.

Transportation – unnecessary movement of materials and paper around the work place and business.

Inventory – any supply in excess of a one piece flow through your process – needs to be balanced with exposure to risk of Waiting due to lag times for inputs supplied outside the business (cartons, chemicals, seed)

Motion – any movement of people (typically walking/number of steps) or equipment that does not add value to the product.

Excessive processing – effort that adds no value to the product or service from the customer's viewpoint.

While our case study growers had eliminated much waste in their operation, the DOWNTIME template we used seems a useful tool for reviewing different work areas of the business.

The 'eight wasteful activities' need some rethinking to better align them with the realities of producing a perishable product where the 'customer' is usually not the consumer.

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Waste Hunt – Current Process
DOWNTIME

Focus on an existing process and identify the wastes.

Process: Rhubarb Pack Shed
Date: 28/7/2016 Who: B. Linda, A. Mann

Waste	Identified Example
Defects & Corrections	*Picking out of specification…currently 10% target 4%. E.g. Stalks split & too green.*
Overproduction	*Harvested in excess of customer demand and pack-house storage capacity.*
Waiting	*Waiting for harvested product bins.* *Waiting for bunches at boxing.* *Waiting for instruction.*
Not using your resources potential	*Improvement suggestions from pack-shed staff not encouraged/documented/actioned.* *Significant clutter – poor use of space/layout.* *Frequent breakdown of key equipment – lost capacity.*
Transportation	*Double handling required to access packaging materials.*
Inventory	*Excessive number of packing boxes occupying floor space.*
Motion	*Need to find tools to perform a machine adjustment.* *Pack shed staff looking for supervisor – need instruction.*
Excessive or inappropriate processing	*Leaves trimmed too much – not required by market.*

Value Stream Mapping (VSM)

This activity has at first glance much in common with operational flow maps that a business may have developed as part of its HACCP or QA accreditation.

As with the other tools, the main value lies in reviewing operational flows in a systematic way with Lean value adding concepts in mind. It uses three categories to 'map out' different activities of the operational (process) flow:

- Activities that add value that are necessary – grow, harvest, clean, sort, pack?
- Activities that are necessary but do not add value – receive, store, move, check, invoice?
- Unnecessary activities = waste = any activity or process that absorbs resources (people, time, equipment, material, space) that does not add value and is not necessary

According to QMI, it is not unusual to find that the non-value-add/value-add ratio at a typical manufacturing business is somewhere between 88 to 97% non-value adding and 3 to12% value-adding.

VSM aims to identify all non-value-add and value-add processes, determine the actual ratio and specifically the improvement opportunities.

What is value to your customer?

What are they happy to pay for?

Product, service, fast delivery, flexibility, reliability, standards compliance?

What do they not want to pay for?

Storing, waiting, double handling, reworking/correction, checking/inspection (testing), order entry/tracking, invoicing?

Value stream map (VSM) example

The Value Stream Mapping exercise is very visual and uses post-it notes and colour stickers to map out and analyse the material flow and information flow of a packing line using the value and non-value adding concept.

In the case study work, participants saw only limited value in this activity. The format needs tightening up, needs to better build on existing (QA) operational flow documents and keep in mind that the business probably has already eliminated the most obvious areas of waste.

Focused improvement /problem solving

Once action priorities are identified, the A3 DMAIC method provides a step by step format for working through an issue and finding solutions to improve. A3 refers to the paper size of the template. It includes space to formulate a title for the issue, describe the background of the issue then work through DMAIC:

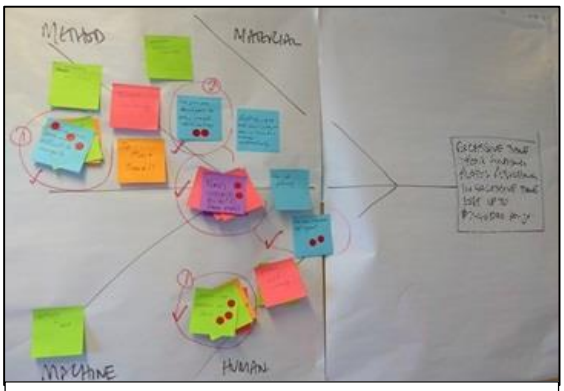
Define → **M**easure → **A**nalyse → **I**mplement → **C**ontrol

As with some of the other tools, some parts of the process have similarities with HACCP or QA risk analysis and control but with a different focus. A3 provides a useful template for discussing and documenting a problem area and some possible solutions.

Other Lean concepts and terms

Root cause analysis may be a term new to horticultural growers. It is about getting to the heart of a problem before thinking about solutions.

Along with the A3 DMAIC tool, there are a number of other methods for analysing a problem and finding solutions. The method we used was the Fishbone technique to tease out factors that impact on fruit quality. Some other tools are the Pareto diagram (80:20 rule – the significant few versus the trivial many), the 5 Whys (drilling down through the symptoms to get to the cause of a problem) and brainstorming.



Fishbone technique example

Theory of constraints – ensuring primary effort is focused on bottlenecks within a process

Pull Systems/Just in Time – focus on identifying causes that cause delays between processes and so reduce throughput and increase lead times

Visual performance measures – the best way to communicate is directly between the sender and receiver to minimise risks of garbled or altered messages. Lean focuses on making information (such as performance measures) visible to workers as it is needed so that everyone, not just the supervisor can track progress and respond to meet target performance. Visual performance measures could be about safety, quality, cost, delivery, morale.

What we learnt:

The case studies did not go as well as we had hoped. This was partially due the strong manufacturing flavour of the material, a lack of linkage with existing systems and processes, and last but not least, the timing of the workshops at a busy time of the year so that field and shed operations could be assessed at full production.

Nevertheless, we think there is value in Lean concepts and tools for the Australian vegetable industry.

The workshop materials – presentation, examples, documents, templates, check lists – need reworking to improve their relevance and value to horticulture. Workshop delivery needs to be tightened up significantly.

The link between existing systems, processes, thinking and grower experience especially with regards to HACCP and existing QA documentation needs to be better acknowledged and built upon.

The training and assessment workshops are usually held over a longer period followed by a number of repeat visits to help implement improvements. QMI adjusted their standard program to fit in with our case study requirements. For vegetable growers, it would be useful to break the training and assessment into two parts:

- A strategic introductory training and assessment module (2 days maximum) which is hands-on and illustrates concepts and tools in as practical and active a way as possible, includes an initial Lean benchmarking assessment, develops a draft priority action list and is held at a quiet time of the year.
- Detailed analysis of different areas of the business once operations are in full swing. Start with results from the Lean assessment and priority list and build on these.

The two contrasting workshops require different skill sets on part of the facilitator – big picture vs detailed. The workshops could be further broken down into several modules delivered over a number of months and then followed by repeat visits to implement improvements.

The facilitator/consultant needs to spend adequate time familiarising themselves with the industry and individual enterprise:

- Prior to the first on-farm visit to obtain a thorough understanding of existing systems and processes particularly those areas with partial overlap – HACCP and QA process flow maps (Value stream mapping), business plans and decision making culture of the organisation (Lean audit & A3 problem solving), standard operating procedures (DOWNTIME, 5S) – the aim is to link in with existing resources to illustrate relevance and save time.
- At least a half-day walk through of the operation at the start of the first farm visit.
- The facilitator/consultant also needs to be clear about how and what the workshops will deliver at the outset – provide a 'road map' of session plans.

Did growers make any changes to their operations in response to the workshops?

Lean did help growers identify areas where existing processes could be improved and prioritised some areas that needed attention – perhaps already on the 'jobs to do' list. A number of these improvements have been implemented.

- The Lean workshops highlighted the importance of defect sorting on pack out rates and in response, the manufacturer was asked to recalibrate a grader to better sort defects for pre-pack lines. Future grader recalibrations are planned.
- Through 5S, made some minor changes in pre-pack shed including yellow safety lines on floors and a clean-up of the area, also a 'time management' study with the QA start-up crew in the main shed; in machine workshop tidied up and re-structured the area, painted it a lighter colour and installed shadow boards.
- Through 5S, will be looking at efficiencies of people and product movement in the new shed and will be looking at the "whole" shed to find efficiencies.
- Reviewing shed and field practices to better measure peoples work rate and productivity – boxes picked and packed in standard time period – formalise a system and set a "pack goal".
- Instigate a system for business manager meetings where recurring issues are colour coded – red, amber or green – to take the blame of individuals in meetings but highlight an issue as a group 'must fix' priority.

On reflection, what did participants think of the workshops?

At a busy time of the year, there was frustration about the slow pace of the workshops and lack of horticultural examples. Participants struggled to see the cost: benefit for the time invested. Koorelah Farms made the decision to complete the half day follow up workshop, Holt and Sutton Farms declined.

- Our case study growers use similar processes in their business all the time and have done so for some time but not that formally, at that level of detail or with those tools – need to much better link to existing systems, build on information supplied by the business before the first workshop and

substantially tighten up workshop delivery. Growers are also used to making decisions quickly and on their feet.

- The material was very detailed – one grower said the material was very good. It took a long time to deliver and was very machine focused. It needs to be adapted for horticultural situations and broken down into smaller modules that can be delivered gradually over several months.
- The 5S module was particularly useful as it had direct practical application.
- Not only did the workshops take more time than expected, they also were not quite what growers were expecting: a consultant looking over different parts of the business with 'fresh' eyes, then providing a report card and some recommendations with minimal input from the enterprise's management team. There is still interest but also some uncertainty about employing a consultant to do detailed Lean analysis of different parts of the business.
- Poor timing – at peak production it was difficult to stay focused on a lengthy workshop with many other demands on the management team's time and energy – do the introductory conceptual workshop outside peak season.

Acknowledgments

Information in this leaflet is in part based on material provided by Geoff Wakeley from QMI Solutions for the case studies. Its purpose is to provide vegetable growers with a better understanding of Lean concepts and tools so that they in a better position to decide if Lean is of value to their business.

Our thanks to Leanne and Wayne Born, David Holt and Brock Sutton and their staff for participating in the case studies and their willingness to share confidential information with us.

For more information please contact:

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David Carey at Gatton on 0467 746 302

Steve Ginns at Bundaberg on 07 4132 5541

Appendix III: Prototype testing to deter and detect ducks in Baby leaf

Vertebrate pests are a major issue for many Australian horticultural producers. Each year, reports of severe crop damage and subsequent economic losses are regularly printed in local newspapers and industry journals. Stonefruit, pome fruit, mango, other fruit and nut crops as well as a range of annual vegetable crops are attractive food sources to birds, wallabies and other vertebrate pests especially in times of drought when other common food sources are in short supply.

Lettuce and Baby Leaf Salad crop yields are regularly impacted by birds notably around the full moon. Problems are well documented and have been the subject of previous research efforts in Australia. Bird damage is highlighted in the Horticulture Australia Limited final report for the project **VG09188** "**The production of baby-leaf lettuce under floating crop covers**" by Munton (2013). The report describes damage suffered by Britton Produce, an experienced baby leaf salad producer near Stanthorpe in Queensland. At times 100% of a block was affected by wild ducks with lesser damage from rabbits. Sometimes damage was limited to a few random leaves however this can still make product un-harvestable as contamination by bird faeces makes product un-saleable.

During the trial period, Britton Produce lost no product to ducks or other contamination where it was grown under protective floating row covers. However during the same period, Britton Produce recorded a loss of product valued at $43,500 due to ducks feeding on an unprotected section of the same farm. Similar experiences are reported by baby leaf salad and lettuce producers in the Lockyer Valley and Eastern Darling Downs. Reports of product losses valued at $15 000 – $18000 in a night as a direct result of duck feeding is not uncommon. Losses do not factor in the time and money spent trying to ward off and prevent these feeding events with scare guns, flashing light, noise machines and other deterrents, often with little effect.

Babyleaf salad production in Australia has seen exponential growth over the last 5 to 7 years. In the Lockyer Valley for example this increase in production has seen grower numbers increase from 1 to 5 in recent years. Babyleaf is grown in all states of Australia with all production areas suffering varying degrees of damage throughout the season as a result of duck feeding.

Prototype development and testing

Better options for managing vertebrate pests based on automation, robotics and sensing technologies emerged as an industry priority in VG13113. As a result, we are investigating a prototype autonomous intelligent system to detect and deter vertebrate pests with CSIRO and a grower collaborator in Gatton.


CSIRO Deter node

The prototype is based on a distributed wireless sensor network underpinned by CSIRO/Data61's digital engineering capacity. This prototype test network was constructed using commercially available technology – sensors to detect movement which, when triggered, activate sound or light. A camera to record activity was integrated into this network and includes a sophisticated 'sentinel' system that can potentially record and classify

pest incursions and their reaction to various deterrents.

DAF project staff procured and supplied the off-the shelf 'pest repeller' and sensor components and assisted with grower liaison. CSIRO supplied their expertise, built the test gear, carried out deployments and analysed the data. Three on farm deployments were completed in 2016:

Who: Phil Valencia and Ashley Tews from CSIRO and David Carey from DAF

Where: Baby leaf vegetable farm in the Lockyer Valley

When: 1st deployment 26 April; 2nd deployment 21 July; 3rd deployment 20 September

These in-crop field deployments allowed CSIRO to quickly evaluate technologies and gain a first-hand appreciation of the scale of the problem. There are a number of engineering challenges to solve in order to make the system weatherproof, large scale, provide 360◦ crop coverage , secure (from tampering and theft) and minimise power consumption so that it can be deployed long term (ideally seasonally). Further on farm testing by CSIRO to address these issues is planned for the first half of 2017 as part of a small, internally funded DAF innovation project.

The idea is to minimise human input so that the grower can sleep soundly at night in the knowledge that the mobile phone will sound the alarm if the system can no longer cope

The aim is to develop an intelligent autonomous system that can not only detect vertebrate pests but can stay one step ahead of the pest bird or animal as it 'learns to adapt to the different deterrents that the system has at its disposal. A small DAF innovation project will continue investigations in the first half of 2017.

CSIRO (Data61 Cyberphysical Systems group) have patented the prototype and are in discussion with Hort Innovation Australia, DAF and industry to develop a concept proposal to scale up and progress this technology towards commercialisation. The proposal would involve further evaluation of deterrent options and the development of the autonomous (robotic) and distributed sensing systems. This partnership would also involve CSIRO's animal behavioural scientists. An autonomous intelligent and adaptable detect and deter system would provide an environmentally and ethically acceptable solution to reducing the frequency and scale of vertebrate pest attacks on susceptible crops on Australian farms.

References

Robert Munton (2013). The production of baby-leaf lettuce under floating crop covers Horticulture Australia limited – final report VG09188.

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Acknowledgements

Our thanks to Phil Valencia and Ashley Tews from CSIRO who provided their expertise and time free of charge to trial this prototype technology on farm. We look forward to future collaboration with the CSIRO team to bring the concept to its full potential. A particular thanks to Desleigh Jackwitz from Imperial Produce for her time, patience, ideas and making her farm available for trial deployments.

Appendix IV: Challenges, constraints and opportunities

The grower and industry surveys as well as other project activities highlighted a number of challenges and constraints to successful commercialisation and implementation of automation, robotics and sensing technologies on Queensland vegetable farms. It also revealed some opportunities. These are outlined below. They are followed by Return on Investment (ROI) and payback period examples for several identified industry priority/ technology combinations.

Challenges, issues and constraints

Vegetable growers are not a homogenous group, horticulture is a complex business and each farm is different. While the major constraints to implementing MARS technologies continue to be cost and critical gaps in technology, both in part a function of the inherent variability of vegetable production systems, a number of other factors also need to be considered:

- Intellectual Property (IP) – freely available or not? This impacts on continuity of R&D and flexibility/adaptability of software/hardware to achieve specific tasks
- Workplace, Health & Safety issues – machinery/technology can help overcome but may also present challenges
- Servicing technology – timely access to spare parts, expertise & software, ability to fix breakdowns/problems quickly to minimise downtime or adjust/improve function
- Customising equipment/machines and retro-fitting – are they still covered by warranty?
- Compatibility of software and hardware – interface vs integration of different systems – is 'plug and play' concept achievable in horticulture?
- Big Data – data islands – upload and download speeds in regional areas (on farm WiFi) - data output vs information on which growers can make better decisions: can data be interpreted in situ? How much data is actually needed for decision making?
- Automation & robot ready farms – system, crop, plant redesign - reducing variability to enable integration of automation, sensing, robotics into the farming system – interlinked with variable rate technology and precision agriculture

To be successful and affordable, practical automation, robotics and sensing applications for agriculture are likely to differ from manufacturing and mining in several aspects:

- Small, light and less expensive – perhaps combined with larger machinery as part of controlled traffic/gantry farming
- Flexible and moveable (easily transportable)
- Many units rather than one or two – to give flexibility, avoid reliance on one large machine
- Exposed (outdoor –dusty, wet, uneven terrain/ light levels, high vibration environment), rather than sterile (fully enclosed) environments

- Adaptable with integrated swappable components suited to specific operations such as modules that can be used for various platforms and tasks such as spraying, harvest, pruning, plant health monitoring or packing, rather than full scale single use systems
- Agricultural automation needs to be user friendly with local service support staff

Opportunities

The industry survey target at project start was to interview a cross-section of owners and managers of enterprises that we thought were interested in and potentially capable of implementing automation, robotics and sensing technologies. Some interesting trends emerged and these were confirmed at regional industry forums, on farm visits and during end of project survey interviews.

- A significant proportion of the Queensland vegetable industry is in the midst of generational change (or has it already happened?)
- The attitude to automation and robotics is overwhelmingly positive
- GPS guidance systems are widely accepted and adopted – the Queensland Variable Rate Technology (VRT) project has started a conversation about how to make better use of these existing systems
- QA systems are in place with widespread use of harvest aides and colour vision graders.
- Large, professional enterprises looking for improvements and efficiencies
- Widespread and increasing use of mobile/smart phones, email and social media

These changes show that compared to only ten years ago, the industry is now in a much better position to adapt and integrate practical automation, robotics and sensing innovations into their farming systems.

Some other opportunities:

- There is a large potential resource located in vegetable producing regions: local engineering firms who have been building farm machinery for decades and increasingly, software firms that support horticultural enterprises with digital capacity. Local consultants and agronomists (and key farm staff) are also becoming increasingly digitally literate by implementing paperless systems based on IPads and smart phones. They are 'training' their clients in the use of these digital systems. Two firms have invested in UAVs to expand on the suite of services they can offer their customers.
- Higher skilled (and paid) technology oriented jobs may entice young people to stay, return or relocate to regional centres. The media is helping to generate a more positive image of agriculture and this may help attract future young professionals into the industry and the regions.
- As Precision Agriculture (PA) technologies such as VRT gain traction and are more widely implemented on the back of more extensive and better use of GPS technology, crop variability will decrease and plants and product will become more standardised. In some respects, this will make field operations more amenable to MARS technology deployment with the cropping system better suited to the machine - as has already happened in packing sheds and to some degree in protected cropping.

- The experience of the QLD VRT project team shows that intensive work with grower collaborators and industry is needed to fully realise the opportunities inherent in PA for productivity through input savings – energy, chemicals, labour – for better yields and environmental outcomes (Limpus 2016).

Much of the above was echoed at the recent AgFutures conference in Brisbane (DAF 2016). Speakers discussed issues around:

- Data: what is actually needed to make good decisions, in-situ processing of data to turn it into information, on farm WiFi, data provenance, attaching probabilities to data sets and data monopolies being as bad as economic monopolies

- Technology: the promise often does not measure up to reality - theory of inflated expectations; that the technology needs to work and the market must want it; and that there is usually inadequate market validation and testing

- Stop inventing and start innovating: that big gains can be made by better implementing existing technologies more effectively – that's a long term, resource intensive, one-on-one, systems focused process

During project activities, growers volunteered ideas on how to overcome some of the constraints of technology costs and the complexity of integrating technology into farming systems. This included outsourcing/contracting of specific services as already happens for a number of operations: laser levelling; tomato pruning; bedding up, trickle and plastic mulch laying; contract harvesting. The purchase of UAVs by two consultancy/agronomy firms shows that this business model holds promise for automation, robotics and sensing technologies. Data processing and management may prove challenging however crop consultants/agronomists are in a good position to ground truth data effectively.

Growers and industry thought that step changes rather than complete system changes were likely to be more effective for the obvious reasons: step change implementation reduces up-front investment costs and the technology can be trialled and evaluated on farm before making a major commitment to the change. We encourage research organisations to take advantage of the willingness of farmers and their service providers to test, adapt and experiment with evolving technology.

Example costings – return on investment (ROI) and payback period

Initial Return on Investment (ROI) work suggested that estimates of payback period may be a more relevant metric for the vegetable industry. From survey results, a two year payback period was seen as desirable increasing to three years where workplace, health and safety issues are of concern. The examples which follow illustrate that this may be an unrealistic expectation for some automation and robotics technologies.

An article that appeared in Vegetable Australia earlier this year is useful for taking a more holistic view of investing in automation and robotics. Krupp (2016) discusses four key economic indicators to take into consideration when deciding whether to invest more funds into labour productivity:

- Current interest rates – cost of investment capital

- Wage rates – if wage rates are significantly lower than the cost (and risk) of investing more capital then it makes sense to employ more labour rather than investing more capital
- Debt to equity ratio – impacts on the ability of a business to service a debt and therefore ability to obtain funding for capital investments and its cost
- Market sentiment – capital is generally more fixed in comparison to labour so potentially reducing business flexibility and capacity to respond to changing market needs and opportunities

From industry surveys, we know of instances where growers are making decisions on these economic indicators although they may not use the above terminology. For example, one grower decided to stop attempting to further mechanise/automate planting and harvesting operations when it became clear that investment costs were on par with the annual backpacker wages bill. Another grower made a similar decision when maintenance costs and difficulties in sourcing parts were accompanied by unacceptable down time when using the new machine – the old system was in fact more economically viable.

Growers are also increasingly looking to diversify in an effort to spread (market) risks and this must impact on the decision making equation when considering investing large sums of capital into technology that further locks them into a certain crop type, style of farming or market segment.

Costing assumptions

Activities costed in these examples are not recommendations but examples of general current industry practice based on the attached gross margins, our combined 60 plus years of agricultural/horticultural production experience and information provided during survey interviews.

Estimates of what automation, robotics and sensing innovations might cost are based on our very limited understanding of what these technologies might entail. This will become clearer once the technologies are closer to commerialisation. No allowances have been made for variations between seasons, changes in enterprise mix, input price changes or impact of interest, inflation and tax rates on investment costs. We used a seven year time horizon as that seemed a more realistic time scale for vegetable growers than ten years.

FORM is fuel, oil, repairs and maintenance of vehicles, machinery and plant. Estimates tend to be unreliable and can vary widely depending on equipment age, suitability for the task, the farming or packing system and the environment (soil, weed load, crop grown). FORM does NOT include labour costs.

Labour includes ONCOST and is estimated at $20/hour for base casual rate, $30/hour permanent/skilled rate and $50/hour for technical support.

Autonomous weed management example

Inter/in row spraying/weed eradication based on weed detection and identification using small autonomous platforms/robots and various vision and sensing technologies.

Enterprise size: 100 ha of trickle irrigated vegetable crops (capsicum, tomato, zucchini, melons) transplanted into plastic mulch

The current system

Example costings of existing weed control inputs

Inter row weed control – two operations per crop	$/ha	$/100 ha
FORM – inter row (shielded) spraying	3	300
Herbicides	145	14,500
Labour – 8 hours/week x 30 weeks x $30/hour		7,200
	TOTAL	**$22,000**
In row weed control		
FORM – bed forming/tape & mulch laying	204	20,400
Labour - contract bed/tape/mulch laying	244	24,400
Plastic mulch - $0.13/metre	750	75,000
Mulch lifting $260 and mulch/trickle tape roll up $120	380	38,000
Mulch disposal - contract	135	13,500
	TOTAL	**$171,300**

As the above table of current weed control methods shows, for inter row weeding the main costs are herbicides and labour costs. Better targeted, strategic spot spraying might reduce herbicide inputs and substantially reduce labour costs. An autonomous system will need checks by a trained person to minimise risk of system and machinery failure.

For in row weed control, the main costs are in plastic mulch - material, labour and disposal costs. An effective autonomous weed management solution capable of replacing plastic mulch in the system is attractive. Number of weeding operations would increase and with these, herbicide costs. The bedding up, trickle laying/removal operations would be done in any case although at slightly less cost. In French bean and sweet corn crops, plants are generally direct sown and plastic mulch is not used so an autonomous system is likely to be less cost effective.

Calculations for the autonomous system are made on the following assumptions:

- Inter row 2 Bot system - $40,000 per Bot + $20,000 for the system
- Inter and in row 8 Bot system - $40,000 per Bot + $100,000 for the system

The autonomous system

Example inputs and costings of the innovation

Inter row weed control – a 2 Bot system can cover 100 ha	$/ha	$/100 ha
FORM – inter row weed eradication	3	300
Herbicides – targeted (shielded) spot spraying	80	8,000
Labour – technical 2 hour/week x 30 weeks x $50/hour		3,000
	TOTAL	**$11,300**
In row + inter row weed control – a 8 bot system can cover 100 ha		
FORM – bed forming and tape laying	180	18,000
Labour - contract bed and tape laying	210	21,000
FORM – inter + in row weed eradication – six operations per crop	30	3000
Herbicide – spot spraying	250	25,000
Labour – technical 12 hours/week x 30 weeks x $50/hour		18,000
Trickle tape roll up	20	2000
	TOTAL	**$87,000**

Based on the above assumptions, the potential return per year by investing in an autonomous weed management system for a 100 ha trickle irrigated, transplanted, plastic mulch vegetable crop are:

For a 2 Bot inter row weed management system only: Current inter row $22,000 less operational costs of the innovation $11,300 = $10,700

For an 8 Bot inter and in row weed management system: Current inter row $22,000 plus in row $171,300 costs = $193,300 less operational costs of the innovation $87,000 = $106,300 per year in weed management savings for a 100 ha trickle irrigated vegetable crop.

Return on investment

Inter row only	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**
Cash In	-$100,000			-$10,000				-$100,000
Cash Out	$10,700	$10,700	$10,700	$10,700	$10,700	$10,700	$10,700	$85,400
Net Cash Flow	-$89,300	$10,700	$10,700	$700	$10,700	$10,700	$10,700	-$35,100
Internal rate of return	-12%							
Multiple	0.8	-0.75						
Initial cost includes training and set up costs, system needs upgrading in Year 3								
Inter and in row	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**
Cash In	-$420,000		-$50,000			-$50,000		-$420,000
Cash Out	$106,300	$106,300	$106,300	$108,900	$108,900	$108,900	$108,900	$744,100
Net Cash Flow	-$313,700	$106,300	$56,300	$106,300	$106,300	$56,300	$106,300	$224,100
Internal rate of return	18%							
Multiple	1.8	-1.77						
Initial cost includes training and set up costs, system needs upgrading in Years 3 & 6								

Payback period

Inter row		**Inter & in row**	
Initial investment	$100,000	Initial investment	$420,000
Average return/year	$9,271	Average return/year	$92,014
Payback period	10.8 years	Payback period	4.6 years

Additional benefits

Based on the assumptions in this example, the autonomous **inter row** weed management system does not look like a commercial proposition. However there are several reasons why it might still be worth considering. If the system cost is halved to $50,000 @ $20,000 per Bot x 2 plus $10,000 for the system, the internal rate of return (IRR) is 10% and payback is in 5.4 years. Even if this cost

structure is not realised, the inter row weed management system could provide the 'learning, development and adaptation vehicle' for implementing the technology under practical, commercial conditions under a range of crop and farm operations - the step change to build confidence.

If this step change 'starter pack' can be expanded in size (system) and adapted to other tasks, it may provide the hardware and software platform for spin-off operations to manage diseases, pests, nutrients, soil and water. If linked with advances in precision agriculture such as variable rate concepts for minimising inputs while maximising outputs for a given area of land, effective use of an autonomous crop management system has important implications for productivity and environmental impacts.

Improved defect sorting

Defect sorting equipment currently used in vegetable packing sheds can cost up to $200,000. Effectiveness seems to vary depending how well it has been/can be calibrated for the product being sorted. Defect sorters are suitable for round fruit but have limitations for products such as capsicum. There may be scope to improve effectiveness of existing equipment. Defect sorting was listed as an industry priority.

Defect sorting is a tedious task. It also takes some skill. Any improvements in automated sorting will reduce training requirements by simplifying decision-making for staff. Reducing defect fruit entering and moving through the packing line also simplifies decision-making for packers. This decreases risks of out of specification fruit in pack outs which can have serious implications for keeping current and future market contracts/supply options. Customer branded product usually cannot be sold elsewhere without costly re-packing.

Tomato example

If two staff can be taken of sorting tables, what cost savings might be made?

Assuming an average of 6 hours per day x 6 days per week x 20 weeks per year = 720 hours per person/year = 720 hours x $25/hr x 2 people = $36,000/year

Return on investment

Defect sorting to reduce labour input by two staff								
Return Calculation								
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**
Cash In	-$150,000			-$20,000				-$150,000
Cash Out	$36,000	$36,000	$36,000	$36,000	$36,000	$36,000	$36,000	$252,000
Net Cash Flow	-$114,000	$36,000	$36,000	$16,000	$36,000	$36,000	$36,000	$82,000
IRR	18%							
Multiple	1.7	-1.68						

Initial cost includes training and set up costs, needs upgrade in Years 4

Payback period – sensitivity analysis for new defect sorter

At $150,000		**At $175,000**		**At $200,000**	
Initial investment	$150,000	Initial investment	$175,000	Initial investment	$200,000
Average return/year	$36,000	Average return/year	$36,000	Average return/year	$36,000
Payback period	4.2 years	Payback period	4.9 years	Payback period	5.6 years

Autonomous pest bird management – detect and deter

Vertebrate pests can be a major problem for some growers in particular crops, on some farms and across production regions. Some pests are seasonal, some attack only at night. Vegetable crops are particularly attractive to birds, wallabies and other animal pests during drought conditions. Available management options are limited and often ineffective.

CSIRO are developing an autonomous, adaptable system based on wireless sensor network technology and their Data61 digital capacity which may provide an effective, ethical, environmentally friendly solution with a minimum of human input. They are currently testing an early prototype on a Gatton farm (described in more detail in Appendix III). The following example is based on crop losses through duck attacks on baby leaf and lettuce crops using a mobile system that can protect 50 ha per season.

Pest bird protection on 50 ha of leafy vegetable crop

Current methods	$/ha	$/50 ha
Crop loss - $10,000 per month (around full moon) x 8 mths		80,000
Labour – technical 20 hours/month x 8 months x $50/hour		8,000
Operational cost of hardware – scare guns, flashing lights, noise	10	500
Anything else?		
	TOTAL	**$88,500**
The autonomous, mobile, adaptive system		
Crop loss - $2000 per month (around full moon) x 8 mths		16,000
Labour – technical 10 hours/month x 8 months x $50/hour		4,000
Operational cost of hardware – scare guns, flashing lights, noise, ground and air robots	50	5000
	TOTAL	**$22,500**

Based on the above assumptions with average annual crop loss of $80,000, the innovation if reasonably effective could result in $66,000 of savings per year.

Return on investment

Autonomous adaptive pest bird management system - mobile to cover 20 ha of vegetable crop								
Return Calculation								
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Total**
Cash In	-$200,000		-$20,000		-$20,000			-$200,000
Cash Out	$66,000	$66,000	$66,000	$66,000	$66,000	$66,000	$66,000	$462,000
Net Cash Flow	-$134,000	$66,000	$46,000	$66,000	$46,000	$66,000	$66,000	$222,000
IRR	37%							
Multiple	2.3	-2.31						

Initial cost includes training and set up costs, needs upgrade in Years 3 & 5

Payback period – autonomous pest bird management system

At $200,000		At $300,000	
Initial investment	$200,000	Initial investment	$300,000
Average return/year	$60,286	Average return/year	$60,286
Payback period	3.3 years	Payback period	5.0 years

The length of time it will take to recover the initial amount invested in the equipment

To play with the assumptions, if average annual crop losses are $50,000, the innovation might result in $36,000 of savings per year.

At $200,000		At $100,000	
Initial investment	$200,000	Initial investment	$100,000
IRR	2%	IRR	45%
Upgrade costs	$40,000	Upgrade costs	$20,000
Average return/year	$60,286	Average return/year	$60,286
Payback period	6.6 years	Payback period	3.0 years

Floating row covers were shown as an effective method of eliminating crop losses caused by ducks in Baby-leaf lettuce in the final report for VG09188 (Munton 2013). Based on their costings on importing the floating row covers:

$10,000/ha to import 0.8 Flea beetle net + FORM and labour to lay and retrieve $270/ha (from our example above)

For 20 ha of Baby-leaf, the cost of the row cover option $205,400; for 50 ha it is $513,500 and therefore appears the better option based on our assumed savings and costs.

Additional benefits

An autonomous vertebrate pest management system would substantially improve the farm owner's or manager's quality of life by allowing them to sleep easy in the knowledge that their mobile phone will wake them if the system can no longer deal with the pest incursion.

There are substantial environmental and ethical benefits associated with detect and deter systems for managing vertebrate pests which are non-destructive. This particularly applies to protected native species where control options are limited.

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