final report

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A paddock based digital hub for automated cattle monitoring and management

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Executive summary

Using remote watering points as attractants and automatically capturing data on cattle performance has potential to significantly increase the amount of information that is available for cattle management decisions. This information could aid daily planning, marketing and genetic improvement. The most recent example of the use of remote monitoring has been the development of walk-over-weighing. Despite the early proof of concept for walk-over-weighing and a number of research and commercial entities developing these opportunities, there has been no systematic review of the state of the science and how this relates to industry needs.

This project completed a systematic literature review, consulted with producers and - based on the information gained from these two activities - developed an easy to follow industry guide for remote monitoring of cattle using radio-frequency identification and walk-over-weighing. In addition the project also explored if and why there was low adoption of the technology and suggested some issues that might be restricting uptake.

The systematic literature review identified there has been significant research on walk-over-weighing that was started as far back as 1967. The research has demonstrated that it is not only possible to monitor the weights and growth of cattle but also to infer a range of other performance measures. Recent publications have seen the technology used to automatically record date of calving, mothering up, age of puberty and some recent research has shown that there is evidence that it might be possible to record individual oestrus events. Adding new sensors to the weigh platform has revealed their future as integrated digital data gathering hubs acting as automated livestock monitoring systems.

While the producers were enthusiastic about the opportunities the technology could bring, they were generally not happy with gap between the proof of concept and a commercial reality. There were concerns about reliability, price and lack of transparency in the algorithms in off-the-shelf commercial packages that are currently available. There was demand for lower cost do-it-yourself systems that include auto-drafting capabilities and a web platform that allows easy access to both raw and interpreted data to enhance timely decision-making.

It is clear that further consideration needs to be given to the business models for delivering these emerging technologies to industry. The current state of the commercial applications falls into the category of the commercialisation ‘valley of death’ where the investment required to move from proof of concept to a financially viable product has not yet occurred. The refinement of the technology requires further investment, although there are some positive signs that producers may be ready to start to invest. However, this investment will require more choice, better service and a clearly articulated value proposition. Ongoing investment needs to be coordinated to ensure the cattle industry is able to invest in the innovation and in so doing lift the technology out of the ‘valley of death’ and into the open market.

This project has provided some pointers to the issues and direction for automated remote cattle managements systems. Perhaps most importantly it has attempted to provide an easy to use guide to help producers better understand what they need to do to participate in the new innovations. As industry starts to adopt the new remote monitoring technologies, the guide will need to be updated on a regular basis to reflect the new learnings as the early adopter’s shape the new business models.

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1 Background

1.1 Beef production in northern Australia and the use of automated monitoring systems

Approximately half of the Australian cattle population is located within northern Australia where the dominate enterprise is breeding. The average herd sizes of 1,490 cattle and average area farmed of 21,260ha (Martin 2015). However, across the different country types stocking rates are extremely variable - the more extensive areas, such as the Alice Springs, can run one livestock unit (400kg dry cow or steer) to 62 hectares as opposed to the more fertile country, such as in Central Queensland, which can run one livestock unit to 5 hectares (Gleeson *et al.* 2012). Due to the extensive nature of many areas of northern Australia, cattle are routinely only processed twice per year (Bortolussi *et al.* 2005) which means minimal production information is gathered. There is an obvious need for northern beef producers to record production information with greater frequency than has traditionally been the case and the use of technology could play a part in this happening.

For more than 50 years technology has been available to automatically weigh beef cattle in a rangeland setting without any labour requirement. Recent advances in technology are making walk-over-weighing (WoW) more suited to real-world operating environments and generating a new wave of interest from beef producers. Since the mid-2000s WoW has been researched in the northern Australian beef industry for its ability to record information on rangeland cattle. Outputs from WoW include it being used to weigh and draft cattle (Leigo *et al.* 2012); model methane emissions (González *et al.* 2014b); monitor effects of weather on liveweight (González *et al.* 2014a); model liveweight change (Greenwood *et al.* 2016); determine maternal parentage (Menzies *et al.* 2017a); and estimate calving date (Aldridge *et al.* 2016; Menzies *et al.* 2017b). The latter outputs shows that the benefit of WoW is moving beyond just monitoring weight, with WoW units now featuring additional technologies that work in conjunction with scales as a cohesive automated livestock monitoring system.

Despite the strong focus of researchers and some limited industry uptake, there has been no project that has explored the practical requirements linked to the broader benefits of developing watering points as a digital hubs. This report aims to provide a review of the literature and link this to the practical application of WoW in order to develop a set of industry guidelines for the installation of automated livestock monitoring systems. The systematic review of the literature, information on outputs from WoW, hardware and software requirements, how to train cattle, input from early adopters and producer engagement generated from the project, should together assist in engendering confidence in the new technologies.

2 Project objectives

The objective of the project was to gather existing information on the use of WoW as a central platform of an in-paddock 'digital hub' featuring a range of automated monitoring technologies. The work aimed to complete a gap analysis of existing technologies, a review of system outputs, a best practice guide on the installation of automated cattle monitoring, and an assessment of producer opinions on the use of watering points that can act as a digital hub. More specifically the project met the following objectives:

- Using a systematic literature review and stakeholder engagement to determine gaps in existing technologies and offerings
- Review practical aspects to help optimise configuration
- Enhancement of Data Muster tool through working with producers

- Produce an industry guide book on use and applications of WoW and further incorporations such as birthweight, parentage and other data collection
- Extension activities and assessment of impact.

3 Methodology

3.1 Systematic Review

A systematic review of literature pertaining to remote weighing of cattle and its use within rangeland production systems globally was conducted. The databases searched were Scopus, Google Scholar and ScienceDirect. Search terms used included 'walk-through weigh*', 'walk over weigh*', 'remote livestock manage*', 'dynamic weigh*', 'remote weigh*', 'precision livestock manage*', 'automat* weigh*' in conjunction with 'cattle' or 'livestock'. In addition to the scientific literature and due to the fact that a large body of literature exists in rural print media, print articles were also taken from searches using the above search terms with Google. Articles that pertained only to intensive livestock industries such as pigs were excluded although references to dairy cattle were included. Articles referencing sheep production were included but only if they were from extensive production systems. References that were published in a language other than English were excluded.

From the review and through previous project work the research team developed a best practice guide for the implementation of paddock-based automated monitoring and management. The guideline includes information on the necessary components, training cattle to voluntarily cross a WoW to have their weight and identity recorded, yard design, telemetry options, data management and reporting, system maintenance and service providers.

3.2 Evaluating on-ground activities using paddock-based automated digital data collection

While the systematic literature review aimed to provide a structured examination of published material the project team also gathered information from more un-structured on-ground activities. The objective was to pool knowledge and know-how as well as direct industry feedback. Using the CQUniversity Data Muster platform as an example software system, the project team explored opportunities for refined software solutions. The hardware and software evaluation was based on a solid foundation of published material and this enabled the development of a set of guidelines that producers could use to implement a paddock-based digital data capture system.

3.2.1 Ethical Clearance

All animal procedures associated with evaluation of technology directly related to this project were approved by the CQUniversity Animal Ethics Committee (approval number - 20610) and similarly the surveying and input from beef producers was approved by the CQUniversity Human Research Ethics Committee (approval number - H17/04-056).

3.2.2 Consent to Collaborate and Survey of Collaborators

Prior to working with collaborating producers they were given an information sheet on the project and asked to sign an Animal Owner Informed Consent form pertaining to the use of their cattle in the research project. After completing the Animal Owner Informed Consent form and upon arriving at their property to install the WoW collaborators were surveyed on the enterprise and interest in WoW.

4 Results

4.1 Systematic review of paddock based automated monitoring

A major objective of the project was to review all literature on the use of automated paddock-based monitoring, in particular the use of walk-over-weighing within the rangeland beef production but also in the dairy and sheep industries in order to compile a comprehensive review. Below is the review of literature.

4.1.1 The history of paddock based automated digital data capture

The first reported use of an autonomous weighing system was by Martin *et al.* (1967) who measured oscillations in electric current as animals walked across a purpose-built weigh platform. There were many similarities with the objective and the design of their system and those used today such as the platform being of similar dimensions, wanting to record animals as they walk to feed or water, only having one animal on the scale at a time, the use of a race and spear gates to enable one-directional flow and the need for conditioning of animals for them to walk freely across the platform. The authors stated that the system was able to accurately record weights without disturbing the animals (Martin *et al.* 1967).

In the late 1970s and 1980s the development of walk-over-weighing continued to be researched within both rangeland production systems and the dairy industry. Within the dairy industry, Filby *et al.* (1979) described a system of weighing cattle as they exit a herringbone milking parlour. Their work provides the first description of a method of removing erroneous weights based on a comparison of the recorded weight with the current running average with the weight being accepted if within ±30kg of the running average. Although the installation was powered by mains power and did not including a satisfactory animal identification system, Filby *et al.* (1979) stated that it was able to provide trends in bodyweight of cows throughout lactation and provide a better indication of weight trends than monthly static weighing.

Rangeland WoW systems were researched by a group at the Jornada Experimental Range, New Mexico in the 1980s. The first completely autonomous rangeland system was described by Anderson *et al.* (1980) where they used a complexed set of one-way gates and spacers to encourage cattle to individually-enter a compound and be weighed. An air-operated pneumatic gate would swing in front of the animal as it stepped onto the weigh platform enabling the animal to be stationary for a minimum of 2 to 3 seconds for the weight to be recorded. The cattle had a transponder (14cm x 25cm) inserted behind their shoulder in order to have a unique identity within the transponder interrogated by an antenna whilst on the weigh platform. The researchers suggested that the automatic weighing system "offers a precise, alternative to the investigator when weight change is to be obtained" (Anderson *et al.* 1980).

In the mid-1980s, Adams *et al.* (1987) described an automated range-animal data acquisition system that had been implemented at the USDA Fort Keogh Livestock and Range Research Station, Miles City, Montana. The system included a telemetry component so that information from numerous weigh stations could be accumulated with data being transmitted up to 10km to a central computer through a radio link. The design enabled water consumption to be measured while the animal was being weighed but meant that the animal entered and exited the 'weigh box' through the rear of the scale platform rather than walking over the platform. Although the weigh box was transferrable between grazing sites it required AC power, pressurised water and the fastening to a concrete pad. The authors stated that the system would greatly enhance data collection and improve range-animal research (Adams *et al.* 1987).

In the late 1980s, Anderson and Weeks (1989), published further information on the use of their automatic weighing system. The system now involved an animal negotiating a maze before stepping onto the weigh platform, which would trigger a light beam and in turn close a gate in front of the animal for approximately 11 second for between 4 and 6 weights to be recorded. The work by Anderson and Weeks (1989) discusses a method of comparing the variance between automatic weights and manual weights collected every 28 days by accumulating automatic weights on a weekly basis and deriving a mean weekly weight. The authors stated that automatic weighing had the potential to derive cause and effect relationships more readily that infrequent manual weighing therefore optimising herd and individual animal practices (Anderson and Weeks 1989).

A group of Japanese scientist who examined walk through weighing in the early 1990s found good correlations with static and walk through weights when the animal speed was reasonable but faster walking speed across the platform created greater variation between the two weighing methods. Their study showed that the accuracy (size of deviation from static weighing) of walk-through weighing and precision (size of deviation from the mean walk-through weights) decreased as animal speed increased (Jisheng *et al.* 1991).

During the late 1990s and 2000s there was a large amount of research into WoW with the global dairy industry. This timeframe coincided with the integration of radio frequency identification into animal production with the use of RFID ear tags for individual identification. The types of information that was inferred from the collection of WoW data included change in body weight associated with health problems (Maltz 1997); welfare and restlessness (Pastell *et al.* 2006); physiological status (Alawneh *et al.* 2011); short-term changes in weight (Dickinson *et al.* 2013); and reproductive events such as detection of oestrus (Alawneh *et al.* 2014).

Walk-over-Weighing has been investigated within extensive sheep production since the mid 2000s. A group from with the Cooperative Research Centre for Sheep Industry Innovation was the first to demonstrate that the sequence with which ewes and lambs had their RFID number recorded could be used to assign maternal parentage (Richards and Atkins 2007; Richards *et al.* 2007). The recording of maternal parentage did not, however, involve recording animal weights and the literature is conflicting as to whether sheep weights can be accurately derived from WoW. Brown *et al.* (2014) suggested that weight data derived from WoW did not achieve the desired repeatability and hence that it was not recommended for on-farm decision making. This contrast with the view of Richards *et al.* (2010) who suggested that WoW can be used to calculate growth paths and in turn predict target weights and dates as well as detecting subtle changes in weight well before it is obvious that the animal is losing condition.

In the mid 2000s WoW continued to be researched in the extensive beef industry. Charmley *et al.* (2006) devised one of the first systems using off-the-shelf components and incorporating solar panels to generate the power. Similar to other researchers out of north America whose systems either involved gates closing in front of the animal or the animal entering and exiting through the same entry point ((Martin *et al.* 1967; Anderson *et al.* 1980; Adams *et al.* 1987; Anderson and Weeks 1989) the system devised by Charmley *et al.* (2006) did not involve the animal walking over the scales but rather the weight captured when the animal was stationary. Although the WoW was consistently 10 to 20kg higher than traditional weighing (with some of the discrepancy accounted for as a result of animals urinating or defecating on the way to traditional weighing as well as the WoW weights including consumption of water while being weighed) there was a high correlation between the weighing methods ($R^2 = 0.92$). The authors suggested that WoW provided a simple method of capturing an animals weight using available technology and could be adapted for a number commercial applications (Charmley *et al.* 2006).

Modern WoW systems incorporate many of the features researched over the previous 50 years. These include a race with a weigh platform, RFID reader interfaced to a weigh indicator with the

system powered by solar power with battery backup power. The data accumulated in the system can be stored locally or transmitted to an off-site computer using a telemetry system. Various authors have described accuracies from WoW systems of between 1% (Jisheng *et al.* 1991), 2% (Cveticanin and Wendl 2004) and 5% (Dickinson *et al.* 2013) compared to statically-recorded weights.

4.1.2 The use of walk-over-weighing in rangeland production systems to derive growth paths

Much of the information on WoW within rangeland systems in the last decade has been presented in rural media rather than coming from scientific publications. In 2010, Precision Pastoral Pty Ltd was established to manage the developments from the Remote Livestock Management System (RLMS) which has been used in a number of industry-funded trials. The RMLS has primarily been used for collecting animal weights in extensive production systems without the need for labour or mains power (Ninti One 2016). In addition to recording cattle weights the RMLS can include auto-drafting capability with a reported accuracy of the weighing system of 98% compared to manual yard weighing and a drafting accuracy 96%. It suggested that the auto-drafter could be utilised to segregate sale cattle or animals for supplementation, for weaning or for culling due to poor growth rates or poor reproductive performance (Leigo *et al.* 2012).

The RMLS has been utilised to better time decisions such as timing of supplementation and the sale of animals within a producer demonstration site. Using the weekly liveweight data the addition of a supplement to the steers utilising the system at Richmond in North Queensland (Hegarty *et al.* 2015) was delayed by six weeks until their liveweights had plateaued, which resulted in a saving $5.04 per animal. Similarly, the weight gain information garnered from the system enabled the beef producers to delay the sale of the animals by three months allowing the animals to gain further weight (Hegarty *et al.* 2015).

Other benefits can be achieved from deriving the growth path of cattle in rangeland production systems. The RLMS has been used to identify superior animals for growth so that their genetics can be traced and replicated within a bull breeding herd; to determine when animals are losing weight prior to it being evident via their body condition or through pasture assessment and identifying underperforming animals based on their growth paths so they can removed from the herd and thereby improving animal welfare and increasing labour efficiency (Meat & Livestock Australia 2016).

4.1.3 The use of paddock-based automated monitoring to derive reproductive measures

Rangeland production systems are typically utilised for the breeding of cattle rather than finishing cattle to a particular market. Within these production systems reproductive efficiency is a key profit driver and hence the age at onset of puberty, the inter-calving interval and the total weight of calves in a cows lifetime at key attributes. Walk-over-Weighing has been utilised in a limited number of research projects to accumulate date on these attributes in a labour-saving manner.

Aldridge *et al.* (2017) used a Precision Pastoral Pty Ltd manufactured WoW system to monitor the growth paths of cows from April to June 2013. Of the 162 cows monitored, data from the WoW system enabled correct prediction of the calving date for 96 (59%) of the cows within a 7-day period. The authors suggested that changes to the system would be warranted to improve the reliability including improving the accuracy and repeatability of the weights, improving the read range of the RFID panel reader, improving the time devoted to training the animals and limiting the flow of animals so that the system is one-directional (Aldridge *et al.* 2017).

A WoW system was again utilised by Menzies *et al.* (2017b) to attempt to determine the calving date of rangeland cattle. The system differed from that used by Aldridge *et al.* (2017) in that cattle

entered and exited the water compound through separate speargates and cattle were trained in using the WoW system for a longer period to ensure they were conditioned prior to data collection beginning. Menzies *et al.* (2017b) tested a number of different methods for removing erroneous data as well as algorithms for deriving the calving date. The calving date was observable in the growth paths of 78.3% of cows and an algorithm was able to automatically determine the calving date to within 10 days in 63% of cows.

Similar to the work done within extensive sheep production systems, WoW has been utilised to determine maternal parentage in rangeland beef production. Menzies *et al.* (2017a) used the temporal sequence of RFID readers derived from cows and calves crossing a WoW system and an algorithm utilising the half-weight index to calculate the animal associations. They were able to determine maternal parentage for 97% of cow/calf pairs within 27 days of data collection (Menzies *et al.* 2017a).

Another component of reproductive efficiency that has been researched with the use of WoW is oestrus activity either in pre-pubertal heifers or post-partum cows. A number of the WoW systems currently in use in northern Australia include the ability to capture still images of cattle crossing the WoW platform. Chowdhury *et al.* (2016) devised vision recognition software in order to recognise Kamar™ heat detection devices and be determine whether they had ruptured, which would indicate that the cow is in oestrus. Corbet *et al.* (2018) utilised Kamar™ devices and ultrasonic ovarian assessment to determine the time of oestrus activity and then compared this data with the time between a cow and bull having their identity recorded when crossing a WoW system. This has the potential to autonomously determine the length of time from parturition to first postpartum oestrus event and therefore identify cows with extended anoestrus periods (Corbet *et al.* 2018).

With a large body of research over a number of decades WoW has been able to derive the growth paths of animals in rangeland production systems. The accuracy and precision of WoW systems is between 1 and 5% of traditionally-recorded static weights without incurring the labour component and the weight loss and stress on the animal. There have been many 'spin-off' benefits from WoW including being able to assess pasture condition from growth paths, determining time of supplementation and timing marketing of cattle, determining maternal parentage, date of calving and preliminary work on determining oestrus events. The use of automated livestock monitoring systems offers enormous potential to increase the level of data collection from rangeland production which typically have limited opportunities to gather such information.

4.2 Evaluating on-ground activities using paddock based automated digital data collection

A gap analysis was conducted and compiled as part of the first milestone report from the project. The gap analyses is framed within the context of the current state of paddock-based automated cattle monitoring and identifies opportunities including addressing the challenge of increasing adoption. The project team have used formal and informal consultation methods to determine gaps and opportunities.

4.2.1 Project engagement and consultation

Throughout the project the project team has engaged with the community through methods including speaking opportunities at field days, seminars and workshops; publication of the project activities through print and social media; and engagement with potential collaborators interested in implementing paddock based data capture. Below is a summary of the project team's activities. The project staff have spoken at a number of industry functions, which are documented below. The engagement events have allowed the project team to use formal and informal methods to capture feedback that has contributed to the gap analysis.

Date	Group	Particulars	Numbers
19/04/2017	National Agricultural Technology Institute (INTA), Argentina	Video conference with presentation	2 staff from INTA
18/05/2017	Pastoral Company 1	Demonstration of WoW systems at Belmont Research Station plus meeting to discuss future collaboration	2 Pastoral Company 1 station managers and 1 staff member from head office.
25/05/2017	Pastoral Company 2	A number of presentations by key CQU staff to Pastoral Company 2 staff members	4 Pastoral Company 2 station managers and head office staff.
19/06/2017	Developing Northern Australia Conference, Cairns	Poster presentation by Prof. Dave Swain	
21/06/2017	Adaptation and Diversification Multi-Topic Forum, Middlemount	Presentation to beef producers from the Middlemount, Dysart, Nebo areas	25 beef producers plus staff from commercial companies and government agencies (Fitzroy Basin Association, Capricornia Catchments Inc, Landcare)
11/07/2017	Telecommunications company & CQUniversity presentations and meetings	Presentation to Telecommunications company CEO and numerous other staff who funded the PhD work by Don Menzies on WoW	20 people from Telecommunications company and CQUniversity
21/07/2017	Demonstration of WoW to Professor Luis Felipe Silva of University of Qld	Presentation on tropical pastures and uses of WoW technology to monitor cattle growth.	1 University of Qld researcher
04/09/2017	Presentation to entrepreneurs from Chongqing China on WoW	Demonstration of WoW at CQIRP	2 visitors
14/09/2017	Biosecurity and beef breeding - information day, Ubobo	Presentation to beef producers from the Boyne Valley region	20 beef producers plus staff from government agencies (Queensland Department of Agriculture and Fisheries, Fitzroy Basin Association, Landcare)
30/09/2017	Installation of WoW system at “Berrigurra Station”, Blackwater	Hardware installation and testing and initial training of cattle to use WoW system.	20 students and 3 staff members from Qld Agricultural Training College, Emerald Campus
06/10/2017	AgKnowledge two-day workshop, Charleville	Presentation and demonstration of WoW to	50 beef producers plus students and staff from government agencies and

		beef producers from the Charleville region	private companies (Queensland Department of Agriculture and Fisheries, Qld Agricultural Training Colleges, Telstra, Murweh Shire Council, AgForce Qld)
20/10/2017	Cattlemen's Challenge Field Day, "OK Station", Clermont	Presentation and demonstration of WoW to beef producers from the Clermont region	30 beef producers and staff from government agencies and private companies (Queensland Department of Agriculture and Fisheries, Elders, Westpac Bank)
14/11/17	"Berrigurra Station" field day	Presentation to Sinar Mas Agribusiness & Food, Indonesia on WoW	3 staff from Sinar Mas Agribusiness and Food plus Qld Agricultural Training College and CQUniversity staff
16/11/2017	Young Beef Producers Forum, Roma	Presentation to young beef producers on the use of WoW to derive growth and fertility parameters	150 beef producers and staff from government agencies and private companies (Queensland Department of Agriculture and Fisheries, AustSafe Super, Auctions Plus, Teys Bros., Resource Consulting Services, Meat & Livestock Australia, Westpac Bank)
4/12/2017	National Agricultural Technology Institute (INTA), Argentina	Presentation to INTA staff and interested Argentinian beef producers	Expecting to deliver to presentation to approximately 120 Argentinian beef producers about the benefits of WoW

4.2.2 Project Media Promotion

Media promotion has included publication of the project teams work in both rural press print and digital media as well as dissemination through social media channels such as Twitter and Facebook.

Date	Media Outlet	Particulars	Numbers
08/06/2017	Twitter	Promotion of WoW (including capturing drone footage) to staff from Resource Consulting Services (RCS) & World Wildlife Fund(WWF)	4 RCS, 2 media & 1 WWF

14/06/2017	Twitter	Promotion of the Adaption and Diversification Multi-Topic Forum, Middlemount	Liked and retweeted.
19/06/2017	Twitter	Promotion of Prof. Dave Swains presentation at the Developing Northern Australia Conference	Liked and retweeted
21/6/2017	Twitter	Images published from the presentation by Don Menzies at the the Adaption and Diversification Multi-Topic Forum, Middlemount	Liked and retweeted
11/07/2017	Twitter, Channel 7 & WINTV local news	Telstra & CQUniversity presentations and meetings on the research generated from funding the PhD by Don Menzies which included WoW	Broadcast on the regional TV news and tweeted extensively by Telstra and CQUniversity
21/07/2017	Twitter	Presentation to Professor Luis Felipe Silva of University of Qld on tropical pastures and uses of WoW technology to monitor cattle growth.	Liked and retweeted
04/09/2017	Twitter	Demonstration of WoW to entrepreneurs from Chongqing China	Liked and retweeted
03/11/17	Twitter	Presentation on WoW at the Cattlemen's Challenge Field Day, "OK Station", Clermont	Liked and retweeted
16/11/2017	Twitter, Queensland Country Life & Beef Central website	Presentation at the Young Beef Producers Forum, Roma on the use of WoW to optomise beef production.	Published widely throughout Australia in both print and digital mediums.
17/11/2017	Twitter	Presentation to Sinar Mas Agribusiness & Food, Indonesia on WoW at "Berrigurra Station"	Liked and retweeted

20/11/2017	Twitter	Promotion of the enhanced mapping functions being provided by FarmMap 4D and incorporated into the Data Muster platform used by CQUniversity to accumulate and report on WoW data.	Liked and retweeted

4.2.3 Engagement with producers that expressed interest in implementing paddock based automated data capture

Through the promotion of the project within the media and at various speaking engagements the project team has had a considerable amount of interest from beef producers interested in adopting digital data hubs located at watering points. Listed below are pastoral businesses that have contacted the project team, been supplied with information on the cost and benefits of implementing WoW and their current level of involvement.

Location	Type of Enterprise	Level of Involvement
Central Queensland	Backgrounding	Waiting on auto-drafting solution
North Queensland	Breeding & backgrounding	On hold
Central Queensland	Breeding & backgrounding	On hold
Central Queensland	Breeding & backgrounding	Installed on 1st September 2017
Kimberley, WA	Breeding	On hold
Barkly Tablelands, NT	Breeding	Accumulating equipment for installation
North Queensland	Breeding & backgrounding	Waiting on satellite modem telemetry system
North Queensland	Breeding & backgrounding	On hold
Central Queensland	Breeding, backgrounding & finishing	Waiting on funding
Central Queensland	Breeding, backgrounding & finishing	On hold
Central Queensland	Backgrounding & finishing	On hold
Southern Queensland	Backgrounding & finishing	Accumulating equipment for installation
Southern Queensland	Backgrounding & finishing	On hold

At the start of the project it was hoped that a number of producers would be able to provide direct case studies and testimonials. While there has been significant interest in adopting the technologies the importance of combining data capture systems with drafting technology at a reasonable price limited the opportunity to complete the case studies within the time line of this project.

4.3 Gap analysis of existing technologies and offerings

4.3.1 Current Situation

Walk-over-weighing has been commercialised and is being marketed by Tru-Test Pty Ltd within Australia but there is limited information on the accuracy compared to static weighing, the value proposition for implementing WoW and the guidelines for installation.

It is possible for producers to access walk-over-weighing systems which can vary from off-the-shelf hardware with no remote access component or data processing software, to systems that have remote access but no data processing software, and finally to complete system with remote access, automated data processing and a user interface. It is not clear how many producers have implemented walk-over-weighing technology. The general feedback suggests that producers have been accessing a number of systems as part of research projects. Currently there is only one commercial supplier of walk-over-weighing systems. In general the feedback from producers suggested that paddock-based automated monitoring systems showed potential but needed more refinement and better support.

4.3.2 Future State

The implementation guidelines developed as part of this project will provide producers with a single document demonstrating the benefits and steps required to implement WoW.

Compared to mustering and crush-side performance recording, walk-over-weighing has the potential to provide more timely and regular (daily or weekly updates) information on cattle performance. The digital infrastructure that forms the basis of WoW could extend the value and provide a broader range of performance measures. The use of digital hubs that act as automated livestock management systems has a number of both current and potential future uses including:

General Production Information

- Providing paddock inventory and daily roll call
- Providing end of financial year stock on hand
- Providing asset numbers for greater security/surety to finance companies
- Monitoring frequency to watering

Using Livestock to Track the State of the Production System

- Monitoring growth paths to time turnoff and/or supplementation
- Forecasting future turnoff numbers or dates based on existing growth rates
- Linking growth rates with remote sensing of pasture conditions

Providing More Accurate and Cost Effective Information for Genetic Evaluation in the Seedstock Sector

- Minimising the labour component and financial cost of deriving:
    - maternal parentage.
    - calving date
- Using maternal parentage and calving date to generated pedigree and Days to Calving EBVs

Enabling Commercial Producers to Identify and Select their Most Elite Females

- Determining maternal parentage and calving interval.

- Assessing breeders on kilograms weaned per cow.

4.3.3 Increasing Adoption

To increase adoption the following strategies need to be followed:

Greater dissemination of the benefits of WoW

- Dissemination of scientific and commercial results in industry publications such as rural press, websites, radio and TV interviews.
- Greater dissemination of scientific results in journal publications that demonstrate the technology and science is valid.

Greater knowledge of what is required to implement WoW

- Simple guides on the equipment required, the set-up, installation, the training of cattle and the cost of implementing. In addition, providing case studies to validate the information.
- Dissemination of industry contacts such as the companies providing complete systems, individual equipment suppliers, service providers and research organisations.

Field sites for hands-on demonstrations

- Field days at research stations, collaborator properties, new adopters etc

4.3.4 Next Actions/Proposals

There is a requirement to accumulate all research on the use of WoW with the livestock industry (sheep, dairy & beef) within a systematic review. Walk-over-Weighing technology was first researched in the late 1970s within the extensive beef production systems but since then most of the research output has been from the dairy industry. A systematic review of all research related to WoW within the beef, sheep and dairy industries has provided a synopsis of the technology and its uses (see earlier section on the systematic review).

Summarise data on accuracy of WoW

A potential impediment to the adoption of WoW is the perception that it will not be as accurate as recording static weights. The accuracy of WoW data is effected by numerous factors including the length of the weigh platform, the speed with which animals cross, the methods used to clean the data, the temperament of the cattle, etc. All data on the accuracy of different WoW systems needs to be accumulated as well as statistical analysis of previously unpublished WoW data compared to periodic static weights.

Discuss limitations and benefits of WoW

Northern Australia is typified by extensive properties with poor communication infrastructure, with distinct wet and dry seasons and properties that only process cattle irregularly (perhaps twice a year). The perception is that WoW won't work due to surface water, lack of ruggedness of the equipment and the inability to operate remotely. Perceived benefits are the reduction in labour and cost to collect regular management information without the loss of condition on the cattle.

While there needs to be more work done to better understand how cattle interact with technology that is located at watering points, there is a growing body of knowledge to show accessing water via spear gates and digital infrastructure is not just impacted by standing water. Time of year, shade,

animal history, feed availability, compound design and paddock configuration can all have both positive and negative impact. More refined management guidelines require a more systematic approach to better understand how management strategies can be used to optimise watering points as digital data collection points.

The practical guide that has been developed as part of this project aims to provide beef producers with a document that highlights the advantages of WoW but also discusses the limitations. Based on experience and feedback the guide aims to provide advice on equipment options, costs, installation and livestock training, as well as providing a case study to show how the systems are being used. The guide also provides a list of contacts of the key people that have been researching and delivering WoW systems. The practical guide aims to increase adoption of WoW by all sectors of the northern beef industry (see appendix 9.1). It is recognised that as adoption rates increase and more feedback is available that the practical guide will need to be updated.

4.4 Software development: a case study using the Data Muster platform

The Data Muster software application has been developed by CQUniversity as a data integration software platform that includes paddock based data collection. The Data Muster system provides cloud-based computing for researchers to access data. The platform also integrates paddock-based micro-processor capability via a Raspberry Pi[1] platform. As part of the ongoing CQUniversity development that falls outside of this project, a number of modifications have been incorporated to the platform. The software developments have been used to engage with producers to provide an indication of the practical developments that will enhance the use of digital hubs at watering points. Automated data capture systems including the integration of user-authenticated logins for producers so that they can refer to their own property data from the digital hubs enables easy access to feedback on cattle performance.

The raw data from the walk-over-weigh systems includes erroneous records. As cattle access water they can cross the WoW system together resulting in shared weights. Off the shelf data collection systems allows producers to download the data but it is difficult to apply robust data cleaning. Producers expressed a desire for weekly averaging but they also wanted to know how the data was being cleaned and be able to access the raw data so they could check the quality of the data. The Data Muster software has a weekly averaging algorithm that removes outliers but also allows producers to set what level of variance they are happy to accept and the number of records that are required to derive a weekly average weight. Producers also wanted to be able to easily see changes in individual animal weights over time but also to be able group cattle based on different classes e.g. age, sex, paddock or production group. Building confidence and delivering a practical system requires software that can removes erroneous data, calculates the weight profile for the mob and presents the information in an easily-interpreted format.

Producers also expressed a desire to see paddock-based digital data that could easily be integrated with other data flows. The Data Muster platform has been developed to link into the FarmMap 4D application with project staff able to map the property and include reference points such as fences, watering points, cattleyards, etc. All property, paddock and animal information in securely stored in a database structure, which is then accessed when a user is authenticated. This integration and sharing of data allows producers to get the most value from the remote automated data capture systems located at watering points.

[1] The Raspberry Pi platform is a small cheap linux based micro-processor that can receive multiple sensor inputs. It is also able to connect to a range of networks including 3G, local WiFi, LoraWan and Iridium satellites. The unit can process, store and transfer data to servers as well as provide actuation for auto-drafting.

While there has been a strong focus on walk-over-weighing, there are a number of other opportunities that can be linked to automatically recording the date and time an animal's radio-frequency identification tag is read when it goes to water. Other software applications that have been written for the Data Muster application includes a roll call function, generation of calving dates and maternal parentage and the detection of postpartum oestrus events. The Roll Call function is regularly used when a new mob of cattle is being trained to use a digital hub that includes spear gates to control movement on and off water. The roll call determines the frequency and the number of animals that have visited water including the identity of the individual cattle. The roll call application in Data Muster enables the system to identify animals that have not been recorded in the previous 72 hours (this time period can be customised) as well as generating the frequency of visits. Producers do not want to rely on accessing cloud-based software to access critical information - they want an alert and ideally via a mobile phone. The Data Muster platform integrates the option for mobile phone alerts.

The generation of the calving date and maternal parentage from RFID tags and WoW has been validated in previous project work (Menzies *et al.* 2017a; Menzies *et al.* 2017b) and provides a valuable addition to weight information. The calving date calculation requires cows to have the growth path calculated from just prior to the calving period until after the last cow calves. Software such as Data Muster could run weekly checks to determine the data of calving and provide the owner/manager with calving dates based on the weight change associated with parturition. Similarly, the generation of maternal parentage requires calves to have NLIS tags applied at branding and cows and calves recorded for approximately 30 days. The mothering up algorithm uses association patterns of cattle as they access water to identify the cow calf pairs. The published mothering up and date of calving algorithm can be integrated into Data Muster, however, these algorithms have been validated on small numbers of cattle they need to be tested across a larger number of properties. In particular it is not clear the extent to which rainfall events can impact the accuracy of the algorithms particularly when cattle are accessing drinking water in other parts of the paddock. Producers interested in using water points as data hubs were keen to test the hardware to find out how best to deploy the system and also to determine whether there were management options that could overcome some of the issues e.g. adding supplements as an additional attractant.

Preliminary work has been completed using the sequence with which cows and bulls are recorded when crossing a WoW system to infer oestrus events in postpartum cows (Corbet *et al.* 2018). This technique shows enormous promise in identifying cows that have extended post-partum anoestrus intervals, which is a major cause of reproductive loss in northern Australia and under genetic control. Currently a journal article detailing these findings is under peer review and the algorithm hasn't been incorporated into the Data Muster software. However by using the intervals between cows and bulls during mating (or year round for properties who are practicing year-round mating) could be used to detect when cows are cycling and the time period from calving to conception.

The software solutions for remote paddock based data capture require an extended data ecosystem that is built around an internet of things (IoT). Currently the extended software includes the transfer of data and information from the paddock. The in-paddock software solutions being developed as part of a distributed set of micro-processors allows data transfer in low bandwidth settings. The Data Muster platform integrates a number of transmission methods including 3G/4G, UHF radio and satellite communication. Recent expansion of the mobile networks under the 5G LTE IoT platform will form part of an expanded solution for the Data Muster platform. The in-paddock processing to deliver smaller data packets for satellite modem communication is currently being tested and will installed on a remote collaborators property in north Queensland in the coming months.

The two-way communication infrastructure allows producers to remotely deploy auto-drafting schedules. The software that controls the drafting gates is being tested and will be installed on collaborators properties early in 2018.

The Data Muster platform provides a flexible cloud-based software application that has been used to explore how refined algorithms and user interfaces can be developed to extend the value of paddock-based digital data infrastructure.

4.5 A cattle industry guide to setting up and using paddock based watering points for automated cattle monitoring

The Industry Guide for walk-over-weighing was compiled to provide a summary of the state of knowledge and practical assistance in setting up paddock based automated livestock monitoring systems (see appendix 9.1). It pulls together information on the components of WoW, training of cattle, yard design, data management and reporting, telemetry options, system maintenance and current service providers. Before this guide is made available to producers it will need some refinements and updates. In particular working with other industry and research providers of walk-over-weighing systems to ensure they are happy for their contact details to be included in the brochure.

5 Discussion

5.1 Insight and practical implications

The systematic review provides a structured assessment of the literature and provides an overview of the full extent of research work that has been conducted on in paddock individual animal data collection systems, with a particular focus on walk-over-weighing. The review provides the first overview and synthesis of the scientific literature and provides a detailed assessment of research that has been conducted on walk-over-weighing. The review also provides an insight into areas such as removing erroneous data, methods of decreasing speed of animals crossing the walk-over-weighing platforms and additional information that can be derived from a digital hub that is located at a watering point. The review can now be modified into a journal manuscript for publication and dissemination to the scientific community.

The project activities have included industry engagement which has resulted in increased interest and awareness of the potential of automated paddock-based data capture. Project staff have been involved in numerous speaking engagements and this has raised interest from producers that want to develop automated management. The project team is progressing installations and planning for future installations on a number of producer properties. One of current issues is for producers to be able to easily access equipment at a price point that they feel meets their expectations associated with the risks of implementing a new technology solution. The ability to easily access the data from walk-over-weighing systems as well as trust in the information derived from the data processing algorithms was raised as an impediment to adoption. Developing more open, transparent and easy access to data will help adoption.

5.2 Additional research and project improvements

The emergence of paddock-based digital data hubs is a relatively new innovation. It is clear that the current knowledge base is very general and producers have lots of questions related to the specific requirements for their own set of commercial needs. More work is required to refine the advice and knowledge that will lift adoption of what all producers agreed is a much needed technology solution. In particular information related to the installation of the systems, training of cattle, both more and

more refined algorithms, increased sensors that can deliver better measures and increased automation.

Due to producers having specific needs, the time available in the project and the requirement that producers would put in their investment for equipment, the project failed to deliver a set of meaningful case studies. Most producers indicated that they needed auto-drafting as well as walk-over-weighing. They liked the lower cost of a DIY solution but as they understood how the system worked they realised that there is currently no DIY auto-drafting unit available and this slowed down participation in the case studies. The cost of a fully integrated customised walk-over-weighing and auto-drafting unit is too much for many producers that want to explore the opportunities for a paddock-based digital data hub. While the project is working to help these producers, there needs to be greater choice and a number of price points to enable producers to select an option that meets their price and functional needs. CQUniversity is working with hardware manufacturers to address this gap in the market.

5.3 Extension messages

One of the key goals of this project was to deliver a set of guidelines that producers could use to help guide them through the process of establishing remote automated cattle monitoring. These industry guidelines form part of this report. They may need to be refined before they can be formally used.

6 Conclusions/recommendations

This project has shown that automated monitoring of cattle at watering points has had significant amount of research. However, despite the detailed research there needs to be further work to increase adoption. Producers are very interested in using the technology but there is a lack of choice of in technologies and very little information about the application of the technology. This project has provided an important starting point in firstly raising awareness with producers, synthesising the research and expert knowledge via a practical guide and exploring the range of potential industry applications that can be derived from automated monitoring. There are no simple solutions to addressing what is recognised as the commercialisation ‘valley of death’ (see fig 1).

The research shows that paddock-based automated cattle monitoring has achieved proof of concept and there is increasing evidence of successful products emerging. However, more work is need to develop the technology as a business solution to achieve commercial success for all stages in the industry (suppliers of the equipment and producers). It is likely that there will need to be further investment in focussed research to refine the industry guidelines. In particular there needs to be better developed guidelines for cattle training protocols, paddock and compound design and expectations for visits to water during rain events. In addition developing systems that ensure cattle regularly visit the compound either through training or including additional attractants. Cattle ID is also an issue especially for young calves prior to having a tag fitted and cows that lose their tags. The software offerings that are currently commercially available do not meet industry expectations. While there was a desire expressed for producers to have their data delivered through a single point, they also recognised that algorithms and data delivery methods were still in a development phase and often this work sat in research institutes. The ongoing development of software makes it difficult for producers to use the data from these systems as part of their daily decisions making.

The business model for paddock-based data capture needs to be further refined and there needs to be greater diversity in both price and product from suppliers of walk-over-weighing. There were a number of reports of poor support from researchers and commercial operations. Despite these reports, overall the producers were optimistic and keen to keep working towards establishing a

system that they believe will deliver significant potential benefits from being able to better optimise their daily management practices, through to easier data capture for genetic improvement, and finally through reduced costs.

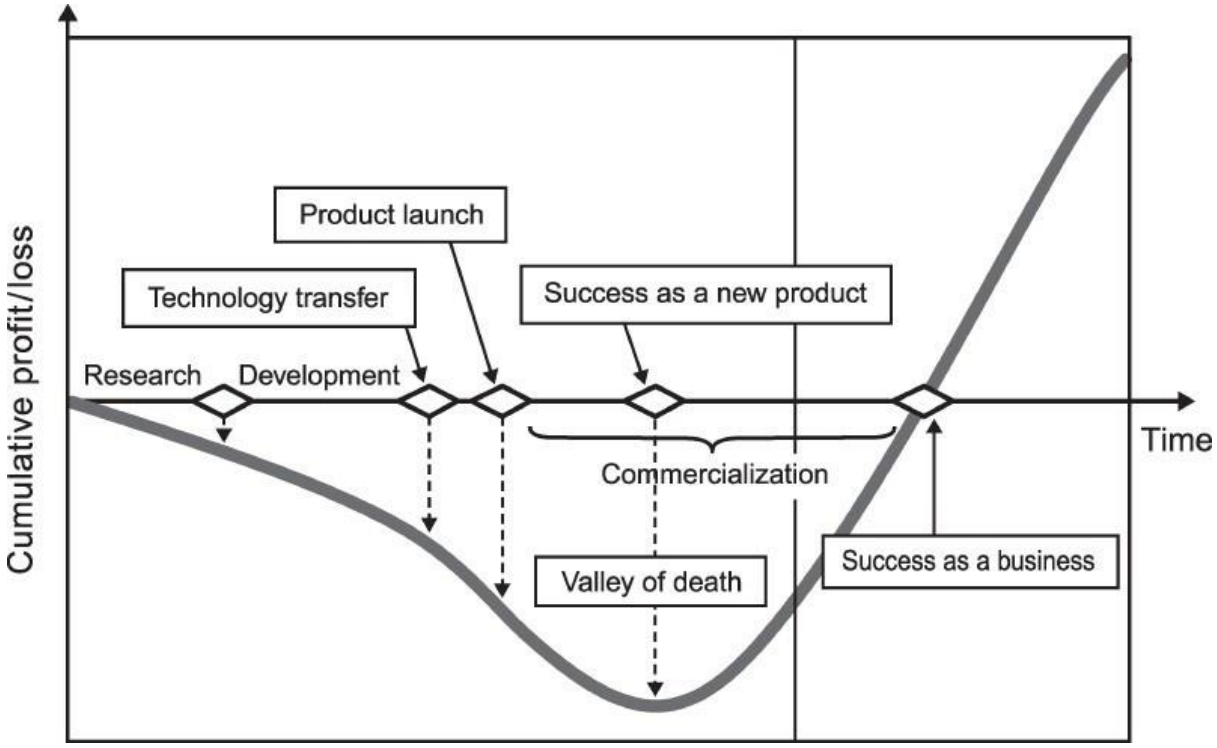

Figure 1 – The time between the development of research innovation and commercial success is referred to as the 'valley of death' http://timkastelle.org/blog/2012/04/three-hidden-factors-that-make-innovation-diffusion-hard/.

The project team points to the technology being framed around new, emerging and potentially disruptive business models. With this in mind there will likely need to be ongoing research support to explore these new ways of doing business.

7 Key messages

While this project did not conduct an economic assessment, the interactions with producers indicated that there was widespread acknowledgement that paddock-based automated data capture and management systems would yield significant benefits. The data and the automated management needs to be considered by all involved in the development and use of these systems as creating new business models.

Researchers need to progress towards a more systematic set of experiments that breaks the big problems down and works closely with industry to develop more refined knowledge about all aspects associated with using water points to remotely monitor cattle. The research has progressed from a proof of concept to a refinement agenda.

There needs to be greater choice and much better support from the suppliers of the technology (hardware and software) that will underpin the uptake of the new technologies. It is clear that walk-

over-weighing has been the catalyst for the technology development, however, future value will be derived from a much broader range of sensor platforms coming together as an automated livestock monitoring system, that can provide a broader range of information on cattle performance.

Currently the business case for these automated livestock monitoring systems can be considered as being in the 'valley of death' where returns are not covering the investment. With current interest in the technologies this is likely to change, however, stakeholders in these technologies need to be aware that further investment may be needed to keep moving the technology forward to a point that it meets the industry expectations.

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