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On property benefits of Precision Livestock Management

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Abstract

Precision livestock management technologies (PLMTs) provide opportunities to increase the efficiency of production in extensive beef production systems. While these technologies have the potential to improve profits, there is a lack of knowledge on how this may be achieved. This project surveyed five case study properties located across northern Australia to explore how five emerging technologies might provide an economic benefit. The technologies included: e-Preg, Walk-over-weighing and auto-drafting, coarse-resolution location cattle tracking, fine-location cattle behaviour and tracking, and automated pasture assessment.

The economic benefits were assessed using a subjective methodology to estimate the production and cost saving benefits. The economic modelling approach used inputs of the estimated benefits as assessed by project team members and the managers of the case-study properties. The distribution profile for each technology provided data that could be used to estimate the risk of an economic return for a given technology.

The results were used to identify opportunities and challenges for PLM technologies that provided the greatest potential economic benefit to individual case study properties. All of the technologies showed potential benefits on at least one property; however, the potential costs of the technologies were shown to restrict the economic value.

Executive summary

This project addresses the lack of connection between the assumed economic drivers of precision livestock management and the technology solutions within the northern beef industry. There have been a growing number of developments in precision livestock management technologies in the last 5 years. These developments have created a technology push for the northern beef industry. Identifying beef industry economic drivers should create a signal for technology developers helping to shift from a technology push to a technology pull. This project used an economic modelling approach to understand how emerging precision livestock management technologies might enhance the profitability of northern beef production systems.

The objectives of this project were to:

1. Analyse and rank the economic benefits for promising precision livestock management (PLM) technology applications on five beef properties in northern Australia.
2. Develop recommendations for a three-year implementation and evaluation plan for the most promising technologies on each of the five case study properties.
3. Document recommendations for priority PLM R&D that could be undertaken in conjunction with the on-property demonstrations.

The project considered five emerging PLM technologies:

1. Electronic pregnancy scanning
2. Walk-over-weighing and auto-drafting
3. Coarse-resolution cattle location devices (greater than 50 m accuracy e.g. for finding cattle)
4. Fine-resolution cattle location devices (less than 10 m accuracy e.g. for behavioural classification)
5. Automated pasture sensing (e.g. remote sensing)

Using a subjective assessment method that was linked to an economic model, probability distributions of the potential economic benefits for each technology on each property were derived. The estimate of the extent of a benefit included input from the property manager and three project team members. The in-depth interviews provided a framework to not only identify the benefits but to also discuss the extent of the benefit. The discussion explored whether the estimated benefits were justifiable in the context of the available research literature. In most cases the benefits were shown to represent a more progressive approach to the potential future operation of the case-study business.

All technologies were estimated to provide some benefits but not all technologies did so on all properties. The estimated benefit-cost ratio suggest that the cost of implementing technologies such as coarse-resolution location devices outweighs the benefits from either increased production or reduced operating costs.

The results of the in-depth interviews that were used to identify the benefits suggested that perceived benefits were linked to the focus of the manager and the direction of the business. For example, a producer that was very focused on improving pasture utilisation had a much better idea of potential benefits for automated pasture assessment than for electronic pregnancy scanning. Hence, PLM technologies need to be considered as part of a diversified set of end-user needs.

Not all technologies were likely to be economically viable on all case study properties. Walk-over-weighing was identified as having a range of benefits, with a focus on using the information to better manage growing cattle. The opportunity to use continuous weight data to enable better forward marketing needs further work. Mustering predefined groups of cattle from a larger mob has potential but the value of this application needs to be further defined. The effectiveness of walk-over-weighing and auto-drafting in situations where it is difficult to control watering points remains highly problematic.

The project team and managers found it most difficult to identify benefits for the e-Preg technology. The consensus was that e-Preg didn't provide significant additional benefits over existing methods i.e. it wasn't cheaper, quicker or more accurate. However, the opportunity for an unskilled person to use the technology was seen as a potential benefit. The accuracy and value of an unskilled person pregnancy testing using e-Preg needs further work.

The coarse-location devices showed benefits for reducing the cost of helicopter mustering and to improve paddock clean outs. The major challenge for coarse-location devices is the cost to deploy the technology at the farm scale. Testing the benefits for improving mustering efficiency needs to be investigated further to identify whether there is potential for an economic benefit.

All of the producers felt there should be some benefits from automated pasture assessment, especially for tactical pasture management decisions (i.e. stocking rates). One manager had a strong focus on pasture management and was most able to identify direct benefits of automated pasture assessment. Given the relatively cheap cost of the technology and therefore the potential to derive large benefit-cost ratios, it is likely that remote sensing has good economic potential. The specificity of the remote sensing information needs to be clearly identified in relation to the practical application of the technology by producers.

A number of potential benefits were identified using behavioural information derived from the fine-resolution location monitoring devices. In particular the opportunity to identify non-working bulls and reduce the bull-to-cow ratio. Given there is no commercially available device; further work is required to refine the benefits from collating behavioural information.

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1. Background

Precision livestock management (PLM) refers to new technologies and applications with potential to improve productivity, price received, labour and/or cost efficiency through enhanced measurement, monitoring, or management of animals and/or pasture. A report titled "The business case for investment in Precision Livestock Management (PLM) technologies and applications" (B.NBP.0597) sought to inform future RD&E investment in this area. While the economic study was comprehensive, no clear investment area or technology applications could be confidently identified. Difficulties predicting and defining how various emerging technologies could be applied and the lack of empirical, property-level data on which to base assumptions about technology costs and production responses all contributed to the inconclusive outcomes.

This project worked with commercial beef producers to identify how PLM technologies might be applied at the paddock level to produce significant benefits, aiming to identify potential benefits that could increase profits (increase operating margin by at least 15%).

2. Project objectives

1. Analysed and ranked the economic benefits and feasibility of promising PLM technology applications for five northern beef case-study properties.
2. Developed a detailed implementation plan, project schedule and budget required to install, demonstrate, measure and analyse the productivity and economic benefits of candidate technology applications at the paddock scale for five northern beef case-study properties over three years.
3. Documented priority R&D opportunities and estimated budgets that could be undertaken in conjunction with the Phase 2 on-property demonstrations.

2.1 Overview of six Emerging Precision Livestock Management Technologies

Non-invasive sensor-based pregnancy detection (e-Preg)

Introduction (what is the technology)

The e-Preg pregnancy-testing device developed by Heard Systems is able to pregnancy test a cow using a non-intrusive sensor that can be operated by an unskilled operator. The e-Preg contrasts with the current method of pregnancy testing, rectal palpation and ultrasound scanning, which require significant training and ongoing practice to accurately assess the pregnancy status of a cow. A veterinarian or a trained operator usually undertakes both current

methods whereas the e-Preg system aims to be used by relatively unskilled operators.

How does it work?

The e-Preg system works by detecting the presence of the foetal heartbeat using electrocardiograph (ECG) and audio signals. These sensors produce data, which are subjected to pre-processing and filtering, algorithms are used to determine the presence or absence of the foetus. The handheld sensor (Figure 1) is pressed against the flank of a cow and held in place for a period of time (Fig. 2). The speed at which the unit can be operated is 30 - 60 s per beast, which is slower than current methods (rectal palpation and ultrasound scanning). Animals that are pregnant are faster to scan than those that are not. The developer has suggested that this time will be reduced, as algorithms are refined.



Figure 1 - The handheld e-Preg sensor developed by Heard Systems



Figure 2 - The e-Preg system in operation

What data does it provide?

The current e-Preg sensor provides an indication of pregnancy status with the developer indicating that an accuracy of greater than 90% can be achieved. The developer intends to pursue technology to enable foetal ageing.

How can producers use this?

The application of the e-Preg device can be used where skilled pregnancy testers are not readily available. There is also a suggestion that the e-Preg would allow opportunistic pregnancy testing in situations where it is currently deemed unfeasible, including scanning heifers brought on to the property that are considered non-pregnant or heifers being sold in small batches into markets where pregnancy attracts large penalties.

Cost and current stage of development?

The e-Preg system will cost \$1,500-\$2,000 for the hand-held unit and users will purchase credits for approximately \$2 per test. The objective is to provide a cheap, convenient and reliable method of pregnancy detection that can be used with minimal training and experience. The business model is designed to allow both large and small-scale properties to own at least one unit and use it as needed. An ultrasound device would cost around \$15,000 by comparison and require training and ongoing practice. The e-Preg system is expected to be available within the next 12 months when the hardware and software have been completed.

Walk-over-weigh (Remote autonomous animal productivity monitoring)***Introduction (what is the technology)***

Walk-over-weighing (WoW) technology for the beef industry has been in development for many years (Martin *et al.*, 1967). WoW technology is now commercially applied in several livestock sectors including the pork (Slader and Gregory, 1988) and dairy industries (Filby *et al.*, 1979), however these systems are largely deployed under cover and in sheds. One of the key challenges in the development of WoW for extensive livestock industries is the ability for the system to operate in the field under more extreme environmental conditions. These conditions include no access to mains power and limited ability to monitor their operation. While there have been several demonstrations of remote WoW technology in the extensive livestock sector (Figure 3) the system has not been widely adopted in the Northern beef industry. There is currently a significant effort to commercialise remote WoW by the CRC for Remote Economic Participation (CRCREP).



Figure 3 - Producers inspecting a remote WoW system on a station in the Northern Territory (NT)

How does it work?

A basic automated weighing systems consists of a crush, weigh scale, and data logger (Charmley *et al.*, 2006) that is set up so that livestock are forced to use the crush to access an area of interest such as a water trough or supplementary feed (

Figure 4). These systems have been refined so they can record the weekly weight of individual animals as they walk over the weigh platform. These data are integrated to examine the weight and weight change of the herd or mob as a whole, this is known as mob-based WoW (MBWOW) (Brown *et al.*, 2012). To gain an understanding of individual animal performance, radio frequency identification (RFID) tags need to be deployed on each animal and a panel reader located on the crush. This system enables the recording of individual animal weights; however the information remains stored on the data logger. A further development is the integration of a telemetry system, which uploads the information in real time to a user interface (WWW) or office computer. Walk-over-weighing systems can provide a platform for a range of other sensors including frame height sensors and cameras that deliver timed digital still images of the livestock.



Figure 4 - WoW platform showing the different components including: the weigh platform, crush, RFID panel reader and data logger and drafting gate (left). Front entrance to remote WoW system operating on a station in the NT (right). The spear gate prevents animals from returning back over the platform and forces them to use an alternative exit.

What data does it provide?

The basic WoW system provides a weight estimate of the animal each time it walks over the platform. If RFID tags and a tag reading panel are used the weight and weight change of individual animals can be recorded; if not, the mean herd weight and distribution can be derived. It has been recognised that the raw data from WoW systems provide a poor correlation with actual weighed data (from static weights) and filtering techniques have been developed to improve this accuracy (Brown *et al.*, 2012).

How can producers use this information?

The WoW system enables producers to keep track of individual and mob live weight and weight gain. For animals destined for sale this means that market specifications with respect to live-weight can be met. For breeding animals this means that body condition changes can be monitored (assuming the relationship between cow live-weight change and body condition change is known) and interventions considered to meet body condition targets. It has been suggested that the date of calving can be recorded for breeding cows. If calves are subsequently tagged with RFID this means that individual breeder performance can be better assessed.

Cost and current stage of development?

A prototype remote WoW system was developed and tested by the Desert Knowledge CRC (DKCRC) and Precision Pastoral, as part of the CRCREP, is currently undertaking commercialisation. Several systems are currently in use

within research trials across Northern Australia. Systems currently cost approximately \$30,000 for an off-the-shelf kit, which includes an Auto Drafting system.

Remote management of livestock through automated drafting

Introduction (what is the technology)

An auto-drafter (AD) is a race and gate system that enables unsupervised drafting of animals into separate yards or paddocks. Auto-drafting systems have been used for many years as part of stockyards and in dairy systems. However it is only in recent years that these systems have been applied to remote areas for completely unsupervised animal management (Bowen *et al.*, 2009). Auto-drafting systems use RFID tags and readers and algorithms based on some criteria to determine which animals should be drafted which way. An AD system could technically be deployed as a stand-alone system but the only current suppliers of this system (Precision Pastoral) integrate it with their WoW system (Fig. 5).



Figure 5 - Auto-drafting gate on the front of WoW platform. The auto-drafting gate swings towards the viewer allowing animals to be drafted either straight ahead or towards the viewer. This auto-drafter uses compressed air to operate gas struts, which change the gate position.

How does it work?

An auto-draft system consists of a race which cattle move along and an automated gate or series of gates, which open or shut to direct cattle to different yards. The gates can be driven by several means; however, compressed air is most commonly used. The setup of the yards depends on the particular application of the auto-draft system: for cattle drafted for sale a larger holding paddock is required, for cattle targeted for differential supplementation a separate yard with spear gate exit is required (Figure 6). Like WoW systems, auto-drafting system requires cattle to pass through a race; water points are the most commonly used attractant for the cattle.



Figure 6 - This auto-drafter at station in the NT enables cattle to be drafted into one of two sets of yards for differential supplementation.

What data does it provide?

Unlike the other monitoring based technologies auto-drafting systems are designed to implement a management. However a standalone auto-drafting system (with RFID) still provides producers with some information in terms of the individual utilisation of the attractant resource (e.g. water and/or lick), which may assist in making management decisions (e.g. timing and quantity of supplementation).

How can producers use this?

One of the key applications proposed for the auto-drafting system is the autonomous mustering of cattle at market weight. This drafting would include integration with a WoW platform and the development of small holding paddocks however the concept appears feasible. The targeted supplementation of cattle based on their individual weight records has also been proposed and has been demonstrated in sheep (Bowen *et al.*, 2009) and cattle (Fig. 6). Auto-drafting systems could be used to assist in reproduction management with the automated removal of bulls from cow herds enabling tightening of joining periods. It would also be possible to selectively remove feral bulls using the system. The auto-drafting system would allow automated weaning and, where integrated with WoW, could be used to draft animals at different weaning weights. It has also been suggested that auto-drafting systems could be used to rotate animals through different paddocks.

Auto-drafting systems based on RFID of individual animals work by identifying animals as they move through a race using a RFID reader and ear tag in the animals ear. Once the tag is read a database is interrogated to determine which way the animal should be drafted. This drafting system has been demonstrated for applications such as differential supplementation of sheep with relatively high accuracy (97.9%) (Bowen *et al.*, 2009). This system can also identify animals without an RFID tag, such as feral cattle, and these can be drafted into holding yards. Auto-drafting systems based on WoW platforms

have the added benefit of being able to draft animals based on weights, enabling drafting to holding paddocks of animals near market weight or targeted supplementation of animals exhibiting weight loss. Auto-drafting systems could also be used to selectively muster animals based on other criteria developed from other monitoring technologies or previous data records. For example animals identified as showing signs of aberrant behaviours from a tracking system might be selectively contained for physical examination.

Cost and current stage of development?

Currently the only commercially available AD system is integrated as part of Precision Pastoral's WoW system. Several systems are currently in use within research trials across Northern Australia. Walk over weighing/Auto-drafting systems currently cost \$30,000 off the shelf.

Autonomous spatial livestock monitoring – course-resolution real-time tracking

Introduction (what is the technology)

Autonomous Spatial Livestock Monitoring (ASLM) systems have been used for years as a research tool in the animal sciences (Swain *et al.*, 2011). Recently there has been some private sector investment in the development of ASLM systems targeted at commercial deployments (Stassen, 2009; Andrews, 2010). Most research applications have used Global Navigation Satellite System (GNSS) positioning (often GPS) and have been deployed as collars. Many of the commercial systems being developed are based around an ear-tag form factor and are either GNSS (e.g. Sirion and Wandering Shepherd Systems) or radio beacon triangulation (RBT) (e.g. Taggle system). The Taggle system uses RBT positioning to provide an estimate of the location of a tagged animal at a regular time interval. The accuracy of this system is still being developed with positions within a 50 m radius currently achievable (Trotter, 2012). Increased accuracy of the Taggle System is expected with the development of better signal processing and other GNSS based systems are likely to enter the market also with improved accuracy.



Figure 7 - A Taggle system ear tag that periodically emits a radio signal that is received by static towers enabling triangulation of position (above) and a Taggle System receiving antenna on a simple tower (below).

How does it work?

The Taggle system consists of four components; the ear tag, the receiving antennas (Figure 7), a server that processes the data and a data interface. The ear tag emits a radio burst at a programmed interval (usually set at 15 minutes), which is received by the antennas. A minimum of three antennas are strategically located around the property so that the time of flight of the radio signal recorded from each ear-tag enables its position to be calculated by triangulation. The raw signal data from each antenna is sent via mobile or satellite network to the server that processes the data into positional records.

This information is then presented in real-time on a GUI accessed on mobile device or personal computer (PC). Taggle currently have a working relationship with Agtrix who provide this GUI.

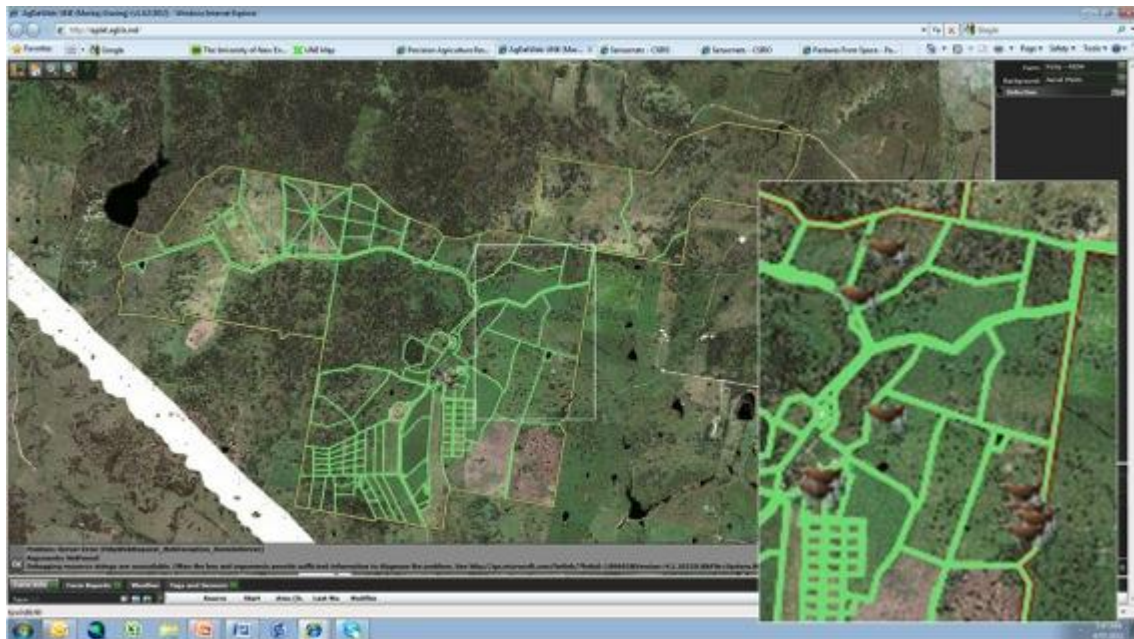


Figure 8 - The Agtrix graphical user interface (and enlarged inset) which provides a platform for delivery of the Taggle system positioning data

What data does it provide?

The Taggle system currently provides real time livestock positioning at a programmable duty cycle. Most of the testing of Taggle tags has used a 15 minute sample interval allowing the tag, in theory, to last up to 3 years based on the batteries stored energy. While the sample interval can be reduced, this will shorten the lifetime of the tag (e.g. 5 minute intervals will allow a tag to run for approximately 12 months). As discussed previously, current trials are reporting an accuracy of around 50 m, however, this is dependent on terrain and antenna tower placement.

How can producers use it?

One of the primary applications of the Taggle system is the simple geo-location of livestock. Knowing where animals are before beginning a mustering event could potentially save significant time and expense, particularly where helicopter mustering is used. Simple geo-location data provides an indication of the security status of livestock potentially preventing theft and loss through straying. The relationship between water and available feed is not necessarily well understood on individual properties and provision of historical landscape utilisation data for cattle as related to water points and the feed base (through satellite imagery) may enable better management.

Many other applications of course-resolution spatial monitoring rely on the ability of this data to be used to model behaviour. Most of the research undertaken so far, exploring the potential for behavioural monitoring from

spatial sensors, has used uncorrected GPS with an accuracy of approximately 2 – 5 m.

Costs and current stage of development

There are currently two deployments of Taggle Systems in a research context including Taggle's own demonstrator in the Tweed Valley and the University of New England's system at Armidale. There are no current fully cattle commercial deployments of a Taggle System. At the time of writing this report Taggle are still developing their ear-tag in collaboration with a large RFID ear tag manufacturer. They are also still refining their base stations and developing solar powered base stations that will enable tower deployment independent of mains electricity. A Taggle system currently costs approximately \$5,000 per tower and \$20 per tag. A four-tower system would cover 100 km² (10 km x 10 km) under ideal conditions. The Taggle system overcomes the battery power challenge of satellite based location technologies. A Taggle ear tag that is programmed to ping every hour will have a life expectancy of at least five years.

Remote autonomous animal behaviour monitoring – fine resolution real-time behaviour and location monitoring

Introduction (what is the technology)

Remote autonomous behavioural monitoring is currently used in several agricultural industries. For example accelerometer and audio sensors are currently used in the dairy industry to predict cow oestrus and health (Saint-Dizier and Chastant-Maillard, 2012). Despite several applications relevant to the beef cattle production being developed there remains little commercial development of products suitable for deployment in a rangeland environment.

How does it work?

There are several potential sensors that could be applied to create an autonomous behavioural monitoring system. These include accelerometers, magnetometers, spatial positioning, pressure sensors, light sensors, audio sensors and proximity logging devices. Some sensors have the potential to provide better information about behaviours of interest than others and all have different energy requirements and other attributes which make them more or less suitable for remote area deployment. CSIRO have made a substantial investment in the development of a new monitoring platform (Figure 9) which integrates several sensing technologies to provide an understanding of the key data streams that would be required to develop an autonomous behavioural monitoring system. High resolution spatial monitoring (GPS) including accelerometers and magnetometers have been successfully used to model the behaviour of livestock (Guo *et al.*, 2009). Proximity sensors have also been proven to effectively identify cow and calf association (Swain *et al.*, 2007) and could provide an estimate of time of conception where bulls and cows are simultaneously monitored.



Figure 9 - An early version of the CSIRO Smart Tag

What data does it provide?

Devices containing GPS provide absolute spatial location data accurate to 2 – 3 m at high frequency (once per second for example). Relative location data, for example the location of one animal in relation to another, will be significantly more accurate. By calculating inter-animal distances, behavioural attributes, where the relationship between animals provides information about their status and health and wellbeing can be determined. For example, behaviour can be used to determine oestrus and age at puberty. Many of the devices also include additional sensors and often tilt sensors or accelerometers, magnetometers and gyroscopes. These sensors can be used to determine the animal's activity and when and where this occurred. Activities that are of interest include walking, ruminating, grazing, resting etc., but the sensors could also monitor for changes in the animal's routine. These changes in behaviour might indicate that the animal has become sick, is about to give birth, does not have water or its feed supply is less than ideal.

How can producers use this?

All of the benefits of the Autonomous spatial livestock monitoring – course resolution real-time tracking system - described previously are also available from this system. In addition, these systems can provide the producer with data for individuals related to aspects of production. It might be possible to use the information as part of a genetic selection index, for example identifying age of puberty. Such systems could identify in advance that the animals are getting short of feed alerting the producer that growth rates or reproductive performance may be impacted.

Cost and current stage of development?

Sirtrack/Lowtek has a number of devices currently available that can be defined as remote autonomous animal monitoring devices. While none of the devices include all of the functionality of the new CSIRO tracking collars/tags

they are commercially available and range in price from \$550 for the proximity logger to \$3,500 for the real-time GPS collar. CSIRO's new behavioural monitoring platform, which has been developed as a research tool, will be available from mid 2013 and cost around \$300 per animal.

Remote sensing of vegetation and biomass

Introduction (what is the technology)

Remote sensing can characterise vegetation in rangeland systems (Hill, 1996). There is currently no commercial vegetation remote sensing system designed to enable producers to manage production output. Pastures From Space (PFS) Program developed for southern grazing systems provides producers with information on green biomass on the ground (Feed-on-offer (FOO)) (Smith *et al.*, 2011) (Figure 10) and estimates of pasture growth rates (PGR) (Hill *et al.*, 2004) using images from the MODIS satellite platform. These products exist within an internet delivery system (Mata *et al.*, 2004) and can be modified to suit farmer requirements.

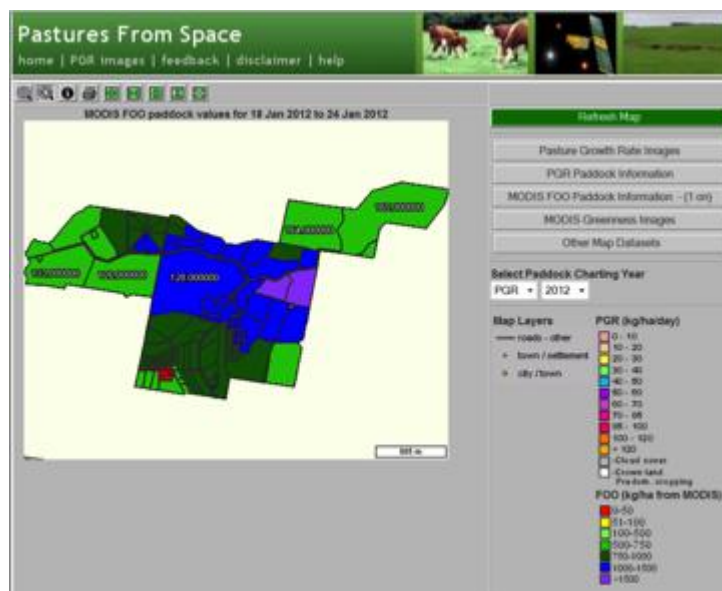


Figure 10 Feed-on-offer (FOO) image as displayed on CSIRO Pastures from Space website

Recently there has been interest in developing a similar system as PFS for the Northern grazing lands and research is currently underway to develop the Forage Assessment Tool – Calculating Head on Pasture (FATCHOP) by the CRC for Spatial Information (CRCSI) (Lamb *et al.*, 2011). The FATCHOP project is investigating the application of RadarSat polarised radar as a means to assess total standing biomass.

Geosys are a private company with a large footprint in Precision Agriculture technology provision in the Northern Hemisphere. This company is developing a similar product to FATCHOP, however complete details are not available at this stage. It is worth noting that Geosys use the same base satellite data

(MODIS) as that employed by the FATCHOP developers. There is also an effort being undertaken by the CRCREP to develop an integrated platform for the display of walk-over-weight (WoW) data and remotely sensed biomass imagery. Prototypes have been developed using FORAGE and Landgates MODIS Greenness Index. However it should be noted that the CRCREP does not intend to develop a vegetation assessment tool using remote sensing.

Proximal biomass sensors are also being tested in the rangeland environment with research currently underway (CSIRO) using Light Detection and Ranging (LiDAR) sensors mounted on vehicles. There is also a growing interest in the potential for Radar satellites to provide estimates of rangeland biomass although the commercial availability of these data, at an acceptable price, remains some way off.

How does it work?

The current PFS and proposed FATCHOP programs work by using Normalised Difference Vegetation Index (NDVI) imagery collected from MODIS satellites. The PFS program provides estimates of green dry biomass (Feed-on-offer (FOO)). The FATCHOP project will be investigating the application of RadarSat polarised radar as a means to assess total standing biomass through direct calibration of NDVI to biomass. Pasture Growth Rate (PGR) is estimated through plant growth modelling which uses the NDVI as an indicator of the Photosynthetically Active Biomass (PAB) available to collect solar radiation (Hill *et al.*, 2004). Whilst the FATCHOP product is unlikely to be based on this exact model, it will use NDVI and seasonal variation in NDVI to provide estimates of rangeland biomass. The initial PGR PFS model developed by Hill *et al.* (2004) for NOAA AVHRR NDVI and since modified for MODIS (Donald *et al.*, 2004) incorporates the capacity within the thermal indices module to adapt to C4 plants. The feature does allow the model to potentially simulate northern Australian annual and perennial natives. Furthermore, the PFS PGR model does have the capacity to adapt to various soil conditions.

What data does it provide?

The purpose of the FATCHOP product was initially to provide end of wet-season biomass estimates enabling Northern Beef producers with limited stocking rate management (i.e. single muster properties) to determine the dry season carrying capacity of the paddocks and calculate appropriate stocking rates for that period. The developers have found interest in within-season biomass estimates and are pursuing the possibility of generating this information in a similar format as is provided to southern graziers through the PFS program (that is FOO and PGR).

How can producers use this?

The FATCHOP project was initiated to develop a system that could provide producers with an estimate of the feed available at the end of the wet season so that stocking rates could be adjusted to match forage supply. There is the potential for this system to provide in-season biomass estimates to enable better management of livestock demand and available feed.

Cost and current stage of development?

The fieldwork for the FATCHOP project is currently underway with development of the algorithms to interpret the remote sensing imagery also started. This project is expected to deliver a working product at the end of 2014. No pricing schedules have been proposed for the FATCHOP product. Subscription costs for the PFS product are available (Table 1) although there should be some discount on this given the property size discrepancy between Southern and Northern properties.

Table 1 - Pastures from Space subscription costs

Pastures From Space Annual Subscription up to 4000Ha	\$363
Pastures From Space Annual Subscription up to 8000Ha	\$605
Pastures From Space Annual Subscription up to 12000Ha	\$847
Pastures From Space Annual Subscription up to 16000Ha	\$1,089
Pastures From Space Annual Subscription > 16000Ha (Initial \$363 + \$242 for each 4000Ha after the first 4000Ha)	
Pastures From Space - Historical Data per Year	\$242

3. Methodology

3.1 Overview of methods

To meet the objective of analysing and ranking promising precision livestock management technologies (PLMTs), the project considered the net benefits of six emerging technologies on five case study properties. The six technologies considered were:

1. Non-invasive sensor-based pregnancy detection (e-Preg).
2. Walk over weighing (WoW)
3. WoW plus Auto-drafting¹
4. Autonomous spatial livestock monitoring – coarse resolution real-time tracking
5. Remote autonomous animal behaviour monitoring – fine resolution real-time behaviour and location
6. Remote sensing of biomass.

The five case study properties were selected on the basis that they represented a diverse range of cattle properties from a range of geographical locations. For all of the case study properties the managers were able to provide reliable baseline production and economic data. These managers

¹ Initially auto-drafting was considered separately to WoW but after discussions with producers these were integrated and considered as one technology.

also had an interest in acquiring better data to enable them to improve their business. All of the managers were enthusiastic but had a healthy scepticism of emerging technology and were therefore focussed on identifying economic benefits. The five properties were located in the Kimberley, Barkly, Alice Springs (one each) plus two properties in Central Queensland.

The net benefits for each of the PLMT's were derived from qualitative data obtained through an in-depth interview of each of the property managers. The interview process initially sought background information. Project members described the technologies and potential applications. The managers were then asked to estimate the benefits of individual PLMT's. These benefits were then assigned to either increased production or reduced costs. The interview process had human ethics approval (CQUniversity ethics committee project number H12-01-008). The interview was semi-formal and the team used the interview process to provide data for the modelling. There was enough flexibility in the discussions to capture the individual focus of each of the managers.

The qualitative estimation of benefits underpinned the economic modelling, which was used to rank the PLM technologies. A subjective assessment of the benefits was adopted because there is no substantive quantitative data available to derive reliable benefit values for the emerging PLM technologies. In the absence of quantitative data the subjective estimates of benefits provided the best option for ranking potential benefits of the precision livestock management PLM technologies. By explicitly acknowledging the subjective nature of the data used in the economic modelling it was possible to incorporate methods to rank the PLM technologies. The specific measures that were used included:

1. Assessment of benefits by both the property managers and project team members.
2. Incorporating inputs of benefits with mid, lower and upper values.
3. Using an interview process to seek justification for a particular benefit estimate.
4. Assessing benefits in relation to measurable performance indicators for both production and costs.

The interview process had the additional benefit of providing the opportunity for the managers to offer alternative benefits that were not immediately obvious to the project team. Some of these benefits were applicable only to individual case studies but some were more generic.

Throughout the report we discuss the assessment of the benefits including the plausibility of the estimates. Although the report provides discussion and justification for benefits estimates the reader should be aware that the data are subjective assessments, which are limited by the knowledge of the team.

3.2 Net benefit function

The economic modelling provided the framework for the interview and the detailed formulation is provided in Appendix 1. The net benefit function describes the change in net present value that could be accrued by the adoption of any given PLM technology. The model considered each property as consisting of two major enterprises: breeding and finishing, as appropriate. Within each of these enterprises there are a series of discrete production outputs e.g. the breeding enterprise comprised calves on the ground with an output that consisted of calves weaned. Similarly the finishing enterprise could have different finishing outputs e.g. live trade, EU etc. Each production unit had a series of outputs (production) and inputs (costs). The project team aimed to collect data on the current inputs and outputs for each discrete production unit. Figure 11 provides an overview of the enterprise details that were considered as part of the assessment process via the semi-structured interviews.

Not all properties had activities in each of the production units. Considering the overall enterprise as a series of discrete units provided the opportunity to map the PLM benefits onto a specific operational part of the business.

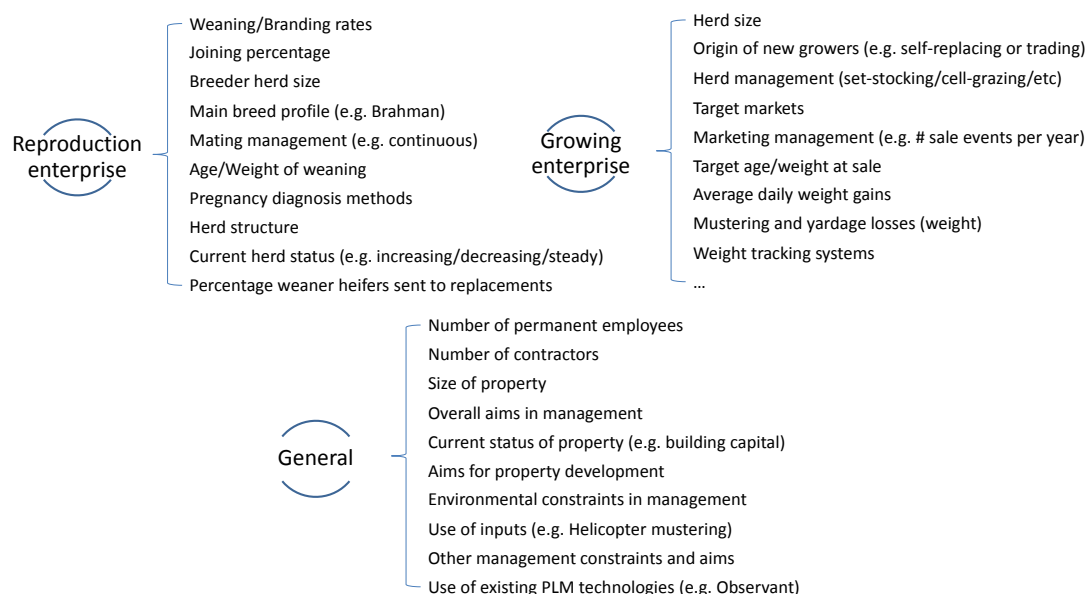


Figure 11 - Outline of enterprise details explored in semi-structured interviews with research participants

3.3 Benefit-cost assessment

To estimate the benefit-cost ratio for each technology, assumptions on the cost of technology were as indicated in Table 2 and include details of the infrastructure requirements such as towers for the coarse location devices.

Table 2 – Assumptions on the cost for the technology for each property that were used to calculate the benefit-cost ratio (fine-resolution location costs are not included as there is currently no technology that is commercially available).

	Property 1	Property 2	Property 3	Property 4	Property 5
WoW					
# units	2	1	3	2	1
Unit cost	\$30,000	\$30,000	\$30,000	\$30,000	\$30,000
Repair probability (x in y years needing repair)	0.2 (1 in 5 years)	0.2 (1 in 5 years)	0.2 (1 in 5 years)	0.2 (1 in 5 years)	0.2 (1 in 5 years)
Repair cost	\$5,000	\$5,000	\$5,000	\$5,000	\$5,000
Other costs	\$0	\$0	\$0	\$0	\$0
ePreg					
# units	1	1	2	2	-
Unit cost	\$5,000	\$5,000	\$5,000	\$5,000	-
# tests @ \$2 per test (max 1000)	1000	1000	1000	1000	-
# tests above 1000 tests (@ \$1.50 per test)	$\sim N(\mu=2,500, \sigma=500)$	$\sim N(\mu=500, \sigma=100)$	$\sim N(\mu=20,000, \sigma=1000)$	$\sim N(\mu=500, \sigma=100)$	-
Other costs	\$0	\$0	\$0	\$0	-
Coarse Location					
# towers	100	-	200	150	3
Tower costs	\$5,000	-	\$5,000	\$5,000	\$5,000
Repair frequency	every 10 years	-	every 10 years	every 10 years	every 10 years
Repair cost	\$1,000	-	\$1,000	\$1,000	\$1,000
# tags	5,000	-	25,000	35,000	1,500
Tag cost	\$20	-	\$20	\$20	\$20
Tag annual losses (avg percent lost)	2.5%	-	2.5%	2.5%	2.5%
Tag replacement timeframe	6 years	-	6 years	6 years	6 years
Pasture sensing					
Total cost	\$10,000	\$10,000	\$10,000	\$10,000	\$10,000

The benefit-cost ratio divides the production or cost saving benefits by the costs of the PLM technologies. A benefit-cost ratio of greater than one represents a net economic benefit.

We consulted the technology developers to provide the costs for the individual PLM technologies. Currently there is no commercially available fine-resolution spatial location technology; therefore we were unable to obtain information on the cost and didn't complete a benefit-cost assessment. The net benefit provides an indication of what the costs profile for fine spatial technology would need to be to ensure a positive benefit-cost ratio.

3.4 Estimating benefits

The benefits that were estimated for the case studies were based on discussions with the property manager and allowed them to identify how they would utilise the technologies within their own enterprise. The project team provided detailed descriptions of the technologies. The technologies were then assessed in the context of the benefits that might accrue for individual production units. The benefits were related to estimates of either increased production or reduced costs. For example, within breeding operations the location-based technologies were assessed on their ability to improve calving percentages. The manager was asked how the benefits might occur and to justify the basis for their estimate of benefits. Notes from the informal interview were written up and used as the basis for the description of the benefits to support the economic modelling.

By using a stochastic modelling approach via a likelihood function, the manager and project team could provide upper, lower and midpoint estimates, which were then used to determine the economic benefits. The full details of the statistical approach can be found in Appendix 1. Throughout the detailed descriptions of the estimated benefits for individual case studies references are made to the range of estimates. When ranges of estimates are discussed they refer to the total range from all of the estimates.

The property managers and each of the project team researchers estimated the benefits and provided justification for their estimates. The technology researchers that estimated the benefits were the core project team members Greg Bishop-Hurley, Mark Trotter and Dave Swain. All three have a background in both technology and livestock production research and all three have been involved in research in northern beef production systems. Greg Bishop-Hurley has worked for ten years in northern Australia and has studied a range of technology issues including virtual fencing, walk-over-weighing, pasture assessment and behavioural classification including reproduction. Mark Trotter has a more southern focus to his livestock research but has also been involved in evaluating remote sensing applications and cattle selection behaviour in northern beef production systems. Dave Swain is based in Rockhampton and has been involved in northern beef research for the last ten years; his work has involved a number of technologies including work on assessing reproductive performance using automated behavioural monitoring

technologies. The stochastic modelling approach required input from a number of individuals. It is recognised that the three researchers do not have detailed practical experience, however, with over thirty years of combined knowledge and research of the potential applications and limitations of technology they were able to provide valuable input into the assessment methods.

4. Results

4.1 Case study descriptions²

Each property manager provided details of their overall operation and business direction. This information provided a setting for assessing the PLM technologies.

Case study one

Overview:

Case study one is located within 2.5 hours driving time of Alice Springs in an East-North-East direction. The property covers 570,000 ha with about 2/3rds of the property in use for breeding or growing cattle. The land is split into 8 main paddocks.

Average stocking rate is 2 LSUs km⁻² although this is reduced when there are repeated poor seasons. Maximum stock numbers are around 5,000 cows and 4,000 growers. Due to previous poor seasons stock numbers are currently approximately 3,000 cows and 1,500 growers. The upper stocking rate is considered to be close to the limit that the property can support.

Case study one is run as a self-replacing operation with seasonal conditions determining the number of cattle that are finished. Santa Gertrudis is the predominant breed although more recently Droughtmaster bulls have been introduced.

Pasture and water management:

Property One is run primarily as a continuously stocked operation with attempts to spell at least one of the eight paddocks each year.

Bore costs are high due to a deep water table and poor success rate with drilling, with approximately 1 in 8 successful. There are currently 20 water points across the property.

Medicators are used on the watering points.

² The use of the terms 'case study' and 'property' are used interchangeably throughout.

Destocking is done based on the pasture available, current herd size, and considerations of possible future weather outcomes. In particular the potential for land degradation/feeding costs in the event of poor seasons weighs heavily on stocking rate decisions.

Breeding:

The breeding enterprise is run on the southern part of the property, which is generally considered to be the less productive country. The growing cattle gradually move north through available paddocks from weaning to turnoff.

Weaner heifers are supplemented with cottonseed and urea for 1-2 months post weaning.

At weaning males and females are initially kept together for a short period. Weaner heifers are 12-18 months old at first joining and the herd is run using continuous mating. The breeding herd runs with 3-4% bulls.

Average annual turnoff is about 3,000 head when the herd is at its target level (approximately 5,000 head of breeders). Weaning rates are estimated to be 75% in 'normal' (good) years.

Growing:

Two main markets are targeted for the sale of steers. Feeder steers account for about 50% of the annual growing herd with the balance going as finished bullocks. In addition to the feeder steers and bullocks the property also sells cull cows and cull heifers.

Generally the manager aims to turn off feeder steers at about 24+ months with an average weight of 380 kg. There is significant variation around this weight target with some animals going at 320 kg and others up around 400 kg.

Bullocks are mustered and sold when conditions allow, often the paddocks are difficult to access due to wet conditions. The bullocks are sold at over 400 kg and the aim is to maximize the weight to achieve a good return. Lack of access to the paddocks means that the bullocks are sold when they can be mustered and this leads to a large range of weights and ages with cattle being sold at anywhere from 2.5 – 7 years old.

Surplus heifers are either sold locally at about 250 – 300 kg and 12 – 18 months of age or spayed and sold. Cull females are normally spayed and vary considerably in weight and age at sale.

Current herd and resource status:

The herd is currently in a period of build-up due to recent good seasons following a prolonged dry period during which breeding herd numbers were reduced to below 1,500 head.

Current technology usage:

The property manager has embraced WoW technology and auto-drafting for the breeding herd. The property is also beginning to use NLIS records combined with phenotype information to identify high-performing cows. These cows form the basis of a nucleus herd that are used to generate replacement cows. NLIS is also being used to record individual steer growth. WoW and Auto-drafting is not in use with the grower herd due to lack of control over watering points in the northern paddocks, however, it would be possible to use it in their feeder steer paddock. Inclusion in the feeder steer paddock would leave only the bullock paddock without the technology.

The property had participated in field calibration for the e-Preg device.

Case study two**Overview:**

Property 2 is a 12,180 ha located near Banana in Central Queensland³. Buffel grass is the main pasture species present. The manager has fenced to soil and vegetation type over concerns that cattle preferentially select Buffel grass over the native pastures. The property is divided into twelve paddocks.

The property manager has recently planted a large patch of leucaena, investing over \$100,000 in the plantation. This is expected to mature over the next 2 years and provide significant improvements in the fattening enterprise. Currently LWGs are around 0.4 kg per day. The manager is optimistic about the returns that the leucaena will provide – on a per-hectare basis it is expected to almost break-even within three years and accumulate approximately 90% of the original investment in each following year. This suggests an average LWG improvement in the order of 100 – 180 grams per day.

The property is run with minimal additional labour input other than itinerant workers. The owner/manager believes it would be possible to nearly run the enterprise on his own, although he might need some additional helicopter usage (estimated at \$20,000).

The property is HGP free which allows the manager to target the EU market. All cattle are weighed and weights recorded whenever they go through the yards.

Future plans include dividing existing paddocks and installing new watering points to more tightly manage mobs.

³ The owners have a second property that they run in conjunction with the main enterprise, however, we have not included this second property in the analysis.

Pasture and water management:

Grazing management involves stocking at carrying capacity. Breeders are split into separate mixed age mobs of between 120 to 300 head with replacements kept separate (away from the breeding herd) until they are 2 years old.

Breeding:

The property is run as a self-replacing breeding/fattening operation currently running 1,800 breeders but usually running 1,500 on average and producing about 1,200 progeny each year (80% branding). Two hundred and fifty to three hundred heifers are kept as breeder replacements with the remainder (300 – 350) being sold as feeder heifers.

Approximately 50 bulls are used (joining at about 3 – 3.5%) with breeding herds on the poorer country and the feeders on the better country. Joining takes place for approximately 6 months of the year starting in December. The manager buys about 8 bulls a year and expects them to last 6 years. The manager pregnancy tests all mated females annually.

Growing:

The 600 steers that are kept for fattening are weaned at between 200 – 250 kg live weights and around 8 – 9 months old (July – September). Currently the feeder market is the target with sale weights for steers/feeder heifers of around 400 kg. Stocking rates are about 2.5 ha per adult equivalent.

Growing cattle are kept in a paddock with easy access to the yards to facilitate access for sale at approximately 2 years old. Mustering takes place 4 times a year and takes approximately 2 hours each time with the manager and a farm hand on motorbikes. Distances are relatively short for mustering so weight loss is thought to be only approximately 20 kg.

Current herd and resource status:

Droughtmaster is the dominant breed but some Charolais bulls have been used to try and improve the LWG of the growing cattle.

Property 2 is currently operating at maximum herd numbers following the recent good seasons.

Current technology usage:

Property 2 uses Stockbook™ by Practical Systems to track average daily live-weight gains, pregnancy status and other production parameters of their herds. This technology uses NLIS ear tags to track individual animals and generate individual, herd, or property statistics for interpretation by the manager. The manager has had some experience of the e-Preg device.

Case study three

Overview:

Property three is located in the Barkly region of the Northern Territory. The property spans 10,000 km². It was purchased approximately 10 years ago in a relatively underdeveloped state. Originally there were 40 bores and turkey nests across the whole property leaving large parts of the landscape unused by station cattle.

Over the last decade the manager has undertaken significant development of the properties infrastructure. The main focus has been the development of water infrastructure. Poly-pipe is being installed at 4 km centres with water tanks/troughs every 4 km to make the maximum distance to water no more than 2 km. By the end of 2012 the manager estimated there was approximately 500 water points operating across the property. Each water point services approximately 200 cattle. The manager has reduced the risk of water delivery failure by ensuring the best possible quality infrastructure with the use of over-pressure release points and high quality trough sealing materials.

Property three is run mainly as a breeding enterprise currently running approximately 50,000 head of which 25,000 are breeders. The herd is predominantly Brahman.

Weaners are not castrated or spayed as they are generally out of the production system before they are three years of age. Mobs of dry stock are kept in a single paddock within their age groups where possible.

The manager is focused on lowering the annual direct costs of production both through lifting production and minimising the use of variable inputs such as labour and helicopters. As a result the property is currently going through a phase of capital investment that aims to increase total production as well as the efficiency of production.

Pasture and water management:

Pasture management is based on a continuous grazing system. Initial attempts to employ a semi-rotational grazing management strategy by turning adjacent waters on and off did not work very well. More recently the property experimented with rotational grazing using fences and regular (6 day) shifts of a mob of approximately 6,500 head, the manager was very happy and felt he had achieved some good production benefits. The manager is interested in extending this trial to operational status once fence and water development of the property is more advanced.

Breeding:

The breeding herd of approximately 25,000 cows currently has a branding rate of 50%, which is of concern to the manager. This is less than previously achieved and the manager is unsure why the branding rate is so low. However he has plans to introduce higher fertility genetics.

Initially bulls were pulled off wet cows after preg-testing. However the manager felt that this disruption affected the milk production so he now keeps the bulls in. He is also looking at early weaning to try to allow the cows time to put on condition and hopefully improve reproduction performance.

Heifers are joined at 14 months with a 20% pregnancy rate. Pregnancy testing is carried out on the majority of the breeding herd using ultrasound. This device requires some skill in use with a good stockman taking two or more days to become proficient. Pregnancy testing results in three main drafts: (1) pregnant with preferred calving date; (2) pregnant but calving outside of the preferred interval, and; (3) empty. Cows that are empty in a second round muster are culled. Fat, but empty, cows in the first round muster are also culled.

The manager is not convinced of the benefits of professional pregnancy testing services: “The professional preg tester was missing 10% of pregnancies – we would send a bunch of cows to Indo [Indonesian live export] as empties and they would come back saying 10% of them were pregnant.”

The manager estimated replacements for the breeding herd at 2,500 each year numbering about half of the annual heifer calf drop.

Growing:

The main market for property three cattle is the Indonesian live export market with expectations of \$500 per head at the farm gate (i.e. net of freight costs).

Current herd and resource status:

It is hoped that both future development and the introduction of new breed lines may reinvigorate the breeding herd and lift branding rates back to around 55%. In addition, future developments are expected to increase the carrying capacity of the property by 30%.

Current technology usage:

The manager has mixed feelings over the use of new technologies on the extensive properties of northern Australia. In the main he was positive about the potential benefits - “If we could do a water run from here [remotely] that would be a real deal”- but is concerned over issues of reliability “If we can’t hit it with a hammer then we can’t fix it! ... [We] backed off on the automatic technologies because we are not convinced it just wouldn’t be a bigger pain”. In particular the manager was concerned over the ability of new technologies to integrate with current production systems – “Our endurance [with technology] is about 30 seconds, if we can’t work it [out] after that we walk away”.

Despite reservations the manager has worked with some remote technologies (e.g. remote water management) and expressed interest in the technologies reviewed in this project.

Case study four

Overview:

Property four is located on the banks of the Ord River north of Kununurra in Western Australia.

The property is a relatively large operation with 20 staff and approximately 680,000 ha with a reasonable level of development. There are 30 paddocks with good laneway development that can be used to move cattle around the property. Smaller paddocks in the better country are used for weaners and fattening.

The herd comprises 18,000 breeders with branding rates at about 68% resulting in up to 13,000 weaners in any given year. All stock are Brahman and NLIS tagged.

Mustering is generally done twice per year for each herd using helicopters, however the fattening herds are mustered up to three times per year with the final muster aimed at 'cleaning out' the paddock. The manager estimates that 1,000 helicopter hours are needed to carry out the musters each year at a cost of about \$400 per hour.

Labour turnover is a significant issue with approximately 40% of staff (6 employees) being turned over each year. The manager's main long-term aim is to increase branding rates and weight gains.

Pasture and water management:

Paddocks are continuously grazed and many have permanent surface water in addition to waters located within a 7 km grazing radius. Water is sourced from bores and the property has a water allocation from the Ord river. The 7 km grazing radius is effectively much less due to the abundance of surface water.

Breeding:

The breeding herd is continuously mated with a joining percentage of 4 – 5% (700 – 900 bulls). First-calf heifers are kept separate from the main breeding herds. Pregnancy diagnosis is undertaken in two stages: Wets and dries are split when they go through the yards at the first round muster. In the second round, wets and dries (from the dry mob) are again split with wets going to the calving mob whilst dries are preg-tested with pregnancy tested empty (PTE) cows going to culls. Generally pregnancy testing is done using farm labour; however, vets are brought in for large lines of testing and/or spaying. Pregnancy testing presents significant labour challenges, as the property needs to train new testers almost every year due to the turnover of employees.

Growing:

The property targets the Indonesian live export market with sale weights limited at a maximum of 350 kg live-weight. Currently weight gains are around 300 g/d annually.

Current herd and resource status:

Herd numbers are currently stable and the property is operating at desired herd levels.

Current technology usage:

The property uses the Tru-Test weight recording system and NLIS tags to record and analyse growth rates, pregnancy and other trends in the herds. Although this provides the manager with detailed information about herd trends and individual animals he is not sure whether it is worth it.

Case study five

Overview:

Property five occupies 16,500 ha south of Emerald in Central Queensland. The property is a trading enterprise with no breeding operation. It is summer rainfall dominant with potentially heavy frosts between April and September. The arrival of frosts signals the end of the pasture-growing season unless unseasonal warm weather follows and there is sufficient soil moisture to support new grass growth.

The property is split into two main country types – the poorer quality range country and the black-soil downs. The range country has been cleared and is intensively used with areas of cell grazing on top of the range that are grazed intensively in the growing season and lightly in the winter. The manager aims to have sufficient good quality pasture to maintain live weights throughout the winter with potential for live weight gain.

The property has a water allocation and crops approximately 400 ha for supplementary feeding in the winter to try to maintain live weight gains. Urea licks are also used throughout the winter.

The manager aims to sell cattle into the feedlot market at about 400 kg. All types of cattle are bought with an aim to maximise profit.

Pasture and water management:

The manager does his own pasture analysis and reporting process informed by an agri-business consultant. Water runs are done 2-3 times a week, which allows him time to see what is happening in the paddock: “I see myself definitely as a grass farmer”, “we have our own rangelands and pasture reporting system” and “I can physically go out and see the differences”. The manager always does the pasture assessments but uses the consulting company to get an idea of what’s happening with the soils etc. The manager

has not noticed any issues over loss of forage production from the buffel pasture on the property but has seen some increase in the diversity of pasture. Overall the manager demonstrated that he was focussed on the health and productivity of his pasture forage base.

Growing:

The manager estimated (based on annual measures) that LWG's are around 1 kg per day in the growing season and up to 0.5 kg per day in the winter. The overall average daily LWG is currently at 0.6 kg per day across the whole year.

Water is readily available in all paddocks with distances to any given water point being no greater than 1 km.

Current herd and resource status:

The property is run as a cattle-trading operation stocking around 5,500 – 6,500 head plus 1,000 head in a Wagyu fattening operation. Some paddocks are set-stocked; however there are 40 cells allowing the manager to cell-graze part of the range country. The manager estimates only 10% of the area is cell-grazed, with 10% rotationally grazed and the remainder continuously grazed. About 60% of the 'range country' is utilised.

Current technology usage:

The property currently utilises an Observant telemetry system to monitor waters. Although it is seen as a 'high maintenance' system, the manager estimates it provides cost savings. A camera is also installed at the troughs, which can link to the Internet and provide images of cattle for prospective buyers. All cattle are NLIS tagged.

4.2 Case study summaries

For comparative purposes and to provide an overview of the main data, Tables 3 – 6 provide the key data that informed the modelling. Table 3 provides overview information and Tables 4 and 5 provide the output for different stages of production.

Table 3 – General property information to provide a relative overview of the five case study properties (the data was derived from the interview with the property manager and has not been independently verified)

	Property				
	1	2	3	4	5
Location	Alice Springs	Banana Central Queensland	Barkly Tablelands	Kununurra	Central Queensland
Annual Rainfall (mm)	280	565	792	820	600
Producers Estimated Average dry season (mth)	7	6	8	7	6
Size (ha)	570,000	12,180	1,087,200	680,000	16,500
Av. Stocking rate (AE ⁴ per ha)	0.016	0.38	0.05	0.066	0.4
Average Number of AE Carried	9,000	3,800	55,000	45,000	5,625
Producer Estimate of Potential Carrying Capacity (AE's)	10,000	3,800	71,500	60,000	5,625
Number of breeders	5,000	1,500	21,000	18,000	
Average culling age for breeders	8-10	8	10	10	
Number of bulls	200	50	840	810	
Bull Percentage	4	2.5	4	4.5	
Herd mortality (%)	3	1.8	5	7.5	2.5
Number of paddocks:	8	14	38	45	18 set stocked, 8 rotational & 40 cells
Average size main paddocks (ha)	13,000	1,200	28,610	15,111	Set stocked = 400 to 1600 rotational = 200 and cells = 40
Number of permanent water points	20	17	458	100	2/3 per paddock
Other water points	10	1	35	45	
AE's/permanent water point (AE's)	300	200	120	450	

⁴ AE is adult equivalent and corresponds to a 400 kg dry cow

Table 4 – Production outputs to provide a relative view of the production profile of the five case study properties (the data was derived from the interview with the property manager and was not independently verified)

	Property				
	1	2	3	4	5
Annual Branding rate (% branded calves/cows put to bull)	75	80	55	67	
Annual Weaning rate (%,weaned calves/cows put to bull)	73	79.4	52	65	
Total number weaned	3,500	1,119	10,920	11,500	
Number Heifers used for replacements	1,200	250	4,200	3,000	
Average age heifers put to the bull (months)	24	24	24	36	
Average Sale weight for live export					
Bulls			550	550	
Cows			420	420	
Steers			290	320	
Heifers			270	310	
Average sale live-weight for store's (kg)					
Steers	400	362.5	370	380	450
Heifers	300	314.7	370	370	400
Average sale weight for weaner's (kg)					
Bulls		385			
Steers					
Heifers					
Average sale dressed weight for finished cattle (kg)					
MSA domestic					
EU		277			
Jap Ox	420				
US	420				

Table 5 – Markets

		Property				
		1	2	3	4	5
Number going to live export						
Cows					700	
Steers				3,850	4,000	
Heifers				3,670	3,000	
Number sold as store's		Only in poor season				
Steers		1,700	599	2,000	2,000	
Heifers		Cull 530	228	500	1,000	
Number sold as weaner's						
Bulls			3			
Steers						
Cull heifers			210			
Finished cattle						
EU			195			
Avg. sale price for live export (\$ per kg)						
Cows				1.20	1.25	
Steers				1.95	2.00	
Heifers				1.80	1.85	
Avg. sale price for store's (\$)						
Steers		650	840			833
Heifers		450	751			680
Avg. sale price for weaner's (\$)						
Bulls			1084			
Heifers			752			
Avg. sale price for Finished cattle (\$)						
EU Heif			732			
EU ox			876			
Jap Ox		950				
US		950				
Avg. sale age for store's (mths)						
Steers		24	18			
Heifers		24	18-24			
Avg. sale age for weaner's (mths)						
Bulls			60			
Steers						
Females			96			
Avg. sale age for Finished cattle (mths)						
MSA domestic						
EU			30			
Jap Ox		24-72				
US		24-72				

4.3 Estimated technology benefits

The benefits for each of the technologies were estimated based on direct impact through either increased production and/or a cost saving. The benefits were mapped onto specific parts of the enterprise. We considered the benefits for the individual technologies across all case studies. The detailed information on the model parameters and outputs are provided in Appendices 2 and 3. We provide a summary of the estimated benefits for each technology across all properties with a summary of the main benefits in the section below.

e-Preg

The assessment of the benefits for e-Preg focussed on both increased production and cost savings (table 6). The beef CRC has shown that increased production benefits can be derived from pregnancy information that can be used to determine the post partum anoestrus interval (PPAI). Post partum anoestrus interval is a heritable trait and accurate and early identification enables improved calving and ultimately branding percentages by providing information that can be used within genetic selection indices. It is acknowledged that foetal ageing can be used to determine PPAI, however, the case study managers felt that e-Preg would have benefits because it could provide pregnancy information using lower skilled labour. We based the benefits assessments comparing changes to current practices. The managers also indicated that non-invasive pregnancy testing might reduce abortions through direct losses and indirect losses through the risk of disease spread. The cost saving benefits came from using cheaper low cost labour for pregnancy testing. The e-Preg device is aimed to provide a simple low skilled pregnancy testing solution, we assumed this was the case, however, it is still unclear what level of skill will be required to operate the device. The detailed explanation of the benefits for each case study is in the following section.

Property one and property two had some experience of trialling the e-Preg device and this provided these managers with a more informed view of the benefits. To estimate the benefits we assumed that the e-Preg device needed to be manually operated and was as accurate as a vet, although the current e-Preg technology does not meet the accuracy figures of a skilled vet. One of the most important discussion points with property managers centred on the time taken by an operator of the e-Preg to get a pregnancy diagnosis. Those producers that had experience in using the e-Preg device felt that e-Preg would take longer to determine pregnancy status than a trained vet. For the case studies, the main benefit of e-Preg was enabling an unskilled person to preg-test small mobs of cattle (Table 5).

Properties, two three and four all undertook some form of pregnancy testing either by trained staff or by a vet. Case study one did not assess pregnancy status but detected empties after calving based on wet/dry status. Assessment of wet/dry status is a cheap and quick assessment but means that empty cows are carried for at least an additional 12-18 months before being detected and culled.

Table 6 – Estimated benefits for e-Preg⁵

	Property				
	1	2	3	4	5
Branding percentage (annual % increase on current rate)	65 (1.38)	80 (4)	50 (1.88)	68 (2.13)	
Herd size (% increase in breeders)	4000 (0.5)				
Stockperson days for preg testing (increased number of days)	10 (1.38)				
Vet costs (\$) (% savings)				45,000 (31.25)	

Case study one

Case study 1 does not typically engage preg-testers so did not use current pregnancy status for management decisions. Rather, past pregnancy status is determined indirectly by assessing lactation status on a wet/dry basis – if a cow is not lactating by the time of a second round muster (the ‘second chance’ muster) she is removed from the herd. This means that ‘empty’ cows are carried for an additional 12-18 months before being detected and culled. E-preg, or an alternative form of preg testing, would permit detection of these animals much earlier, leading to much more efficient management of the breeding herd.

The use of e-Preg was expected to have some benefits based on the opportunity to use unskilled labour for pregnancy testing. The possibility of pregnancy information to determine date of conception and PPAI provides opportunities to identify both top performing and bottom performing females. Information on date of conception would provide opportunities for managing cows as a group based on stage of pregnancy/time of calving, more timely culling of empty cows, improved management of pregnant, but otherwise undiagnosed cows and improved identification of preferred genetic reproductive traits in cows. These effects were estimated to improve branding rates in the order of 1-10% over the medium to longer term (Fig. 12). These benefits were expected to accrue over the medium-term as most of the improvement would come from improved selection and culling - these benefits would take time to accrue. The benefit accrual function was set up to allow 80% of the total benefits to accrue within 10-15 years.

⁵ The benefits are the average median values from the manager and the team members. Individual values including upper and lower values can be found in Appendix 2.

The opportunity to increase the breeding herd size by identifying and removing non-performing breeders was considered a possible benefit. The benefits from using e-Preg to increase the herd size were low (only one person indicated a positive change). The median increase expected was in the order of 0.33% with an upper estimate (10% chance) of a 1.32% increase in herd size due to the use of e-Preg (Fig. 12). The nature of this benefit suggested it would require minimal management changes in order to be implemented and so was included as a rapidly accruing benefit with the accrual function specified to allow 80% realisation of associated benefits within 5 years.

It was anticipated that there would be an increase in labour usage to carry out the pregnancy testing. There were inconsistencies in the estimation of the benefits and costs of using e-Preg in terms of labour. The expectations of an increase in labour tended to outweigh those of a decrease in labour usage. This led to an expected increase in (unskilled) labour utilisation in the order of 1-2 stockmen days. As this means a minor increase in labour costs, there is negligible impact on the bottom line (in the order of \$250-\$500 in additional costs each year). For the purposes of the assessment of e-Preg on property one, stockmen were treated as a variable cost, which were employed as needed (Fig. 12).

Case study two

E-Preg showed few immediately obvious benefits for property two. The property is largely run by the owners with little input from external labour – as a result, preg-testing conducted by one of the owners is an overhead cost and not directly related to any particular production considerations. There were few benefits considered to stem from the use of e-Preg as the manager already employs a full preg-testing routine for the breeding herd.

Despite being no immediate obvious benefits, the project team discussed with the manager about potential benefits associated with e-Preg being operated by unskilled labour. These benefits were mainly associated with a more frequent program of preg-testing. Currently the manager completes the preg testing and he is only able to do this once a year. If unskilled labour could be used for preg-testing then the manager could potentially preg-test more frequently and get more information on the reproductive status of the cows. This detailed preg-testing information could be used to help lift the branding rates by enabling better selection of replacements and to identify bulls that resulted in improved fertility traits. The manager was interested in employing data mining techniques to inform management about individual animal performance as shown by their use of StockbookTM to track weight gains and pregnancy status.

The manager was sceptical over the practical use of e-Preg due to experience with e-Preg prototypes, which proved difficult to use and took too long to provide a pregnancy diagnosis. The manager stated that he would consider adopting e-Preg if pregnancy diagnosis was possible in 15-20 seconds with close to 100% accuracy.

The manager suggested that he could use the information from e-Preg to lift weaning rates by up to 10% (from 80 to 90%). This improvement would be achieved by using the analysis of data from preg-testing to improve genetic selection. By identifying and using the most fertile cows for replacements this would lift the herd reproductive performance (Fig. 12). It should be noted that maternal based genetic improvement would take time to achieve and could be done with existing preg-testing methods. The benefit of e-Preg came from the ability to collect more frequent information on pregnancy status and identify those cows that not only had a calf each year but got pregnant quickly, maintaining a tight calving interval. The assessment assumed that the improvement in reproductive capacity would lead to improved branding rates through improved pregnancy information.

The increases in weaning rates due to e-Preg outlined above would be associated with the opportunity to use unskilled labour to collect extra pregnancy status information. Contract labour costs approximately \$250 per day. Preg-testing was estimated to require two days of labour (1,800 breeders at 25 seconds each is 12.5 hours of testing) meaning an additional labour cost of approximately \$500 per year in order to free the manager from this task (Fig. 12).

Case study three

Property three currently uses an electronic pregnancy-testing device for pregnancy diagnosis of breeders. The main differences between e-Preg and the ultrasound device currently used are: (1) the ultrasound device is a penetrative device, and; (2) the ultrasound device requires a period of training. The manager stated that he “would not consider allowing a less-experienced stockman to carry out preg-testing than he currently does, even if e-Preg was simpler to use”. As a result the only benefits for property three were associated with perceived risks from the process of invasive preg-testing.

The manager perceived that there was a risk of calf losses through invasive preg-testing. The manager estimated the total losses between conception and calving were around 15%. The manager believed that some of these losses might be due to the use of invasive preg-testing. The project team found some evidence that invasive pregnancy testing could lead to both direct and indirect losses, these are discussed later, however, the opportunity to lift calving percentage by using e-Preg was not widely supported and there was significant uncertainty around the estimated benefit. We assume the rate (r) that the majority of the benefits would accrue would be within 1-5 years ($r=0.85$) (Fig. 12).

Case study four

The manager of property four was optimistic over the potential for e-Preg to alleviate preg-testing costs associated both with contracted veterinarians and with regular training of new staff. In addition the manager voiced concerns over an estimated 5% loss in calves between pregnancy diagnosis and calving representing a loss of up to 650 calves. The manager could not

allocate these losses to any particular cause but was concerned that manual palpation may be contributing to some of these losses.

The manager and the project team expected benefits of using e-Preg for property four – namely the opportunity to determine PPAI and through management and breeding strategies increase branding rates. The other important benefit was the savings on vet costs.

For savings on vet costs, all project team members were more optimistic than the manager (who expected 20% savings) the range of savings estimates were from 10-70%. This range of estimates of benefits reflects confidence in the technology and whether the technology could fully replace a vet was debated. In general the project team members assumed that the technology would only be available if it operated at equivalent efficacy of a vet. This assumption resulted in greater confidence in the technology. Until the technology is commercially available there will be no information to determine whether it can replace a vet. The vet saving benefits were partly offset by an increase in the use of farmhands priced at \$250 per day (compared to \$1,150 per day for the vet) representing a saving of \$900 for each day that the vet can be replaced (assuming diagnosis speeds are similar) (Fig. 12).

The vet savings were assumed to accrue immediately whilst branding rate improvements were expected to accrue slowly due to the need for breeding herd genetic changes the rate of change value (r) was set at 0.35.

Case study five

There were no breeders and so e-Preg was not assessed for property five.

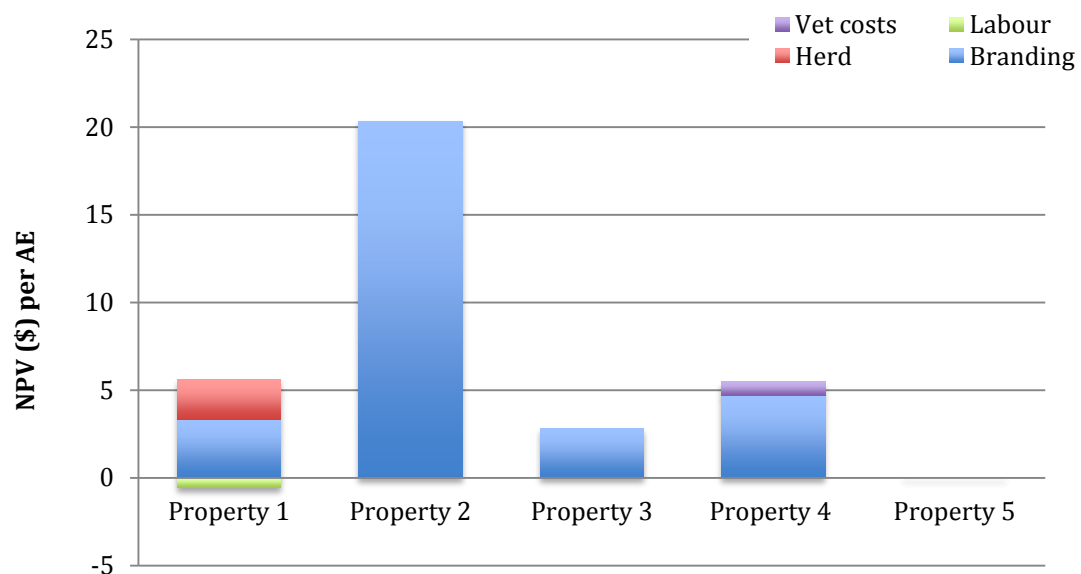


Figure 12 – Net present value benefits per adult equivalent for e-Preg for each of the five properties

The benefit-cost ratio for e-Preg demonstrates that property 2 has the greatest opportunity to derive a positive economic benefit (Figure 13). This

benefit is reliant on obtaining better information on pregnancy status to improve branding rates through using unskilled labour to do more frequent preg testing (value of which has an uncertain level of plausibility).

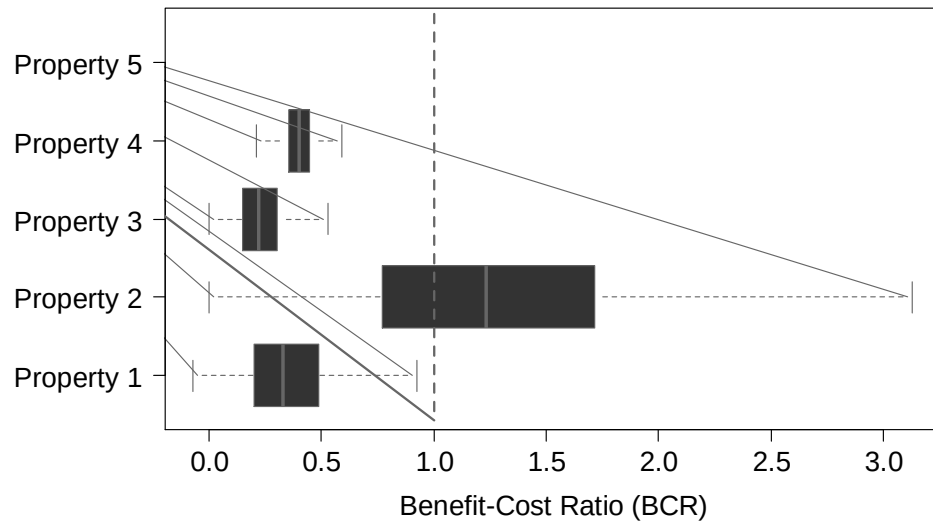


Figure 13 – Benefit-cost ratio for e-Preg on all properties

Walk-over-weighing and auto-drafting

The estimates of benefits for walk-over-weighing (WoW) and auto-drafting focussed on both cost savings and production benefits (Table 7). The manager from property one had experience of WoW and auto-drafting and this enabled him to provide more detailed estimates of benefits. The project team were able to draw on the experience from property one when discussing opportunities on the other four properties. The managers were also able to relate the technology to their own unique set of property conditions and identified additional benefits. The two major cost saving benefits that were identified related to savings in mustering costs, either helicopter or man hours. These benefits were related to the opportunity to auto-draft to enable specific groups of cattle to be identified and separated. The auto-drafting linked to the NLIS tag was seen to have additional benefits over straight spear trap mustering. The production benefits were derived from having more regular live-weight information from the WoW system. The property managers determined that the live-weight information could be used to help them make better management decisions.

The details of the estimated benefits for each of the case study properties are outlined in the following section.

Table 7 – Estimated benefits for walk-over-weighing and auto-drafting

	Property				
	1	2	3	4	5
Branding percentage (annual % increase on current rate)	65 (2.88)			68 (1.13)	
Carrying capacity for cell (% increase)					1000 (4.63)
Average daily live-weight gain (kg) (% improvement)	0.3 (3.5)	0.53 (3.88)	0.3 (1.5)		0.4 (4.13)
Margin per kg (\$) (% increase in margin)	0.3 (3.75)	0.4 (3.75)			
Helicopter mustering costs (\$) (% reduction in flying costs)	30,000 (7.5)		126,000 (14.5)	96,000 (11.25)	
Labour costs (\$) (% saving)				5,600 (17.5)	22,500 (7)

Case study one

The manager from property one had experience and data on the potential benefits of WoW and auto-drafting. The manager was involved in the development of WoW technology. Although the manager had experience of the potential of WoW and auto-drafting the benefits were estimated.

The main aim in employing WoW and auto-drafting was to turn off cattle at the optimum weight taking into account target market criteria, price levels for different cattle classes and freight cost minimisation. There were estimated benefits to the growing herd and WoW has the potential to provide information that could improve management decisions to increase average daily LWG. These benefits are accrued by acquiring more regular information on growth rates so that intervention strategies could be used if growth rates started to decline. Estimates of the likely improved growth rates ranged from 1-10% with estimates of the median in the range of 2-5%. These benefits were estimated to accrue fairly rapidly with 80% of the total benefits being realised within 5-15 years.

The manager was also focused on improving the output of the breeding enterprise and suggested that WoW was able to provide information on both cow weights and calving dates. Using the information on cow performance (weights and calving dates) it was expected that the information could be used to improve herd genetics leading to increased branding rates. The WoW data provided information on calving dates that could be linked to PPAI via

annual calving interval and used for genetic improvement. It is debatable whether this information is better than foetal aging but compared to the current method of using a second-round cull of dry cows it was thought to provide more detailed information on a cow's reproductive performance. By linking the PPAI information to both maternal and paternal genetics this was expected to improve branding rates. Branding rate improvements were estimated by the manager and the project team to be fairly modest – in the order of a 0-6.5% increase in the current branding rate (i.e. from 65% currently and potentially up to 70-72% in the long run). There was good agreement that WoW had the potential to improve branding rates, which were expected to increase over 5-15 years.

Auto-drafting and selecting specific mobs of cattle was expected to reduce mustering costs and this has potential to provide an economic benefit. The reduction in the cost of helicopter mustering – a large input cost for property one – was seen as a benefit of this technology. These mustering cost savings extended beyond straight trapping of cattle as the WoW and auto-drafting allowed for more flexible and targeted mustering of specific sub groups of cattle. There was general agreement that mustering savings had real potential (three out of four team members estimates suggested a benefit). The average savings were estimated to be around 10% of current mustering cost but potentially up to 20-40%. These benefits were estimated to accrue fairly rapidly over the next 5-10 years (Fig. 14).

The project team discussed with the manager potential benefits of WoW and auto-drafting through a price increase by enabling cattle to be more closely aligned with market weight requirements. After the discussion two project team members estimated an improvement in gross margins in the order of 0-15%. The lack of support from the other team member and the manager however led to lower overall expectations for this particular benefit – a 2% improvement in gross margins on average. These benefits were estimated to accrue fairly rapidly with the majority of benefits being realised over the next 5-10 years (Fig. 14).

Case study two

Most of the paddocks on property 2 have a substantial amount of natural water – this was considered a limiting factor for the use of WoW and auto-drafting technologies because the cattle aren't forced to go over the WoW system. The only paddock that was considered to have potential benefits was the planned Leucaena paddock. The main expected benefits for this paddock were associated with optimising production. Automated mustering benefits were considered to be relatively minor as current mustering costs were estimated at only \$300-\$500 per muster using two people on motorbikes over three hours.

The manager was somewhat sceptical over the potential for WoW to provide information that could facilitate improvements in the property's breeding and growing enterprises or to improve mustering and drafting efficiency.

The rest of the project team were more optimistic over the potential of WoW and auto-drafting to deliver benefits to property 2. The three project team members were in agreement over the potential for the combination of these technologies to deliver improvements in average daily live-weight gains for steers running on the Leucaena paddock (approx. 600 head expected to be gaining approximately 530 g per d). The improved LWG was based on optimising the average daily live weight gain by ensuring that the cattle could be rotated to maximise growth rates. The estimated improvements included the opportunity to better market by more accurate tracking of weight gains that could be used to identify dates and numbers of animals that were finished and ready for a particular market.

The two main production benefits were estimated to accrue over a medium time frame (80% of benefits within 5-15 years) and were based on using the WoW and auto-drafting system to provide data that could optimise production and marketing opportunities (Fig. 14).

Case study three

The manager has trialled intensive rotational grazing management on the property and was impressed with the results and the potential for it to increase production. The ability to extend rotational grazing is, however, currently limited by the need to run very large mobs (6,000-7,000 head) over short periods (less than 6 days) in order to get appropriate coverage of grazing effort across the large paddocks. This level of intensive management requires a significant labour input in order to manage it appropriately. The manager expressed some interest in the use of WoW and auto-drafting to optimise the rotations and reduce the labour and mustering input required to make this system work. The benefit of the combined WoW and auto-drafting is that it allows the manager to move the cattle based on the growth rate of the cattle. More conventional spear trapping might save on mustering costs but the timing of mustering is not based on animal performance. For the rotational system, the manager estimated mustering costs at \$7 per head per year and suggested he would have 3 mobs of 6,000-7,000 head each involved in these types of rotations.

The manager did not provide an estimate of the benefits in terms of live-weight gains under such a system so we only take the benefits in terms of the potential savings in mustering costs associated with using an auto-drafting technology. It might be cheaper to use a spear trap rather than using an auto-drafting system to only save on mustering, however, in the context of this study the producer identified auto-drafting as a cost saving technology. The manager estimated that about 30% of mustering costs would be able to be saved with the use of auto-drafting technologies. The use of WoW in combination with auto-drafting could facilitate an improvement in the efficiency of each rotation, and hence daily live-weight gain of a rotational grazing system. This was estimated to provide an additional live-weight gain improvement of 0-10%. The LWG benefit is based on reducing losses by optimising the timing at which cattle move paddocks. Assuming that ADGs are 0.3 kg per day, WoW could increase the daily LWG by up to 0.03 kg per day. We assume that this increase translates directly into additional revenue based

on a price of \$1.30 per kilogram (LW). Both of the above benefits were estimated to accrue fairly rapidly with the majority of benefits occurring within 3-8 years.

Although other benefits were discussed, it was unclear to what extent these would actually apply to property three. It is worth noting that for the finishing cattle only one or two auto-drafting units would be required whilst many more would be needed to obtain benefits for the breeder herd (continuous mating over a very large area). As a result we considered the benefits to cost-savings and efficiency improvements associated with the use of auto-drafting and WoW on a rotational growing system on property three (Fig. 14).

Case study four

The manager was not very optimistic over the potential for WoW and auto-drafting to provide tangible benefits on his property due to a generally large availability of multiple natural watering locations in each paddock. It was estimated that the use of these technologies would only be possible for 60% of the breeding herd that were located furthest from the Ord River and other natural watering spots and where there was some control over watering points.

The estimated benefits arising from the use of WoW and auto-drafting were based on savings in mustering costs (helicopters @ \$400 per hour and stockmen @ \$350 per person per day). There was also consideration of the benefit of selecting breeders using PPAI derived from calving dates from the WoW to shorten the calving interval leading to an improvement in the annual branding rate. Mustering costs could equally be saved using spear traps.

One team member was in general agreement with the manager over the estimated benefits whilst the other two were somewhat more sceptical and were unwilling to suggest that the combination of WoW and auto-drafting could provide any definitive benefits to property four. Uncertainty over the benefits centred on the effectiveness of these technologies to work when there was a significant source of natural unmanaged water available.

The use of WoW to provide more detailed information on breeder performance was considered in the context of improving branding rates. It was thought that the benefits would accrue over the 10 to 15 years to account for the need to integrate the technology and build a data set that could be used to inform management decisions (culling and genetic improvement). Mustering savings (helicopter savings and labour) were estimated to accrue at a within a shorter time period (Fig. 14).

Case study five

The manager of property five was very interested in the potential of WoW combined with auto-drafting technology. The use of cell-grazing on the property means that implementing WoW and auto-drafting would be relatively simple. Case study five's cell-grazing system were located in the portion of the property furthest from yards and weighing infrastructure. In practice this resulted in significant effort when moving cattle between the cell-grazing

system and the yards resulting in loss of condition that would need to be made up by those cattle that did not make market grade and returned to the paddocks, also loss of weight in sale animals due to time off feed. Some shrinkage would still be experienced for those cattle that were drafted using the WoW and auto-draft system, but it would be reduced.

Three main benefits were identified for potential investment in WoW and auto-drafting on property five: (1) labour savings from drafting exercises; (2) reductions in weight loss from mustering to the yards (drafting on weight basis), and; (3) improvements in optimisation of cell-shifts from more detailed weight gain data. Labour used for drafting from the cells was estimated to be 2-3 contractors (at \$250 per person per day) employed for up to 3 days per draft for about 10 drafts per year. The manager estimated approximately one third of this would be saved through the use of WoW combined with auto-drafting. The project team were in general agreement with this although were more sceptical and estimated savings in the order of 0-30% of labour used for drafting from the cells. The benefits from these labour savings were expected to accrue within 2-5 years to allow some period for learning in the use of WoW and auto-drafting technologies.

Reducing weight loss by reducing the amount of unnecessary mustering events and improvements in associated average LWG by optimising the move between cells were the main areas where the team identified potential improvements in the trading enterprise. Currently the manager aims for cattle to exit the cell paddocks at approximately 470 kg LW with the aim to sell them at 450 kilograms on average. The excess of 20 kilograms is due to uncertainty over the range of weights and the risk of having to take substantial numbers of cattle back to the cells due to under-estimated weights. The use of WoW and auto-drafting would allow both more exact measurement of individual weights and exact drafting of in-weight range cattle. These exact measurements would allow the manager to remove cattle at 460 kg or less which is expected to save in the order of 2-4% of feed and allowing a commensurate increase in stocking rates. The project team estimated that there might be between 2 and 12% increase in the carrying capacity of the cells. These figures suggest the project team were more optimistic over carrying capacity improvements than the manager. Benefits associated with carrying capacity improvements were estimated to accrue fairly quickly due to the intensive management approach used on the property, particularly for the cell-grazing component. The benefit accrual function allowed 80% of benefits to accrue in 5-10 years.

The manager and the project team were in general agreement with expectations that the combination of WoW and auto-drafting technologies would allow further optimisation of the cell-grazing system potentially resulting in LWG improvements by better and more proactive management based on cattle live weights. The estimated benefits were in the order of 0.1-5% improvements in LWG arising from cell management optimisation due to improved information, mainly from the WoW technology. These benefits were expected to accrue more slowly due to the need for data collection to aid

management decisions – 80% of total potential benefits were expected to accrue within 5-15 years (Fig. 14).

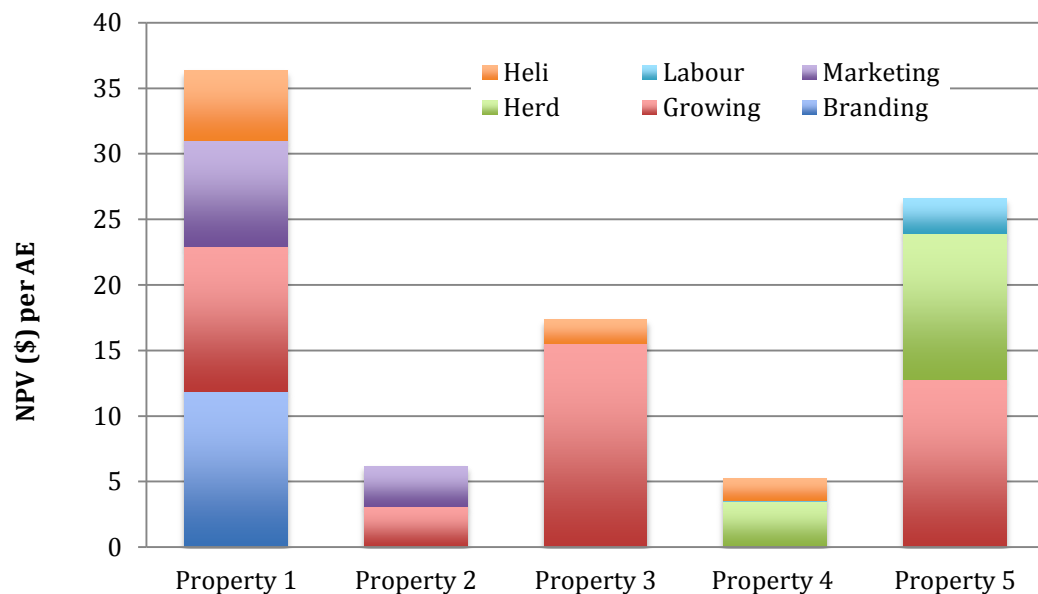


Figure 14 – Net present value benefit per adult equivalent for WoW and auto-drafting for each of the five properties

The estimated benefits from WoW and auto-drafting showed a positive economic return on all properties except property two (Fig. 15). The positive benefit-cost ratio is derived from multiple benefits adding value across multiple applications.

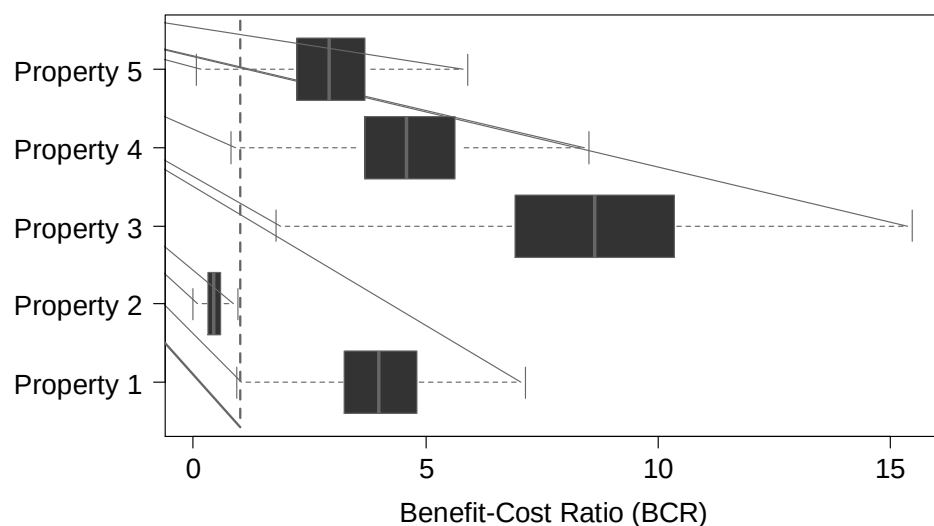


Figure 15 – Benefit cost ratio for walk-over-weighing and auto-drafting for each of the five properties (the costs for WoW and auto-drafting are based on the figures presented in table 2)

Coarse-resolution spatial location

The major benefit identified for the coarse spatial location information was in cost savings associated with more efficient helicopter mustering for three of the five case study properties (Table 8). These savings were based on having prior knowledge of the location of cattle so they could be mustered more efficiently. The production benefits were based on opportunities to improve branding rates and increase herd size, however, the estimation of these benefits were mostly very small, 0.25% and 1% respectively for property one. Property five estimated that there would be a large increase in herd size (25%) from using coarse location information. The detailed justification for this large estimate can be found below, however, the actual benefit came from an increase in productive growing cattle. The manager identified that he had 'lost' cattle that were left in the system for several years that were reducing his ability to carry more growing cattle. This benefit is likely to vary between properties and may be a result of paddock conditions and ability to muster all cattle.

Table 8 – Estimated benefits for coarse spatial location information

	Property				
	1	2	3	4	5
Branding percentage (annual % increase on current rate)	65 (0.25)				
Herd size (% increase in AE)	4000 (1)				5625 (25)
Helicopter mustering costs (\$) (% reduction in flying costs)	30,000 (13.75)		315,000 (18.75)	400,000 (13.75)	
Labour costs (\$) (% saving)				450,000 (2.5)	

Case study one

Coarse-resolution spatial technologies were estimated to be of most immediate interest in determining the location of stock for the purposes of mustering and ensuring that no stock was missing. In addition there was some discussion around the possibility that pasture usage could be increased above the current 'maximum sustainable' limit supporting 5,000-5,500 cows.

The most obvious source of benefits was in cost savings associated with mustering. Savings in the order of 5-30% of helicopter mustering costs were uniformly expected by all team members and by the manager. These savings resulted from the ability to locate cattle prior to the start of mustering – in areas of the rangelands such as in central Australia finding cattle is a

significant component of the time costs for mustering purposes. Information on cattle location prior to the start of a mustering event, or even during it, has great potential to reduce mustering costs. Considering helicopter mustering costs were in the order of \$30,000 per year this resulted in potential annual savings of approximately \$5-\$10,000 alone.

Additional savings were estimated to accrue from reductions in time associated with locating and managing lost stock (~\$500-\$1,500 per year); these benefits were again focussed on reduced flying costs (~\$1,500-\$3,000 per year).

Improvements in potential outputs were mainly associated with the possibility of increasing the number of productive growing stock on the property for a given set of seasonal conditions. Being able to identify and muster all of the cattle means this will free up the paddock for more cattle. The increased stock benefits were debated with one project team member suggesting there would be no improvements whilst another thought there would be fairly significant changes (between 1-10%). The manager reflected that being able to find and muster stock that were left behind would enable him to increase his growing cattle numbers by 5%. Overall improvements were estimated in the order of 0.1-5% reflecting a large range in possible outcomes.

Small improvements were expected in weaning rates based on more efficient mustering enabling better management of the herd in terms of reducing the number of unproductive cows. The value of a more complete muster for the breeders was considered to be relatively small based on the relatively low probability that cows that were left behind were all unproductive. Improvements in branding rates were estimated to be in the order of 0-1.5% (Fig. 16).

Cost savings (helicopter mustering time) were estimated to accrue rapidly, in the order of 3-8 years.

Case study two

Coarse spatial information was not seen as having any potential benefit to property two by the manager or any of the project team. The lack of benefits arose mainly out of the small size of the property and the fact that the area is well developed with little chance of escaped cattle moving far. The manager was easily able to assess cattle location (within 2 minutes of entering a paddock) meaning search costs during mustering are minimal, even without location data. The discussions with the project team suggested that 'knowing when a fence is down' may be beneficial but this was rejected by the manager as not overly important – the fence would need to be repaired and it would not be long, typically within a day, before management were aware of the missing cattle.

Case study three

Property three is an expansive property undergoing major developments aimed at reducing variable costs and improving production. Mustering is one of the key costs involved in managing the herds – estimated at over 1,000

helicopter hours giving a total cost of approximately \$315,000 each year. The manager suggested two potential benefits arising from coarse location information for his herds: (1) Being able to reduce search costs for helicopter mustering, and; (2) reducing animal losses which are currently estimated at 0.5% of the herd each year (over 200 head). The latter is a difficult benefit to estimate, as it is likely associated with significant mortality for which coarse location information is not likely to help reduce. None of the project team estimated that reductions in animal losses would be a factor in the implementation of a coarse spatial monitoring system. We do not include the benefits of finding lost animals in this analysis.

The benefits associated with time reductions for helicopter mustering were, however, widely agreed upon with two of the project team estimating a potential benefit and they were in general agreement with the levels of reduction expected by the manager. These benefits were assumed to require integration of coarse location infrastructure and information into the existing business suggesting a medium rate of benefit accrual of 5-10 years (Fig. 16).

Case study four

The expected benefits due to coarse spatial information made available by these technologies was focused solely on predictions of significant reductions in the search time required when mustering cattle using helicopters. Helicopters costs are a significant cost for property four – estimated at 1,000 hours usage at a cost of \$400 per hour totalling \$400,000 per year.

The expectations of savings in search costs were well-developed by the manager as he had a good understanding of the constraints on helicopter mustering, particularly regarding relocation of split mobs and initial search costs.

The project team and the manager were in general agreement over the level of savings in helicopter search costs to be expected on the property – estimated in the order of 10-20% by team members, with the manager expecting about a 10% saving. The benefits from the use of coarse spatial technology would only need a small amount of work in learning and integration of technologies into the operations. The benefits were estimated to accrue fairly rapidly with 80% of total estimated benefits accruing within 3-10 years (Fig. 16).

In addition to the cost saving benefits, one of the project team felt that there were labour saving benefits from the manager knowing where cattle were located to enable more efficient checks on cattle. These benefits were assumed to accrue relatively quickly but overall only represented an average 2.5% saving on labour. It is difficult to determine the extent that location information will improve the efficiency that cattle are checked. It is possible knowing where all cattle are could increase checking time as there will be a tendency to want to extend checks knowing that cattle are available.

Case study five

Coarse spatial technology was estimated to be of potential benefit to property five in two main areas; both associated with improved control of cattle and associated loss of stock, or 'stragglers' in a few paddocks that were large and difficult to muster. The main assumed improvements were through improved mustering efficiency and leaving fewer stragglers in the paddocks. The stragglers tend to be heavier cattle that have been left for some time and in the range of 800-1,000 kg live-weight meaning that their removal would allow replacement with two weaners. The manager estimated that every year 40-60 bullocks were lost in each of the four larger paddocks. In each paddock, periodic clearing costs include 8-10 hours on a helicopter at \$350 per hour, and 3 contractors at \$250 per day plus 2 station hands for one day. Discussions with the manager suggested that the annual clearing costs would not be recouped with coarse spatial technology – the initial muster would still be unable to find the more elusive cattle. As a result of the discussion, two of the project team did not believe that there would be any benefits in coarse spatial technologies for finding cattle. The manager and one project team member believed that there was some likelihood that coarse spatial technology would provide information that could be used to improve mustering.

The manager estimated a potential increase in stocking rate of 120 weaners for each of the four paddocks that had mustering difficulties. Discussions with the manager suggested that coarse spatial technology would allow a realisation of 50% of the potential increase. The project team were more sceptical of this likelihood with estimates in the range from no improvement to 50%. We assumed that the second clearing muster remained in operation due to the likely persistence of cattle that were difficult to muster. The net benefits were calculated as the realised increase in stocking rate for each paddock (derived from the estimated distribution using the information from the project team and the manager) multiplied by the gross margin for a grown out weaner in the operation (estimated at \$150), multiplied by the number of paddocks which may benefit from this technology (4). We assumed that there would be no change in the value of sold stragglers.

Benefits associated with the increased potential stocking rate arising from reductions in stragglers were estimated to accrue fairly rapidly. We estimated that 80% of total benefits would be accrued within 3-8 years (Fig. 16).

Additional benefits due to search costs for mustering the remainder of the paddocks were considered to be low or insignificant due to the majority of the paddocks being small and easy to muster.

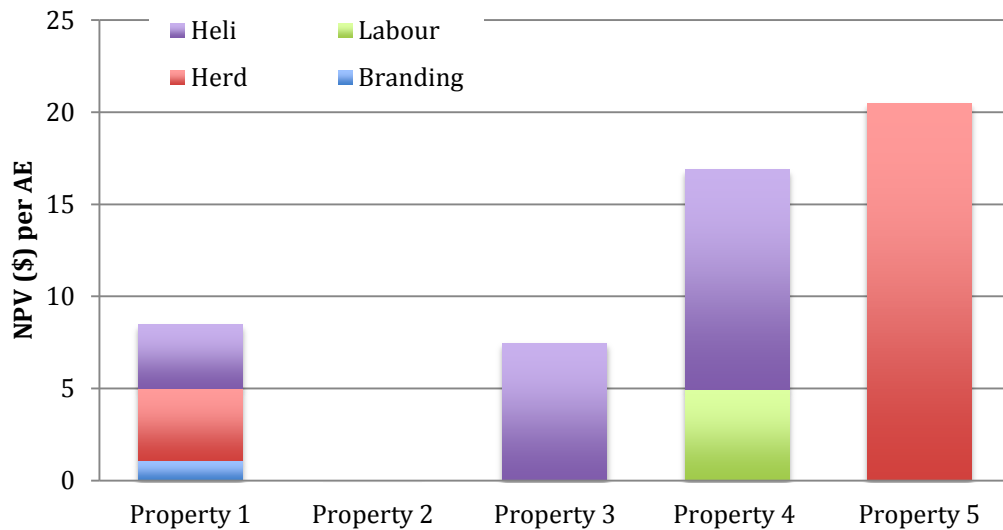


Figure 16 – Net present value of benefits per adult equivalent for coarse location devices on all five properties.

The high investment cost for the coarse location devices reflects the very low benefit-cost ratios (Figure 17). Based in the assumption of increasing the stocking numbers and improving mustering efficiency property five shows the greatest potential of achieving a positive economic return. The more intensive (more animals per hectare) production system of property five enables the costs of towers to be reduced increasing the chances of achieving a net economic benefit from the technology. Although the more intensive production systems are able to reduce the fixed costs there are likely to be less benefits from location monitoring.

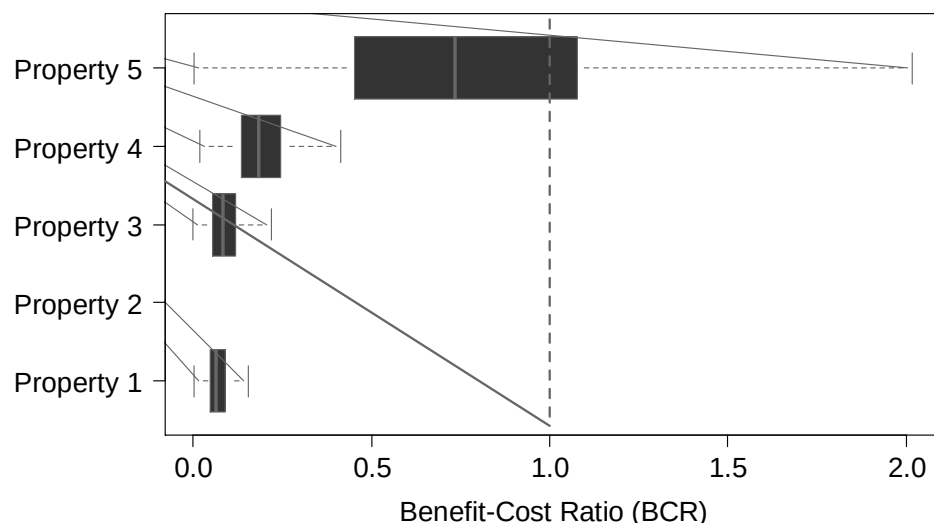


Figure 17 – Benefit-cost ratio for coarse location technology for all properties, it assumes all cattle are fitted with a device and cattle can be located across the whole property.

The major benefit that was estimated for the coarse location technology came from helicopter mustering savings. We explored whether only fitting 10% of

the herd with tags would provide cost savings, the technology still fails to achieve positive economic return (Figure 18). There appears to be a significant positive economic benefit for property five when the coarse location technology is fitted to 10% of the herd. Although property five has good positive benefits these results should be viewed with some caution, as the benefits were dependent on identifying all lost cattle in a particular paddock. If all cattle need to be reliably identified and found then 100% of the herd will need to be tagged.

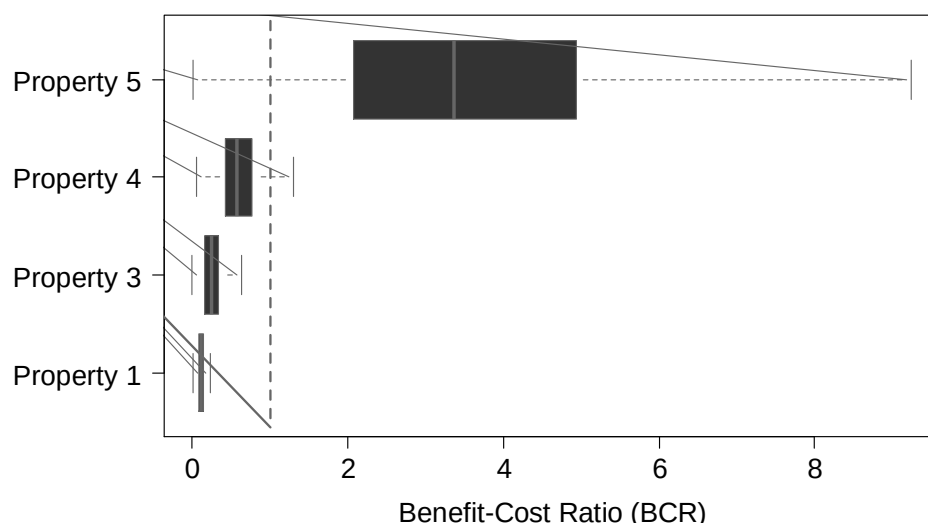


Figure 18 – Benefit-cost ratio for coarse location technology for all properties, it assumes 10% of the cattle are fitted with a device and cattle can be located across the whole property.

Fine-resolution spatial location

Fine-resolution spatial technologies provide a greater precision of animal location compared to coarse spatial technologies. In this respect they are able to assist in determining behavioural aspects associated with mating, calving, disease etc. Note that benefits assumed from coarse location technology, for each case study, were also included in analysis of fine spatial location. While there were some suggested production benefits in terms of improved branding rates, increased herd size and improved daily live weight gains these were all estimated as very small improvements, with any single improvement being less than 2% (Table 9). We report on the individual case study estimates and assumptions regarding the production benefits but consider these to be relatively minor. The cost saving benefits were, however, much more significant. The helicopter mustering and labour saving cost benefits were based on the same benefits that the coarse-location technologies provided. The major additional benefit related to fine location information related to reduced bull purchases. The details of the cost saving benefit for each individual property are discussed below, however, the assumption for reduced bull purchases related to confidence that the bull was working. This benefit was not considered as a replacement for existing bull soundness measures but rather to provide additional information on bull libido.

Table 9 – Estimated benefits for fine spatial location information

	Property				
	1	2	3	4	5
Branding percentage (annual % increase on current rate)	65 (1.38)	80 (1.04)	50 (0.63)	68 (1.93)	
Herd size (% increase in breeders)	4000 (1.5)				
Average daily live-weight gain (kg) (% improvement)		0.4 (1.25)			0.4 (1.25)
Annual bull purchases (\$) (% reduction)		10,000 (6.25)	270,000 (16.25)	180,000 (6.5)	
Helicopter mustering costs (\$) (% reduction in flying costs)	30,000 (13.75)		315,000 (18.75)	400,000 (17.5)	
Labour costs (\$) (% saving)				450,000 (2.5)	

Case study one

The manager felt that these additional aspects of fine spatial technologies would not be significant and that there would be no additional benefits, to those from coarse spatial, arising out of fine spatial technologies.

In contrast to the manager two of the project team, Greg Bishop-Hurley and Mark Trotter, who both have experience of fine-resolution behaviour data, estimated additional production benefits (to those of coarse spatial) mainly associated with improvements in branding rates. These benefits were mainly expected to be associated with the ability to determine the parents of offspring and in linking this to genetic improvement of production traits. Such information would facilitate implementation of a long-term genetic management strategy to select the top breeders that would be used for replacements to lift branding rates. As such these additional benefits were considered to be a long-term strategy with final benefits due over a significant period of time. To capture this we modelled benefits accrual as a 'slow' process.

Case study two

Although coarse spatial information was not expected to provide any significant benefits to property two, fine spatial information was seen as having more potential to aid the identification of paternity as well as determining which bulls were working.

There was some agreement over the estimated benefits of fine spatial technology for property two. The project team were more optimistic over the potential for long-term gains in average daily weight gain arising from female parentage that could be used as part of more refined genetic selection. The manager was more optimistic over the benefits from savings in bull purchases due to the ability to identify non-working bulls. The former benefit (improvements in daily weight gains) is estimated to be the larger benefit of the two but would only occur over the long-term requiring a substantial period of data collection and data analysis (80% of the benefit within 15-30 years). The latter benefit (savings on bull purchases) is estimated to be smaller but would potentially accrue more quickly (80% of the benefit within 2-5 years) (Fig. 19).

Two of the three project team members suggested that improvements in branding rates could be expected if maternal parentage was linked to fertility information such as date of conception to identify cows that had low post partum anoestrus interval. Identifying and selecting replacements from the most fertile cows in the herd could help to lift reproductive rates. The information on reproductive rates could also be used to identify and select for higher performing bulls. We estimated 80% of these benefits could be expected to accrue within 15-20 years.

Case study three

Fine-resolution spatial information was seen mainly as a way of identifying non-working bulls for property three. All experts and the manager agreed that this type of information could allow a reduction in bull purchases in the order of 20-30%. The percentage of bulls in the herd is 4%, which suggests the property is running extra bulls as an insurance measure. Currently bull purchases are approximately 100 bulls per year at a cost of approximately \$2,700 each meaning that annual purchases are \$270,000 and savings in purchases may be in the range of \$54,000 to \$81,000. The benefits of identifying non working bulls would take some time to accrue allowing for both the deployment and integration of the technology and in developing a greater ability to utilise and analyse generated behavioural data. We estimated that the benefits would accrue over an 8-15 year period (Fig. 19).

Fine-resolution monitoring could be used to lift the branding rate by the removal of ineffective (i.e. non-working) or antagonistic (i.e. hindering good bulls from working) bulls. The estimates associated with this were in the order of a 0-5% addition to the current branding rate. Further work would need to be done to determine a more robust estimate of the benefits. This type of benefit was estimated to accrue over a similar period to the previous benefit involving a similar level of integration with management and production systems.

Case study four

The manager was optimistic about the potential for fine-resolution spatial information to facilitate the development of improved herd behaviour and for the identification of non-working bulls. In particular, the manager was

interested in the ability to link temperament to maternity and paternity to enable a gradual shift to improved behaviour in the cattle on the property.

The project team and the manager were in general agreement about the benefits of fine spatial information to identify non-working bulls. However, the team were not convinced of the benefits of linking behavioural traits of offspring to actions involving culling cows from the breeding herd.

The manager estimated that the benefits in terms of 'good temperament traits', enabling more efficient mustering, would reduce helicopter time costs by up to 20% (in addition to time savings from reduced search costs as for the coarse spatial information). This benefit would however take a very long time to accrue requiring both good time-series data to aid culling decisions based on maternal heritage and significant analysis and integration of data analysis tools into the business. As a result we estimated that the majority of benefits would take in excess of 20 years to accrue.

The manager and one project team member estimated that there would be a reduction in the number of bulls purchased. It was estimated that the majority of the benefits from reduced bull purchases would accrue within 2-5 years.

Two project team members estimated potential benefits for marginal improvements in branding rates arising from the ability to better observe mating events enabling more detailed measures of fertility traits that could be linked to both male and female genetics. These benefits would take a long time. We estimated that 80% of benefits would accrue within 15-20 years (Fig. 19).

Case study five

The manager of property five felt that fine-resolution spatial data (i.e. on behaviours and inter-animal interactions) would provide little benefit. Although benefits were considered, the ability to integrate fine spatial information into current management practices was not regarded as feasible or beneficial at the current time.

Only one project team member considered there were additional potential benefits in the use of behavioural data arising from fine-resolution spatial technologies. These benefits were associated with potentially quantitative measures that could be used to assess and improve health and wellbeing of cattle. These potential benefits are somewhat speculative and it is difficult to assign a reliable value to them. Eight per cent of total benefits associated with these changes were expected to accrue within 15-20 years (Fig. 19). As fine-resolution spatial technology also provides similar benefits to coarse-resolution location information the benefits for coarse-resolution spatial were included in the estimation of total net benefits for fine-resolution spatial technology.

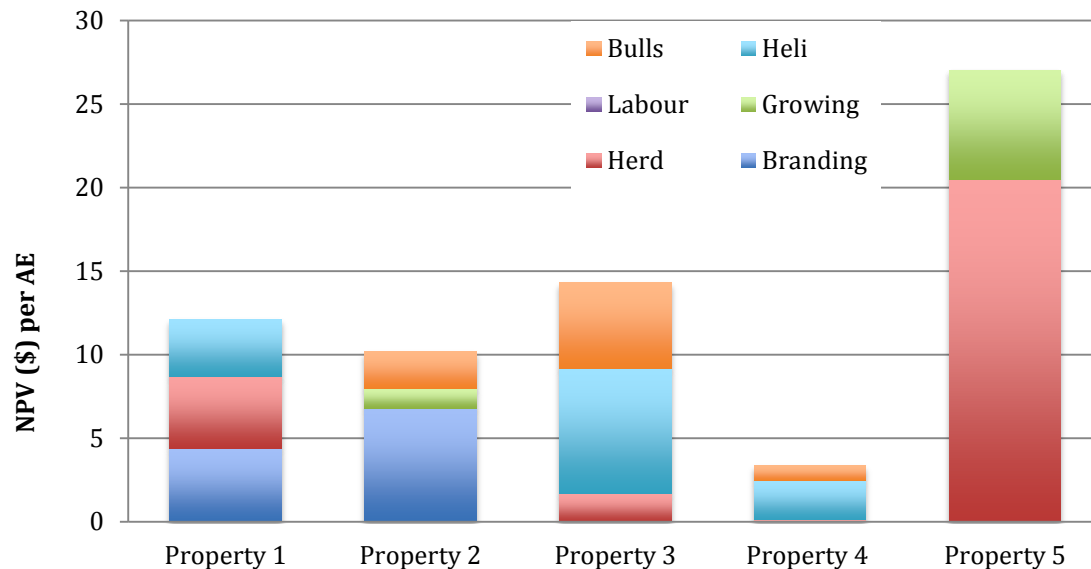


Figure 19 – Net present value of benefits per adult equivalent for fine-resolution monitoring on all five properties

Currently fine-resolution spatial monitoring technologies are only available for research purposes so it was not possible to calculate a commercial benefit-cost ratio. However, the NPV provide an indication of the maximum costs for the technologies.

Automated vegetation assessment

Although the discussion for the automated vegetation assessment referred to generic assessment in reality this refers to opportunities for remote sensing. The earlier section that described the technologies provided information on possible remote sensing products and their potential use to aid management of extensive northern grazing systems. While there are opportunities it is clear that there are also challenges to deliver refined ground truth pasture information from extensive heterogeneous pastures. Despite the challenges the discussions around potential benefits made some assumptions on the information that would be available, these assumptions are provided as part of the individual case study assessments. Table 10 shows that most of the benefits were related to increased production. Case study one property did indicate that regular remote sensing information might reduce the amount of flying costs associated with general checking of the property. The main production benefits related to the opportunity to use more detailed information on overall feed availability to improve cattle feeding leading to improved condition, growth rate or numbers of cattle that could be carried. There are some implicit assumptions that; firstly full spatial monitoring of vegetation condition will identify surplus feed and secondly if surplus feed is found that it can be exploited. It is unclear the extent to which either of these assumptions are true. Overall the estimates of production benefits were relatively modest with most of these estimated average production benefits being below 5%. The largest benefit was estimated on property five, however, these benefits were based on assumed improvements.

Table 10 – Estimated benefits for automated vegetation information

	Property				
	1	2	3	4	5
Branding percentage (annual % increase on current rate)		80 (0.88)			
Flying costs for property observations (\$) (% reduction in costs)	10,000 (5)				
Average daily live- weight gain (kg) (% improvement)		0.4 (0.50)			
Number of growers (% increase in number of cattle grown out)	2400 (3.25)		10,000 (0.88)	10,000 (3.75)	5,500(5.5)

Case study one

Property one manager currently monitors pasture condition during regular flights over the property. The manager also uses bore runs to check the condition of cattle and the pasture. Although this approach to pasture management is necessarily brief and qualitative it is based on many years of management experience allowing effective management of the property at current herd levels.

The manager considered there might be benefits from automated pasture sensing by integrating it with a WoW system. In particular it was thought that linking weight and calving information from a WoW unit to information on pasture quality and availability for the less intensively managed breeding herd might allow an increase in effective pasture utilisation (pasture use efficiency). The manager felt that there was potential for the remote sensing data to give him more confidence in the overall state of his paddocks enabling him to carry more stock.

It was considered that automated pasture assessment might reduce flying time. However this benefit is dependent on the other reasons for flying being non-limiting – i.e. if the key reason for flights tends to be bore checking then the reduction in flying time may be minimal. Nevertheless, one project team member estimated that this benefit might be in the order of a 5-50% reduction in flying time. The highly uncertain estimates for this factor and the lack of support amongst the remaining experts and the manager led to low probabilities for the estimated reduction in flying times.

The reduced flying times were estimated to accrue fairly quickly with 80% of these benefits accruing within 5-15 years. The breeder herd increases were estimated to take more time to accrue due to the need to analyse pasture and calving data to have confidence that increasing stock numbers were not having detrimental effects – we estimated 80% of benefits would accrue within 10-20 years (Fig. 20).

Case study two

The manager on property two carries out regular pasture monitoring as part of their regular operations. They also stock 'conservatively' with only a small chance that they will run out of feed in any given year. As a result the manager saw few production benefits in having additional information over pasture availability than what he currently had available.

Despite the scepticism of the manager, two of the project team members felt there would be some benefits in obtaining robust and regular measurements of available feed in terms of branding rates and average daily live-weight gains or increases in the size of the breeding herd (due to improved feed availability assessment).

Estimations of benefits were nevertheless conservative with one team member considering an improvement in the size of the breeding herd in the order of 0.1-0.5%. This level of benefit is marginal – when averaged across the three project team members and the manager – the average estimation was only in the order of 0.025-0.125% suggesting an increase of only 0.3-1.5 weaners per year. We did not include this benefit in the results due to the overall assessment identifying relatively small potential benefits (Fig. 20).

The use of pasture sensing could be integrated into property two management fairly quickly and would complement the manager's focus on data-intensive property management. As a result we estimated 80% of these benefits to accrue within 5-10 years (Fig. 20).

Case study three

Pasture sensing was seen as an important tool for the manager of property three providing information for planning future development and improving management within the limitations of current resources. Due to the current fast pace of development on property three, the manager found it difficult to estimate expected benefits from the use of remotely sensed pasture information, although he made it clear that he felt there would be some benefit.

The manager found it difficult to estimate the scale of the benefit. Two project team members felt that pasture sensing could provide improvement in the number of cattle that were finished by enabling the manager to optimise the use of the available pasture. The estimate of increases in number of growing cattle was between 2 and 5% (Fig. 20). Such changes would require a medium level of time to accrue due to the need to analyse and interpret data and update development plans appropriately. We estimated that the benefits accrue over a period of 5-10 years ($r=0.5$).

Case study four

Property four currently undertakes pasture monitoring and assessment as part of normal operations. The manager usually undertakes this monitoring and so the associated costs can be classed as overhead costs. Nevertheless, two of the three project team members were in agreement with the manager that quantitative and regular pasture/feed assessment could help facilitate improvements in production associated with increases in the total output of cattle. The estimated benefit from remote sensing is captured in the confidence to respond to changing pasture conditions. Stocking rate over time is determined by a series of short-term carrying capacity decisions. The estimated benefit of remote sensing for property four is captured as an increase in the breeding herd. Such a benefit would require some learning and integration of pasture sensing tools and data into current operations suggesting a medium-slow rate of benefit accrual – we estimated 80% of these benefits would accrue within 10-15 years (Fig. 20) ($r=0.4$).

Case study five

The manager felt that existing pasture-monitoring technologies were adequate and remote pasture monitoring would not provide additional improvements in management, long-term carrying capacity, or risk management. Furthermore, the manager did not believe that the use of pasture monitoring technology would alleviate the costs associated with the current assessment system that are considered as overhead costs.

The project team estimated that an objective and accurate pasture measurement system could help in feed assessment. The benefits were considered in terms of 'better risk management'. In this analysis it was estimated that improvements in long-term carrying capacity were more likely to be the logical result of improvements in pasture monitoring as they are associated with better control of downside risks (droughts, over-stocking etc.).

Benefits were estimated to accrue relatively slowly due to the need for further refinement of this technology and its integration (and building of trust) within current management operations. We estimated that most benefits would accrue within 15-20 years (Fig. 20).

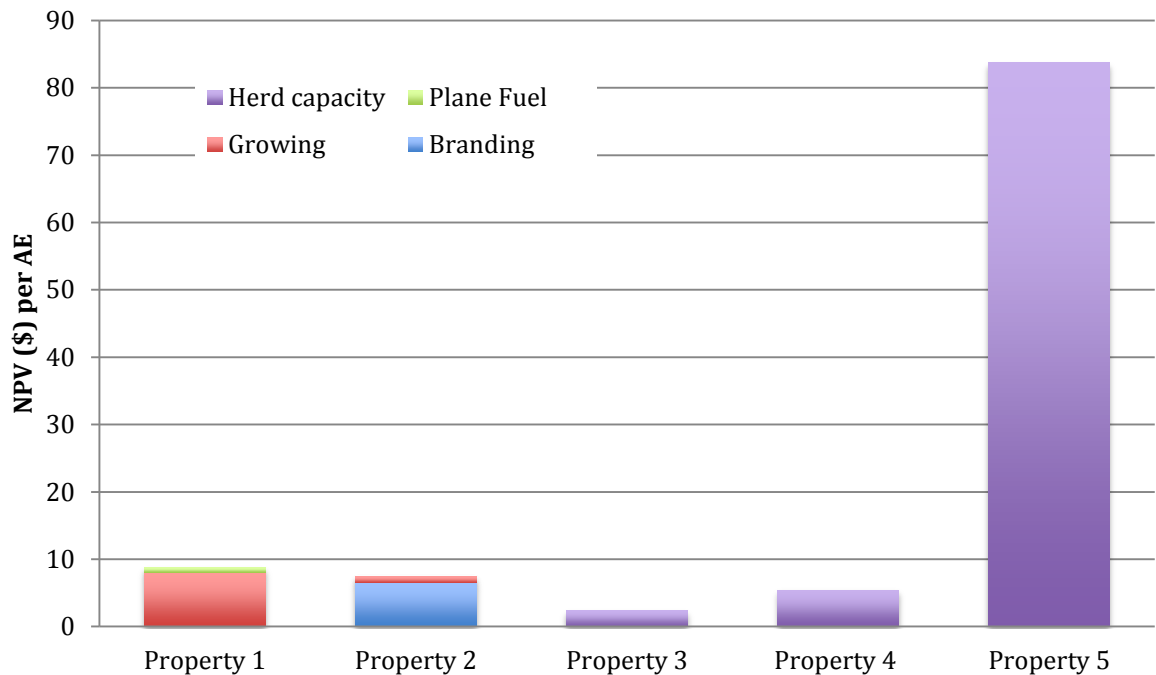


Figure 20 – Net present value of benefits per adult equivalent for automated vegetation assessment on all five properties

Pasture sensing provided the largest potential benefit-cost ratio for all properties (Fig. 21). The reason for such large returns on investment is the modest price of obtaining remote sensing images. The managers were less able to define benefits for automated pasture sensing so although it shows a significant benefit-cost ratio it is not altogether clear how the technology will be used.

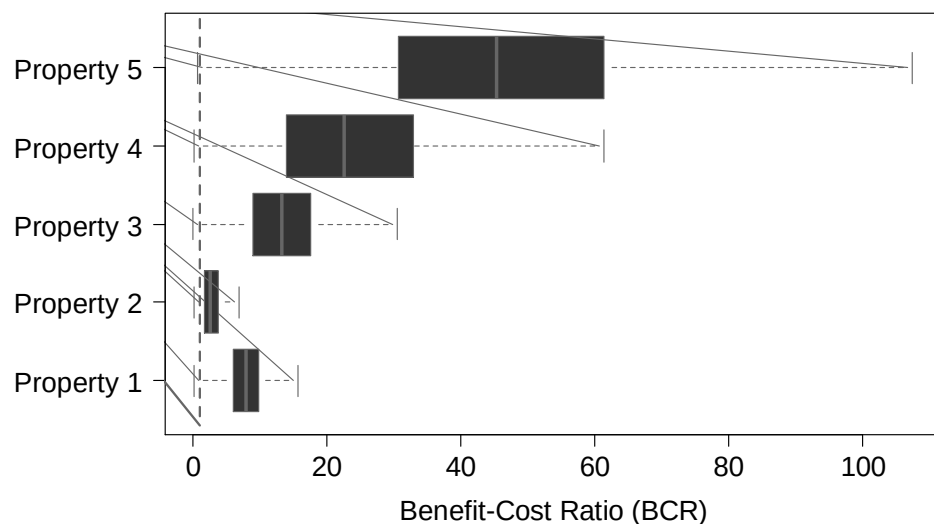


Figure 21 – Benefit cost ratio for automated pasture sensing for all five properties

5. Discussion

5.1 Evaluation of methods

In the absence of actual data the subjective assessment of benefits combined with a statistical model provided a method to rank a number of potential benefits from a number of technologies. The methods used were focussed on the specific conditions of each of the case study properties. Weaknesses of the study include the lack of certainty about the reliability of perceptions of the nature and size of benefits from technologies and the capacity to generalise across the northern beef industry. By involving both the managers and the project team it enabled statistical output that provided an indication of the relative risk of deriving a benefit from a particular technology. The time available to discuss the benefits of six technologies across a whole enterprise necessitated relatively high-level estimation of benefits. The project team put considerable effort in to trying to identify and refine plausible mechanism for a benefit (covered in a later section), however, there is scope for further work to refine and validate these mechanisms.

The semi-structured interview provided the opportunity to explore a range of potential benefits. The process allowed the managers to integrate his/her knowledge of their own property within the benefits assessment. Clearly there is no such thing as a typical property and any atypical characteristics of the individual case studies in part reflected diversity in management focus.

The input from the project team members provided a wider set of values that were used to derive statistical output that formed part of the economic assessment. The project team members all had research knowledge of the technology and over the last five to ten years had given considerable thought to potential applications. The project team members all had knowledge of the drivers behind beef production systems; however, they lacked detailed knowledge of the practical operations of the case study properties.

Confidence in the ranking of the benefits estimates and the link to potential economic outcomes

The detailed benefits estimates and input for the modelling can be found in Appendix 2. Whilst the level of support for a benefit is captured in the outputs these benefits are still only estimates. The benefits are expressed as a percentage improvement in either a cost saving or a production output. While there are no clear cut-off points the estimation of benefits falls into those that have average median values that are greater than 5% and those that fall below 5%. The larger the percentage benefit, as reflected in the average median value, indicates greater agreement and greater confidence in the benefit by the property manager and the project team members. Confidence by the property manager and the project team does not mean there will be a benefit, however, in the context of this study this confidence can be used to help identify technologies that have greater potential benefits.

Using the 5% benefit cut-off value the following were the technologies and applications that were ranked by the project team and the property manager as having the greatest potential impact:

1. E-preg saving vet costs on property 4.
2. WoW and auto-draft saving heli mustering on properties 1, 3 and 5 and labour saving at mustering on properties 4 and 5.
3. Coarse location information saving heli mustering costs on properties 1, 3 and 4 and increasing herd size by reducing stragglers on property 5.
4. Fine location information had the same savings as coarse location plus an additional saving on bull purchases on properties 2, 3 and 4.
5. Automated vegetation assessment could be used to give better manage forage resulting in increased herd size on property 5.

In general there was much better agreement for cost saving benefits. An example of good agreement over cost savings was the estimation of benefits from coarse-resolution location data to reduce heli-mustering time. This agreement was consistent across properties one, three and four. Equally there was very poor agreement and support for coarse-resolution location information to assist in improving branding rates, with only one of the project team members supporting the benefit for property one. There was no support for increased branding rates on properties three or four. Although we report on a potential benefit for coarse location information to increase branding rates the estimated percentage improvement is small (<1%) for property one. The lack of support suggests low confidence and indicates there was not a clear mechanism identified for the technology to have a direct benefit.

Confidence that a technology will have a positive benefit (measured as a percentage improvement) does not mean that it will have an economic benefit. For example e-Preg was estimated to have the potential to make a 30% saving in vet costs for property four, despite having a large impact on vet based pregnancy testing overall this was a relatively low cost item. It was more difficult to reliably estimate production benefits and these benefit estimates tended to be below the 5% improvement level; however, where a technology had the potential to lift branding rates this resulted in a larger economic benefit. Detailed discussion of the benefits estimates follows, however, using technology to measure and record post partum anoestrus interval and linking this to both male and female genetics to improve reproductive performance had important potential economic benefits. The cost benefit analysis showed that WoW with auto-drafting and automated pasture assessment provided the best opportunity to derive a positive economic return from the technologies.

5.2 An assessment of the benefits estimates

It was possible to map some benefits onto specific cost saving or production improvements e.g. coarse location information helping to reduce heli-mustering costs. By breaking the enterprise into sub units we attempted to try and elucidate a more detailed mechanistic explanation of the benefits. This

approach was sometimes successful but within the time constraints for each case study there were situations where lack of background information resulted in the plausibility of the benefit being less well argued. The project team have provided all of the benefit estimates to facilitate discussion and debate around the application of the technologies. The following sections provide some more detailed critical discussion around the mechanisms that could underpin some of the benefits that were suggested through the case-study interviews.

The case-study properties were not always typical industry examples, either in their structure or their operating focus. For example the large investment and intensification on property three made it a very untypical Barkly property. The estimates of a benefit by the manager often reflected a management focus or a particular problem within the enterprise. The importance of previous on-property experience with a technology was demonstrated on property one which had experience of WoW and was able to provide much more detailed estimates of a broader range of benefits for that technology.

Implicit in the discussions with the managers was a realisation that the PLM technologies required a rethink of the operational aspects of the business. It was not possible to fully explore how the technologies would bed into a working operation. The managers, however, did provide some insight into the sorts of factors that were important to realise a particular benefit. Some of the discussion around the mechanisms is provided in the benefits assessment section of the report; we have taken the major themes and explored whether these estimated benefits make sense in relation to the existing literature.

Branding rates

Improving reproductive performance provides a clear strategy for improving profitability, however, branding rates are influenced by a number of factors. In general the improved branding rates provided an easy focus and the estimates of the benefits didn't always make it clear how this was going to be achieved.

The PLM focus for lifting branding rates was based on a need to add value to existing genetic selection. Implicit in the interview discussion was recognition by the managers that selection of replacement heifers based on maternal traits could provide an opportunity to lift rates of genetic gain (Roughsedge *et al.* 2005). The current focus on improving reproductive capacity through improved genetics is less about direct improvement and more about indirect benefits by identifying and removing poor performers. The opportunity to identify the top performers i.e. those cows that have a low post partum anoestrus interval (PPAI) and get in calf early in the mating season, could help lift the overall reproductive performance of the breeder herd. Using female traits to identify elite cows and bulls that can be used for replacements relies on identifying parentage and getting better information on reproductive status (Simm *et al.* 1996). Both spatial location data and WoW provide opportunities for assigning maternal parentage (Swain and Bishop-Hurley,

2007) and e-Preg provides the possibility to extend pregnancy testing and identify cows with a low PPAI. Whilst current pregnancy testing methods including ageing foetuses could be used to identify the pregnancy status of cows the opportunity to have a flexible low skill method for monitoring pregnancy status of the cows was considered an important benefit by the managers. Often ease of use and convenience are important drivers of change and the information collected during the interviews indicated that some of the case study managers would use an e-Preg system in a bid to lift branding rates by identifying those cows that had higher reproductive performance. It should be noted that bull selection was still considered an important determinant of genetic improvement but female selection and female reproductive traits provided an opportunity to speed up and lift the overall rates of genetic gain, particularly when using a nucleus herd to breed bulls.

At least one of the producers indicated that using e-Preg would lift branding rates by reducing losses that were associated with an internal rectal pregnancy test. A review of the literature provides evidence that in dairy cows there is a chance of a small (<5%) direct foetal loss through rectal palpation (Romano *et al.* 2007; Romano *et al.* 2011), in addition rectal palpation results in a strong increase in circulating cortisol indicating that the procedure is stressful (Cingi *et al.* 2012). The literature indicates that there are potential risks of disease spread through rectal examination, for example bovine viral diarrhoea virus (BVDV) (Lang-Ree *et al.* 1994). There is evidence that BVDV can affect reproduction rates in cattle (Fray *et al.* 2000; Grooms 2004). However, the project team could not find details of any direct studies that have been carried out to determine the risk of spread of BVDV through rectal examination in northern Australia. There may be other disease risks from rectal examinations. The benefit of using e-Preg to reduce disease spread and associated losses from either aborted foetuses or through the birth of diseased and weak calves are difficult to determine. The estimates of the benefits provided in the report need further research to provide more robust values. It is clear that e-Preg has the potential to reduce the risk of disease spread, however, until more detailed information on what is causing foetus losses is obtained the estimates of the value of e-Preg cannot be fully determined.

Identifying working bulls

Three of the four properties that were running breeders were carrying over 4% bulls. The industry recommendation is for 2.5% of the herd to be bulls when bulls are selected on the basis of a bull breeding soundness examination (BBSE). The managers from the properties that had higher bull percentages all indicated that they used extra bulls as an insurance measure. All three of the managers also indicated that bulls were a significant cost to their operations. There was estimated to be a benefit to the business by reducing the number of bulls on the property, provided it didn't affect conception rates. Prior to purchasing a bull measures of value via a physical assessment of soundness provide the industry standard for recommended bull:cow ratios.

The physical measure of a bull does not, however, indicate a bull's willingness to work.

Using PLM technology to measure behaviours that identify whether a bull is willing to work were considered to provide benefits. On further investigation these benefits are blurred by practical constraints. For a manager to measure a bull's libido requires the bull to be on the property, once a bull is purchased this eliminates any cost saving benefits. It is unclear the extent that measures of bull libido can complement BBSE measures; further work would need to be done to quantify the potential benefit.

There are a number of PLM technologies where management changes are linked to confidence and associated with better knowledge of risk. Risk management may not have an immediate production benefit but will reduce the chance of a future cost. The discussions with the property managers indicated that if they were able to measure the libido of a bull they would be prepared to purchase fewer bulls. The PLM technology doesn't change the risk of purchasing a bull that doesn't work, however, it does enable the producer to quantify and manage the risk better.

The project did not quantify benefits associated with confidence and associated risk management. Further work would be required to fully explore the effect of PLM on attitudinal changes; however, the informal interview process provided the opportunity for managers to nominate benefits. The association between the PLM technology and confidence of risk management linked to reduced bull purchases may help to explain why three of the case studies put a focus on the benefit of PLM for managing bull purchases.

Growth rates and increased stocking rates

A number of technologies were identified as providing the opportunity for improved growth rates of cattle or enabling increased stocking rates. In particular WoW and remote vegetation sensing. The logic behind the benefits were based on improved direct or indirect information on available feed to make more timely decisions (Woodward *et al.* 1993). It is unclear whether higher spatial and temporal monitoring will be able to identify opportunities to increase productivity and evidence from the Wambiana trial suggests that trying to lift short-term stocking rate above the long-term carrying capacity carries significant risk of degrading the forage base (O'Reagain *et al.* 2011). Grazing ruminant research has emphasised the importance of timely cattle movement to optimise grazing intake and maintain growth rates (Boyd *et al.* 2001). The extent to which the managers on the case study properties were optimising forage resources was not directly measured. A number of managers, however, indicated that they could improve forage use and lift growth rates if they were able to track the condition of available forage. The literature supports that more detailed pasture assessment enables managers to optimise forage resources (Smith *et al.* 2011). Most studies that have assessed pasture-monitoring tools have been focussed on more intensive temperate grazing systems. These more intensive grazing systems are more

homogeneous than the more extensive production systems that typified the case study properties. It is also easier to provide a more complete assessment of the forage availability on smaller more intensive grazing properties. The scale of the case study properties restricted the manager's ability to provide a whole of property assessment of forage availability.

When discussing the opportunities for remote sensing technology the project team avoided discussions around practical limitations of current remote sensing applications. The scenario that was presented to the managers was focussed on a remote sensing technology platform that could provide full spatial coverage and indicate the current state of the paddocks. The current state of the paddocks referred to the forage feed resources. The managers agreed that a direct assessment of the pasture conditions (pasture growth rate and biomass) would be most useful. If it was not possible to provide direct measures of pasture condition the managers indicated that there were benefits that could be gained through indirect measures e.g. using WoW to track cattle growth rates.

The literature supports measures of production can aid management decisions. Whether pasture monitoring can deliver benefits will depend on the extent to which remote sensing of highly heterogeneous pastures can provide useful information to aid management decisions and the extent of the current utilisation.

Auto-mustering

There were a number of managers who indicated that a combined WoW and auto drafting system would reduce mustering costs. Clearly this is a direct benefit, however, the extent to which an electronic based mustering system has any advantage over more traditional mob based mustering systems using spear traps, which are a cheaper option. Whilst the managers referred to using the PLM technology to save mustering costs there was an implicit assumption that this would extend beyond group mustering.

There is very little literature on the benefits of WoW and auto-drafting. The managers, however, were looking ahead in terms of modifying their current operations. There were two examples provided by two managers where they could see direct benefits of combining electronic ID with animal weight data and auto-drafting to enable more efficient mustering. Both of these examples aimed to use the weight and ID information to select a specific class of animal. These classes of cattle would enable property one to optimize loading of cattle that were being trucked off the property and for property five to select cattle that were at target market weight. The selection of subsets of cattle avoided unnecessary disturbance to the larger group and reduced weight loss by shortening the length of time animals are off feed.

The other examples where producers identified WoW and auto-drafting to reduce mustering costs were less clear in terms of the benefits over more

traditional spear traps. The managers did, however, express a desire to use data on the cattle performance to trigger a mustering event.

All managers identified mustering as a significant cost to their business and a desire to reduce this cost. Mustering currently focuses on all cattle in a group in a paddock. The managers indicated that the opportunity to identify and select individual animals using an ID and auto-drafting system could, if coupled with other changes create new ways of managing cattle where more regular work on smaller numbers of cattle might reduce peak labour demands. These benefits were unclear but the interview process indicated that the managers were willing to consider new ways of managing cattle that could capture the benefit of PLM and the use of WoW and auto-drafting.

6. Conclusions and recommendations

The analysis of various PLM technologies across a range of properties provided an opportunity to assess a range of potential benefits. Broadly speaking the benefits can be divided between opportunities to increase production and opportunities to save costs. The cost saving benefits were much easier to identify and quantify and there was generally good agreement between the estimates of the benefit e.g. savings in helicopter mustering or bull purchases. The production benefits were harder to estimate and there was less agreement on the production outcomes. In many cases the manager had a strategic direction for the business and considered the benefits of the technologies in the context the direction the property was heading. All of the managers demonstrated a progressive attitude towards and recognised the importance of detailed monitoring for improved business decisions. On this basis the production benefits of the PLM technologies fell under two sub-categories: those technologies that supported an existing management direction and those that created and helped develop a new business opportunity. An example of the former is property three where the manager was progressively moving towards rotational grazing and wanted to use WoW to reduce mustering costs. An example of the second category was the manager of property two who was moving into leucaena and wanted to use WoW to monitor the growth rates of his cattle so he could refine stocking rates to optimise the new system.

The broad range of benefits that were identified through the project indicates that the informal interview process that incorporated explicit subjective assessment methods was successful in identifying potential PLM benefits. It is less clear whether the process was able to provide a reliable estimate of the extent of a given benefit. Given the lack of detailed data on the operational aspects of the PLM technologies it is not surprising that it was sometimes difficult to estimate the scale of a potential benefit. The subjective process provided an opportunity to identify those benefits that were strongly supported by all assessors. Finally by using mid, upper and lower estimates of benefits within a stochastic model we were able to generate probability distributions of the benefits to allow an assessment of the potential uncertainty and associated risk of implementing a technology. The modelling focused on the net present value of benefits and also generated benefit-cost ratios. Due to

the emerging nature of the technologies there is still some uncertainty around the cost to a producer. Whilst the project team discussed benefits in terms of technologies they always focused on the functional benefits e.g. location rather than global positioning system.

There were a number of technology applications that appeared to show promise but there was uncertainty over whether the technology could deliver. In particular, property three and four identified that buying bulls was expensive and the managers were uncertain whether all of their bulls were working. The managers all agreed that the opportunity to provide quantitative data on bull activity would be useful and for those properties that were running in excess of 3.5% bull to cow ratio there was the potential to reduce these numbers without compromising in calf rates. Understanding how bull libido data might be used to reduce costs needs further investigation. If there is a robust mechanism to use bull behavioural data then a practical application of the either coarse or fine-resolution spatial monitoring needs to be developed.

When mustering larger paddocks a large amount of time is spent searching for the cattle, the opportunity to identify the location of the cattle prior to mustering has the potential to save significant amounts of money particularly when helicopter mustering. Despite the poor benefit-cost ratio of the coarse and fine resolution location devices the managers identified that the technology could help alleviate costs to their production. The Taggle technology has not been widely used, and a deployment may identify additional benefits and possible technology cost savings, which could enable a more significant positive return on investment.

The WoW and auto-drafting system was seen to have value for precision management of growing cattle. This management included better information for forward marketing, selecting the cattle that were ready for market and reduced mustering costs in cell or rotational grazing systems. It was not clear the extent to which WoW systems would facilitate better forward marketing. Whether the WoW and auto drafting system could be used to separate and muster smaller groups of cattle from a larger mob was also not clear. The benefit of WoW and auto drafting compared with alternative technologies such as spear traps alone requires the system to be able to sub-divide larger mobs. There were discussions over how useful the WoW and auto-drafting system would be in paddocks where it was not possible to control access to all water sources. Further work is required on the practicalities of running WoW and auto-drafting in paddocks where water points are difficult to manage.

The main benefit that was identified for the e-Preg system was the opportunity to use unskilled labour for pregnancy testing. It was not very clear how the benefits of using unskilled labour would be realised, however, there was reasonable agreement that with a shortage of skilled labour that the e-Preg system provided an opportunity for an unskilled person to complete pregnancy testing. There may be labour cost-saving benefits by using lower skilled labour to pregnancy test. In addition the e-Preg device could address the problem of having to replace skilled labour when a skilled preg tester

leaves. The managers required evidence that an unskilled person could provide reliable pregnancy diagnosis.

All properties expressed interest in knowing more about the spatial distribution of forage. The larger properties indicated that they tended to stock more conservatively on the basis that it was not good management to try and take the system right to the edge. Property five was adopting the most intensive and detailed forage management system and was most clearly able to identify and articulate potential benefits of automated pasture assessment. The detailed knowledge and intensive pasture management system of property five is reflected in the highest estimated benefit. However, it is unclear whether emerging remote sensing products will be useful for managers to adjust their stocking rates or implement management strategies in response to changing forage availability.

This project has identified a number of questions related to the development and application of a range of PLM technologies. The recommendations aim to create an opportunity to address uncertainty and refine the value proposition. There are three core areas of work that appear to be important and within these areas there are a series of sub-activities. The following provides a series of recommendations:

1. The model developed in this project has the potential to refine the estimates of benefits. Greater confidence in potential PLM applications will result from more refined consideration of specific benefits. This extension of the modelling would enable greater input into the statistical assessment of PLM technologies across a broader range of enterprises.
2. There were a number of estimates of benefits that showed some potential, however, there are issues of the confidence in the subjective estimates of benefits. Specific areas that showed economic potential and would benefit from further work include:
 - 2.1. Testing whether measures of bull libido using PLM can be used to complement existing bull soundness measures; reducing costs on bulls purchases or improving herd reproductive performance.
 - 2.2. Identifying the extent that location information can be used to reduce heli-mustering costs.
 - 2.3. Examining whether spatial and temporal remote sensing information can be used to refine management decisions for northern beef production system and whether short term stocking rates decisions based on remote sensing compromise long-term carrying capacity.
 - 2.4. Exploring whether low skilled workers can deliver reliable pregnancy information using an e-Preg device.
 - 2.5. Identifying how e-Preg technology can be used to determine the post partum anoestrus interval and whether this has any direct cost savings over traditional foetal ageing.

- 2.6. Exploring how ID based auto-drafting can be used to more effectively muster and manage sub-groups of cattle from within a larger mob.
3. Understanding the application of PLM technology to improve overall management requires knowledge on the interactions of technologies within a systems based approach. The PLM work would benefit from demonstration facilities that can evaluate the systems level economic outcomes from emerging technologies. Combined WoW, auto-drafting, coarse location and remote sensing technologies provide opportunities to improve operational and production efficiency and these technologies all had applications that had average benefits estimates that were greater than 5% (e-Preg and fine scale location technologies need further development). Coordinated demonstration and evaluation that uses agreed data collection protocols (e.g. data resolution and delivery) that can be used to explore how these technologies change management practice would help to refine the value proposition. This work would benefit from building on existing research activities being delivered by a number of research groups.

7. References

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