ACIL ALLEN CONSULTING

Precise positioning in the agricultural sector

An estimate of the economic and social benefits of the use of augmented GNSS services in the agricultural sector

Prepared for the Department of Industry, Innovation, Climate Change, Research and Tertiary Education

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Executive Summary

Australian agriculture competes in global markets some of which are subject to protection, others to production subsidies. To maintain competitiveness it is essential that the industry continues to improve its productivity.

Augmented GNSS services are part of meeting this challenge. They are used in agriculture in combination with other technologies such as remote sensing, auto steer equipment and yield monitoring systems. Collectively these technologies are known as precision agriculture.

The main adoption of precision agriculture in Australia to date has been in broad acre cropping (primarily wheat, barley, oats) and other crops such as cotton. This has been at 10 cm accuracy levels.

Precision agriculture is used in a more diverse range of farms internationally than in Australia. This is largely because intensive livestock farming is more common in other countries than in Australia.

Cattle and calf slaughtering is the largest single contributor to value of agriculture in Australia (18 per cent)[1]. Positioning services in this sector are only likely to be taken up if technological change allows low cost electronic livestock tagging.

Wheat (12 per cent) is the next most important product after cattle[2]. More than 87 per cent of grains farmers use some form of precision agriculture, including 79 per cent who use 10cm accuracy GNSS positioning services.

Productivity improvements are estimated to range between 10 per cent and 20 per cent of production costs.

More precise positioning to 2 cm accuracy offers economic benefits in some other agricultural sectors:

- Cotton, where a large majority of growers already use positioning and are set up to take advantage of greater precision, realising increased savings from application of pesticides and fertiliser; and
- Grape growing, where high precision can improve vine canopy management and harvesting. However because the industry has had limited adoption to date benefits will require new investment and thus take longer to realise.

Extension of 2 cm accuracy augmentation signals would support greater adoption including:

- inter-row sowing of crops, with nutrition and water use benefits
- micro-irrigation (delivery of water to individual plants)

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[1] ABS Year Book Australia 2012

[2] Ibid.

- increase in the level of benefits realised from reduced overlap in application of fertilizers and pesticides.

The results show that industries in the agricultural sector grew as a result of improvements in productivity from the use of augmented GNSS in precision agriculture as well as in other industries[3]:

- Output in the sector was between $298 million and $466 million higher in 2012 as a result of the use and application of augmented GNSS in the grains industry and elsewhere. This represents between 0.9 and 1.5 per cent of the grains and cropping sectors' output.
- Output is projected to be between $885 million and $2185 million higher by 2020 with further adoption mainly in the grains and livestock industries. This represents around 2.6 per cent and 6.5 per cent of the grains, crops and livestock sectors' output.

Most of this growth is in the grains sector. Barriers to achieving high levels of adoption outside of grains and cotton include:

- In cattle, costs associated with electronic tagging of beasts well exceed benefits potentially realisable from positioning.
- In dairy, adjustment pressures have limited farmers' ability to invest in tracking equipment. There is also crowding out of investment by the changes being pursued through the "future dairy" initiative.
- in grape growing, scepticism about the benefits of positioning
- in horticulture, the small scale and dispersed nature of many of the businesses involved.

In the latter two cases, encouragement of early adopters and documentation of the financial benefits is likely to lead to a similar "S-curve" adoption pattern as that seen in grains over recent years.

As well as economic benefits there are environmental benefits to the use of precise positioning in agriculture including:

- more efficient water use
- reduced runoff of farm chemicals into the environment
- better management of disease outbreaks.

Key findings

- Economic benefits in cropping from the application of precision agriculture supported by augmented GNSS are large, enabling recovery of investment rapidly, sometimes within less than two years.
- Adoption rates in agriculture fluctuate considerably depending on seasonal factors – farmers' ability to invest in on farm productivity improvement depends on a good season. The highest adoption levels have been in the grains and cropping.

[3] The growth in output is a net effect after resources are reallocated across the economy.

- Applications in the grains industry include automatic guidance and controlled traffic farming, variable rate fertiliser application and inter-row sowing. Cost savings of between 10 to 50 per cent have been reported. By researchers.
- Adoption rates in the livestock and horticulture and viticulture areas have been slow to develop.
- Higher adoption rates will be assisted by extension of GNSS augmentation services at the 2 cm level of accuracy. This could be achieved for example through the expansion of CORS networks in Australia.
- Augmented GNSS can also deliver considerable environmental benefits, particularly in more efficient use of water and minimising chemical runoff.

1 Introduction

ACIL Allen Consulting, in partnership with SKM and Lester Franks Surveyors and Planners, has been commissioned by the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education to assess the value of augmented positioning services in Australia.

The purpose of this report is to provide an understanding of the economic and social benefits of precise positioning information within the agricultural sector. This information is to allow better informed decision-making and assist in identifying areas for growth and investment from both the private sector and government. It will also provide context to the National Positioning Infrastructure Plan being developed by Geoscience Australia.

2 The Agricultural sector

The Australian Bureau of Agriculture and Resource Economics and Sciences (ABARES) estimates agriculture's share of GDP as 2.0 per cent (farm only) or 2.4 per cent (total agriculture))[4]. Higher figures up to 3 per cent of total GDP are used by some sources.[5]

The value of agricultural production varies considerably year on year due to climate and market volatility. For the year ending 30 June 2010, the gross value of agricultural production, in current prices, was $39.6 billion"[6] In the following year, 2010-11, the gross value of total Australian agricultural production was $46.0 billion.[7]

In recent times, the agricultural commodities with the highest value of production by Australian farmers have been beef cattle, followed by wheat, milk, vegetables, fruit and nuts, sheep and lamb meat, and wool.[8]

The 2010-11 Agricultural Census[9] found that there were 135,000 farm businesses across Australia. The majority of these were involved in specialised

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[4] (Agricultural commodity statistics 2012 (chain volume).

[5] As noted by the ABS, "The contribution of agriculture to the Australian economy can be measured in a number of ways" 1301.0 - Year Book Australia, 2012. The range of estimates depends on how wide a definition of agriculture is applied and the methodology for measurement. The DIISRTE publication *Key Facts Australian Industry 2011-12* (www.innovation.gov.au) indicates the share of total industry value added of agriculture, fisheries and forestry combined in 2011-12 was 2.7% and share of GDP 2.4%. The National Farmers Federation estimates agriculture at 3% (Farm Facts 2012).

[6] ABS Cat 1301.0 - Year Book Australia, 2012.

[7] ABS Cat. 7503.0 - Value of Agricultural Commodities Produced, Australia, 2010-11 June 2012

[88] ABS Cat 1301.0 Year Book Australia, 2012

[9] ABS Cat 7121.0, released 29 June 2012

beef cattle farming (28%), mixed grain-sheep or grain-beef cattle farming (9%), other grain growing (9%) or specialised sheep farming (8%).

As noted by the ABS most of Australia's agricultural businesses are "engaged in beef cattle farming, dairy cattle farming, sheep farming, grain growing, or a mixture of two or more of these activities". For mixed farms, farmers' choice of enterprise depends on their individual estimation (based on their own appetite for risk) of likely returns from different products and likely seasonal conditions. This means adoption rates and benefits of positioning are highly variable across the industry.

Agriculture in Australia uses a large proportion of natural resources, including 52% of water use in 2009–10. Spatial information is an increasingly important tool for sustainable management of these resources.

2.1 Positioning and agriculture

Precise positioning with augmented GNSS is a key component of what is often termed precision agriculture – the use of technology to deliver on farm productivity improvements. To date in Australia precision agriculture has primarily been used to deliver improved vehicle guidance, as a result of which better positioning services have been seen largely in the broad acre cropping[10] sector.

Uses include minimising overlap in application of fertilisers and pesticides, lower compaction as farm vehicles' movements are guided precisely to minimise impacts on a paddock, more effective spraying and more precise sowing resulting in lower seed loss. This practice goes by a variety of names including controlled guidance, controlled tracking, or tram tracking. Appendix B provides an outline of the use of GNSS in variable rate and site specific technologies.

The accompanying overview document to this series of reports outlines the infrastructure associated with introduction of augmented GNSS to enhance the accuracy of positioning services.

Agriculture's needs in relation to positioning services are growing. As identified in this study, the current use is primarily in cropping and a level of precision around 10 cm meets present uses. However, productivity through positioning technology could be enhanced through:

- Extending coverage of services in remote areas
- Identifying applications for livestock
- Greater precision down to 2cm to enable emerging applications such as inter-row sowing.

[10] Including grains such as wheat and barley, oilseeds such as canola, lupins (grown as stock feed) and other pulses for human consumption (various varieties of beans and peas).

3 Use and applications of Augmented GNSS in Australian agriculture

3.1 Grains

Grains are the largest segment of the agricultural sector in terms of land under cultivation and second only to cattle slaughtering in terms of value of production. Wheat is the dominant crop, accounting for $4.8b or 12 per cent of the gross value of agricultural production in 2009-10 (ABS, 2012).

Use of precise positioning to date in grains has concentrated in two areas: yield monitoring; and reduction in soil compaction through "tram tacking" of remotely controlled vehicles. This has been possible with 10cm accuracy. Whelan (2012) notes that reducing overlap down to 10cm translates to savings of between $12 per hectare and $23 per hectare on seed, fertiliser and machinery costs at sowing; $1.40 per hectare and $3.20 per hectare on herbicide, fungicide and machinery costs, and total savings of between $13.40 per hectare and $26.20 per hectare (Australian dollars). He also notes that there are associated environmental benefits.

The Grains Research and Development Corporation (GRDC) 2007 report *The economic benefits of precision agriculture: case studies of Australian farmers*[11] provided case studies of Australia farmers adopting variable rate application of fertiliser and realising benefits ranging from $14 to $30 per hectare. Although capital investment was high, from $55,000 to $189,000, the investment was recovered "within 2-5 years of the outlay, and in four out of the six cases within 2-3 years".

Precision agriculture can also enhance productivity by allowing speedier harvest using farm machinery in closer array and also enabling use of machinery in periods of low visibility.

The benefits of auto steer for controlled traffic farming can only be realised through machine guidance, typically accomplished by using high accuracy (±2cm) GPS technology. The key benefits documented in a study of controlled traffic farming on the Darling Downs by Bowman in 2008 included:

- 68% increase in farm gross margin
- 67% reduction in farm labour costs
- 90% reduction in soil erosion
- 93% reduction in Nitrogen loss through runoff
- 52% reduction in CO_2 emissions
- 52% reduction in diesel use
- 45% reduction in repair and maintenance costs (Bowman 2008).

[11] Research conducted by Robertson, Carberry, Brennan, CSIRO Sustainable Ecosystems

Figure 1 **Use of precision guided vehicles**

Source: Omnistar

The GRDC biennial survey of growers shows a significant trend upwards in adoption of precision agriculture:

Table 1 **Grains – survey of growers**

	2010 percentage	2012 percentage
Using some form of precision agriculture technology	77	87
GPS	68	79
Yield monitoring	39	53
Controlled traffic	22	39

Data source: GRDC – interview by ACIL Allen Consulting.

The primary reason for the high rate of uptake in the last two years has been that the cash flow associated with recent good seasons has enabled increased capital investment. Today, precision agriculture is seen increasingly as "the standard way" (GRDC interview) to manage a grains farm. Investments at present are mainly being made in auto steer and yield monitoring equipment. The next steps identified in the adoption curve for precise positioning were variable rate application and satellite imagery for crop management. Adoption of precision agriculture is still underway with a large number of possible future applications with further benefits yet to be realised (GRDC interview).

3.1.1 Benefits of more precise positioning

One of the areas where very high precision (<2cm) has greatest potential for large productivity gains is in inter-row sowing (source; GRDC interview). Sowing between the rows of the previous year's grain crop minimises losses from crown rot, assists germination, enables better stubble management, minimises moisture loss and increases nutrient take-up.

Figure 2 **Inter-row sowing – canola in between rows of wheat stubble**

Source: Whelan 2012t

In this example, a new wheat crop is sown after the canola harvest, meaning the wheat is not sown directly on the stubble of the previous wheat crop. This reduces disease from cereal crop residue, and means the wheat can take up nutrients from the decaying canola roots.

Figure 3 **Inter-row sowing – wheat sown over the canola crop**

Source: Whelan 2012

Based on interviews, the gains in yield are potentially of the order of 10-20 per cent. This translates to a productivity gain of around 1 per cent.

A recent study[12] found that farmers could "profit from inter row sowing via,

- increased production (wheat, lentils, canola) of 0.2 to 0.4 tonne per hectare in stubble retained systems
- reduced costs with less stubble management ($10-25 per hectare)
- increased herbicide efficacy
- reduced sowing problems and improved crop establishment…"

3.2 Viticulture

Based on overseas experience, better vine management and fertiliser application could be expected to increase yields by around 10-15%. These results need to be tested in practice in Australia. The CSIRO project *Precision viticulture, understanding vineyard variability* notes that

> Grape growers and winemakers have known about vineyard variability for as long as they have been growing grapes and making wine…However, without methods for

[12] McCallum, Matt (2011) *Agronomic benefits of inter-row sowing with 2 cm autosteer systems*

> observing or reacting to this variation, they have been forced to treat it as 'noise' and to manage large blocks as though they were uniform…PV addresses variation through the use of enabling technologies, including the global positioning system (GPS) and geographical information systems (GIS), coupled with tools for measuring and monitoring vineyards at high spatial resolution

These possible applications "can be highly profitable" according to CSIRO (2012) but further research is required in order to allow reliable quantification of the possible productivity gains.

3.2.1 Vineyard production and monitoring in New Zealand

Controlled traffic farming has also been adopted in New Zealand as part of vineyard production, specifically in planning the routes taken by vineyard machinery for spraying and harvesting. Augmented GNSS guidance units are used to develop on-screen maps that indicate the optimum route to follow along vine rows (e.g. the best turning circles for harvesters or sprayers to take). An important commercial benefit is the reduction in overlaps. Benefits due to reduced overlap of spraying were estimated in the order of 11% savings on spraying costs[13] . Another benefit is that spraying and harvesting can be undertaken during periods of poor visibility that are affected by weather or the time of day.

Augmented GNSS guidance units have also resulted in time savings due to the ability to monitor the efficiency of production, including monitoring harvester and sprayer route, movement, speed, fuel consumption, and engine temperature. Recent evidence suggests time savings of between 1% and 10% are attributable to monitoring via the GNSS units[14].

Augmented GNSS units also provide data on where in a vineyard certain grape varieties have been harvested from. This allows winemakers to define sub-blocks within a vineyard on the basis of the characteristics of the grapes within them, and to harvest and blend batches of grapes from different blocks. This enhances the traceability of the product, through a record system that can identify sources of components of a wine blend back to their locations within the vineyard[15].

The level of adoption of these technologies in Australia however is low.

3.3 Dairy

Dairy has also been slow to take up precision agriculture. Eastwood (2008) notes that the gap between research and practice has not been bridged and

[13] GPS Equipment Supplier Interview.

[14] Vineyard Estate Owner Interview.

[15] *Lloyd Smith & Peter Whigham 1999:* Spatial Aspects of Vineyard Management and Wine Grape Production. Presented at SIRC 99 – The 11th Annual Colloquium of the Spatial Information Research Centre University of Otago, Dunedin, New Zealand December 13-15th 1999.

attributes this primarily to a lack of a community of practice among dairy farmers in the techniques involved.

Dairy Australia has funded a large and multifaceted project on "Future Dairy" which has a stream on precision dairy, among other things. Even here, the focus is on automated milking rather than use of positioning to improve dairy traffic (movements of cows) as has happened internationally.

For this project we interviewed the largest Australian dairy cooperative, Murray Goulburn. Although their representative thought it was possible some farmers may be using GPS for herd management, he did not personally know of any examples and was not aware of any widespread adoption. Cost pressures and structural adjustment in the industry are possible reasons for low adoption.

3.4 Cotton

Cotton growing in Australia is highly dependent on availability of irrigation water to growers. In recent years plentiful water supply has seen record levels of cotton production, at around one million tonnes. The area planted to cotton is around 500m hectares, primarily irrigated. If ABARES' production forecasts for 2012-13 are realised Australia will overtake India to become the world's second largest cotton exporter after the United States (ABARES 2012). Gross value of cotton production in 2009-10 was $754m.

Smart and Sauer (2011)[16] note that

> "cotton growers in Australia are not only familiar with the term precision agriculture but are also very familiar with the concepts, solutions, and products that are available".

Cotton is a heavy user of agricultural chemicals and pesticides, and precise positioning to reduce overlap and enable accurate site specific application generates large savings. Productivity gains of the order of 1-2 per cent have been reported[17]. Precision agriculture is widely used for application of farm chemicals and more accurate use of farm machinery in harvesting. The use of positioning is combined with electromagnetic induction surveys to identify soil variability and moisture content.

3.5 Beef and sheep

Positioning at either 10 cm or more precise 2 cm levels has no currently feasible widespread application to low intensity cattle and sheep grazing on unimproved pasture, across large areas such as in Australia. The broad range of most Australian beef and sheep farming means that there has been less incentive for farmers to use positioning to determine grazing habits and

[16] In the *Australian Cotton Production Manual – 2011*, Cotton CRC

[17] Cotton Industry CRC

optimise feed availability (the most common applications of GNSS technology for livestock management in other countries with different farm systems[18]).

GNSS has been used as a research tool in studies of livestock movements and habits (for example the University of New England has a number of projects that use tracking devices on stock for research purposes).

There are however potential commercial applications of positioning in future. These include use of pilotless aircraft (drones) for mustering, based on positioning devices attached to each animal – provided barriers of cost and battery life for such devices can be overcome. A study of future potential of precision agriculture to beef cattle found that:

> …remote animal control devices can be used for implementation. This technology relates the GPS position of the animal to spatially fixed coordinates on the ground (the control barrier) and modifies the behaviour of the animal as it approaches the invisible barrier by elicitating an audio or electrical cue from a neck-mounted device. Current research is focused on reducing the size and optimizing the power supply and usage of these devices.[19]

3.6 Sugarcane

Sugarcane for crushing is an important agricultural product in Australia, accounting for $1.4b of the gross value of agricultural production in 2009-10 (ABS 2012). More than 90 per cent is grown in Queensland. In 2009-10 a total of 389,000 hectares of sugar cane was cut for crushing (ABS 2012).

Sugar has been a slow adopter of precision agriculture (see following chapter in relation to barriers to adoption in Australia).

According to the CSIRO recent developments suggest however that sugar is about to move rapidly up the adoption curve:

> Work conducted 10-20 years ago demonstrated that, like other farming systems, sugarcane production may be highly variable at the sub-paddock scale…In spite of this, and for various reasons, whilst growers of grain crops and winegrapes have adopted PA approaches, almost no adoption occurred in the sugar industry.
>
> Over the last two to three years, there has been a rapid uptake of GPS-based guidance and controlled traffic systems as the sugar industry moves towards the 'new farming system' and associated efforts to minimise soil compaction.

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[18] Trotter MG, Lamb DW (2008)'GPS tracking for monitoring animal, plant and soil interactions in livestock systems' In *9th International Conference on Precision Agriculture* Denver, Colorado.

[19] Bell, Charmley, Hunter, Archer (2011) 'The Australasian beef industries—Challenges and opportunities in the 21st century' *Animal Frontiers* Champaign Illinois

3.7 Horticulture

The horticulture sector is highly diverse. There is sparse evidence of use of positioning services at present 10 cm levels of accuracy, and the instances identified in a search of the literature appear to be primarily from promotional materials or experimental trials. Examples include:

- Use of unmanned aerial vehicles to monitor tree health and predict yield and harvest times in macadamia orchards – with tree management at sites located on the ground using GNSS coordinates (Horticulture Australia 2012)
- Use in apple orchards of precision guidance systems for robotic vehicles equipped with colour sensors to detect ripeness[20]

As Horticulture Australia (2012) indicates:

> The horticulture industry however has been slower to take up these technologies due to the smaller scale of our farms and the enormous variability across our growing systems (eg. regions, climatic influences, range of plant physiology – orchards vs plantations vs field crops vs protected cropping, seasonality requirements, etc). However the industry is now showing strong signs of interest to learn…precision agriculture is considered a relevant and important emerging technology.

Higher precision positioning services at 2cm accuracy may increase adoption levels. They open up opportunities in areas such as very precise micro-irrigation (drip irrigation targeted to each plant, resulting in minimal water loss), and improved harvest management of high value horticultural crops (for example, fruit for the Japanese export market).

4 Barriers to adoption

Technology diffusion rates in agriculture are slow by comparison with other industries. Farmers will adopt new technologies only if they offer a clearly demonstrated commercial advantage. If early adopters are seen by others in the industry to benefit, then diffusion can be rapid. However, the inherent variability of farming in Australia due to both climate and market volatility can mask the evidence of commercial benefits and impede diffusion.

Ground based survey marks thus remain the most important element of the geographic information infrastructure for agriculture, and use of positioning outside of grain growing is limited. This is though a common pattern of adoption internationally:

> In new countries (or new crop commodities), yield mapping and the option of variable-rate application for inputs are generally what gets things started as a means to save costs, while, in time, product quality comes more into focus[21]

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[20] 'Robots to drones, Australia eyes high-tech farm help to grow food' Reuters 27th May, 2013

[21] McBratney, Whelan, Ancev "Future Directions of Precision Agriculture" *Precision Agriculture* 6, 7-23, 2005, Springer.

The USA and some parts of Europe were earlier to adopt precision agriculture than Australia. The recognised adoption pattern is outlined in Whelan (2007):

1. optimise average crop management
2. determine the magnitude, extent and responsiveness of spatial and temporal variability
3. optimise the production input/output ratio for quantity and quality. (to maximize gross margin and minimize environmental footprint)
4. Output quality control and product marketing
5. maintaining resource-base and operation information.

As with all industrial technologies, the pattern of adoption follows an S-curve: slow early experimentation, realisation of benefits and rapid take-up, then levelling off as technology matures. Precision agriculture in Australia is only at the start of that curve.

As noted by Robertson et al (2010), a current barrier to adoption is the perceived complexity of precision agriculture "the relative difficulty of understanding and using a new system and lack of industry capacity to provide specialist technical services to growers can be a constraint to adoption…many growers find the complexity of PA technology, its demands and lack of service make it incompatible with their current farming operations".

As the industry matures, the perceptions about complexity are likely to diminish (assuming Australian farming follows the identified international experience). Grain growers have shown that as benefits are realised, adoption spreads wider. In addition, support services will become more available and at lower cost – an inevitable function of market development.

Coverage of augmented positioning is currently provided either commercially through space based or local RTK systems supplied either by Government or industry itself. In some cases farmers employ opportunistic measures such as the back cast of AMSA's DGPS beacons along the coast. The extension of the CORS network would provide a more consistent availability and range of applications. This should result in increased adoption over the longer term as authoritative augmented signals become available more widely.

5 Estimate of impacts

The impacts of the benefits described above are both direct and indirect. We estimated first the direct productivity impacts on the agricultural enterprises studied. This provided the direct impacts on the sector.

The overall impact on the sector and the economy as a whole depends on resource shifts in the economy. The wider results were derived from the CGE[22] modelling.

5.1 Productivity

ACIL Allan (2008) provided a set of estimates of assumed direct impacts of precision farming on agriculture. Based on the information derived from the case studies undertaken for this report, the impacts outside of grains remain small, but the grains impact has increased considerably due to increased uptake by the industry.

Precision farming requires augmented GNSS. Without it the systems and techniques described in this report would not be possible. Therefore we have credited the benefits to the availability of precision GNSS despite the fact that other technologies such as remote sensing and auto steer and yield monitoring systems are also contributors.

A factor that has to be taken into account is the variability in Australian rainfall and other climatic factors that have a marked impact on both the gains from precision agriculture and the take up rates. In those agricultural sectors more affected by climatic variability the benefits from precise positioning are likely to be lower.

The estimates are based on two scenarios – low levels of adoption, and current potential future benefits if adoption rates are higher and in future become more widespread.   The estimates are provided for 2012 and 2020 in Table 2 and Table 3 respectively. The tables list the assumptions.

Table 2 **Productivity impacts of precision farming 2012**

Enterprise	Assumptions	Direct impact (low)	Direct impact (high)
Grains (wheat, barley, etc.)	Controlled traffic, yield monitoring, variable rate application. Adoption averaging 40% across different applications, with 80% of grains farmers adopting at least one GNSS application. Savings in costs of between 12% and 20%.	4.8%	8.0%
Other cropping and agriculture	Low take-up apart from cotton based on evidence from CSIRO and other sources. Adoption 7%.	0.1%	0.3%

Note: Based on case studies and literature review. Precision farming is dependent on precise positioning
Data source: ACIL Allen

[22] CGE stands for Computable General Equilibrium modelling. This is discussed in more detail in the overview report.

Table 3 **Productivity impacts of precision farming 2020**

Enterprise	Assumptions	Direct impact (low)	Direct impact (high)
Grains (wheat, barley, etc.)	Low case as above plus adoption of inter row sowing and other yield improvement methods. High case assumes most grain growers adopting full range of precision agriculture techniques. Assumes 40 per cent adoption for the low case and 100 per cent adoption for the high case. Savings in costs of between 12% and 20%.	12.5%	20.0%
Dairy, beef	Adoption of most promising practices overseas. On an assumption that low cost livestock tags can be developed	1.0%	15.0%
Other cropping including sugar cane	Some adoption as lessons from grains spread more widely. High case as for grains – noting that not all cropping will have the same opportunities for adoption of the full suite of applications.	0.2%	15.0%

Note: Based on case studies and literature review. Precision farming is dependent on precise positioning

Data source: ACIL Allen

The low case is the most conservative, and assumes that the levels of diffusion of knowledge and technology has and will remain limited outside of grains and that costs of entry (estimated between $20,000 to $120,000, CSIRO 2007 and Robertson 2010) will remain a barrier to adoption.

5.2 Economic impact

The productivity improvements described above allow the agricultural industries, to grow through greater efficiency and lower costs. The ultimate outcome for the sector, as for the economy as a whole, depends on resource shifts in the economy. The economy wide outcomes are derived from the CGE[23] modelling which is discussed in the overview report.

The results of this modelling for growth in the agricultural sector are shown in Table 4 below.

[23] CGE stands for computable general equilibrium modelling. For more information see the overview report.

Table 4 **Increase in output from the agricultural sector**

	2012 low case		2012 high case		2020 low case		2020 high case	
	$million	Change	$million	Change	$million	Change	$million	Change
Grains	279	1.9%	434	2.9%	773	7.6%	1,377	13.8%
Dairy, beef	18	0.1%	29	0.2%	105	0.4%	791	3.3%
Other cropping (inc sugar cane)	1	0.1%	2	0.2%	6	0.4%	17	1.1%
Total	298	0.9%	466	1.5%	885	2.6%	2,185	6.5%

Note: All amounts in $2013

Data source: ACIL Allen modelling

The results show that industries in the agricultural sector grow as a result of improvements in productivity from the use of augmented GNSS in precision agriculture [24]:

- Output in the sector was between $298 million and $466 million higher in 2012 as a result of the use and application of augmented GNSS in the grains industry and elsewhere. This represents between 0.9 and 1.5 per cent of the grains and cropping output.
- Output is projected to be between $885 million and $2,185 million higher by 2020 with further adoption in the grains and livestock industries. This represents around 2.6 per cent and 6.5 per cent of the grains, crops and livestock sector output.

The grains industry accounts for over 90 per cent of the higher output from the agricultural sector in 2012. This reflects the relatively high levels of adoption of precision farming techniques by the grains sector and the high efficiency gains the industry can achieve as a result.

The "High Case" outcome for 2020 is somewhat speculative, assuming close to 100 per cent take up in grains sector and significant innovation in the use of augmented GNSS in the livestock industry (see Section 3.5). The latter developments are still at the research and development stage.

6 Other economic and social benefits

6.1 Environmental water benefits

Considerable social and economic benefits to Australian farming and the environment more broadly will arise from improved water usage enabled by precise positioning. Precision agriculture allows savings both as a result of better nutrient take up by crops as well as in irrigation. Techniques such as inter-row sowing have an advantage not only for crop productivity but also for water use, because the stubble from the previous crop shades the roots of the growing inter-row crop enabling it to thrive with lower water input. Inter-row

[24] The growth in output is a net effect after resources are reallocated across the economy.

sowing relies on <2cm positioning to enable the new crop to be grown in between the rows established by the precise positioning of the previous crop

Advances in micro-irrigation enabled by precise positioning are similarly likely to deliver considerable water savings for irrigated crops. To date low levels of take up by fruit and vegetable growers can be in part explained by timing: drought at the early stages of positioning technology and relatively plentiful water supply as precise positioning technology has matured. If however drought conditions were to reassert themselves in key locations in the Murray-Darling Basin, precision irrigation is likely to gain greater prominence as one of the ways of addressing the resultant water shortages.

6.2 Other environmental benefits

More precise application of farm chemicals means less runoff, which has considerable benefits for environmentally sensitive regions. Sugar is one of the industries where runoff has been a particular issue due to the impact of fertilizers on fragile reef systems. According to the CSIRO (2012)

> Part of the intuitive appeal of PA is that by maximising the efficiency with which inputs, such as fertilizers, are used, the risk of them being lost off-site is reduced… the sugar industry has begun to use this idea to promote its environmental credentials.

6.3 Biosecurity

Spatial information can also assist in biosecurity control. As noted in ACIL Allen's earlier report on the value of spatial information, it played an important part in managing the spread of equine influenza in NSW in 2007 through publication of maps showing restriction zones (ACIL Tasman 2009).

In future, this kind of application could potentially be combined with stock tags that could deliver an electric impulse to livestock that strayed close to boundaries. This would enable more efficient management of control zones in the event of a serious and widespread animal disease.

Appendix A Variable rate and site specific technology

Variable rate and site specific technology (VR and SST) allow farmers to apply fertiliser and other agricultural chemicals differentially within a paddock depending on data on yields obtained through satellite surveys.

Figure 4 **Sensors mounted on tractor and trailed sprayer**

Source: McVeagh et al. 2012

Case studies on application of nitrogenous fertilisers in Victoria have indicated that farmer adoption rates for VR and SST have been low because "grain growers do not deem variability within a paddock to be sufficient enough to warrant more precise treatment" (DPI 2012).

Whelan (2012) notes that site specific crop management (SSCM) "creates the opportunity to increase the number of (correct) decisions per hectare made about crop management" with large potential productivity gains. He notes that reducing overlap down to 10cm translates to savings of between:

- A$12/ha and A$23/ha on seed, fertiliser and machinery costs at sowing;
- A$1.40/ha and A$3.20 /ha on herbicide, fungicide and machinery costs
- Total savings of between A$13.40/ha & A$26.20/ha and associated environmental benefits.

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Note: in addition to the references cited, other information has been drawn from the *Proceedings of the 15th Precision Agriculture Symposium in Australia*, 5-6 September 2012, Mildura.