Maximising returns on winter cropping in southern Australia

Viability of continuous cropping and use of unmanned machinery to address labour constraints

A report for

NUFFIELD AUSTRALIA FARMING SCHOLARS

by Bruce Thompson (2007 Scholar)

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Scholar Contact Details
Bruce Thompson
"Eromross"
RSS 3585
Temora NSW 2666

Phone: 02 6973 7552
Fax: 02 6973 7244
Email: eromros@bigpond.com

In submitting this report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

Nuffield Australia Contact Details

Nuffield Australia
Telephone: (02) 69 64 6600
Facsimile: (02) 69 64 1605
Email: enquiries@nuffield.com.au
PO Box 1385, Griffith NSW 2680

Foreword

The comments and opinions in this paper are based on my personal findings. No responsibility for the comments can be attributed to Nuffield Australia or any affiliated party.

Acknowledgments

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Finally, I particularly wish to express my appreciation and gratitude to all those people who generously made time to see me during my study – I have listed them at Annex A.

Contents

Abbreviations

Corn / maize	Grain grown for human consumption, stock feed & ethanol
CIMMYT	Centro Internacional de Mejoramiento de Maiz e Trigo, Mexico (International Maize and Wheat Improvement Centre)
FOB	Free on Board (loaded on a ship at a port)
GMOs	An organism with genetic material that has been altered by genetic engineering
Genetics	The science of heredity and variation in living organisms
Legume	Broad leaf plant which fixes nitrogen in the soil – e.g. soy beans, lucerne, lupins, peas, faba beans
Lucerne / alfalfa	Broad leaf perennial plant used for grazing & hay production
Roundup	Non – selective chemical, Glyphosate, produced by Monsanto
Basta	Non – selective chemical, Glufosinate-ammonium, produced by Bayer
Stacks	Name used for more than one trait in GMO varieties
Bio-fuels	Covers Ethanol and Bio-diesel
DARPA	Defence Advanced Research Projects Agency - US
Autonomist	The name for something that is independent
PTO	Power Take Off – Fixed drive shaft from the tractor to the implement
GPS	Global Positioning System – US satellite constellation of 24 satellites
UAV	Unmanned Aviation Vehicle – Pilot less plane or drone
ROPS	Rollover protective structure – is a cabin or frame that provides a safe environment for the operator in the event of a rollover
Pseudo Satellites	Expensive ground based satellites
IMU's	Inertial Measurement Units - gyros that track movement

Executive Summary

Continuous Cropping

1. Wheat is the biggest winter crop (by tonnage) produced in Australia, and comprises 12% of the world export trade (climatic conditions permitting).
2. Wheat appears likely to remain a competitive Australian crop in global free trade.
3. In southern NSW farmers in most cases, rotate wheat with broadleaf crops to maximise wheat production.
4. Resistant weeds (currently rye grass) are the biggest barrier to continuous winter cropping in Australia.
5. Resistant weeds can be reduced or eliminated with the use of non–selective chemicals.
6. Genetically modified organisms (GMO's) offer the only access to crop varieties with non–selective chemical traits.
7. Crops with non–selective traits give farmers easier management options, with a wider window to address problem weeds, and the use of more user friendly chemicals.
8. New cropping varieties need to be adapted to local conditions – however, it can take significantly less time to adapt varieties with productivity gains than develop new from scratch.
9. Increases in returns from farming the land will make the farming sector hard to beat especially when you factor the capital gain from the land as well.

Robotics / Unmanned Farm Machinery

1. Greater production per labour unit is not new
2. The three components to unmanned farm machinery are GPS, hydraulics and computers.
3. Most of the costs are in the initial computer program, and to reproduce this program is very cheap.
4. Mining and Aviation are trialling and using unmanned equipment.
5. Agricultural systems have been trialled since 2001 but are not commercially available.
6. Removing the operator would bring the liability risk back onto the company who developed and sold the machine.
7. Lead vehicles are being trialled for movements along public thoroughfares.
8. When purchasing in the future, farmers will have a choice of standard or autonomist machines.

Introduction

The general aim of this study has been to examine aspects of farming which could contribute to more consistent farm income. I focused primarily on the potential for continuous cropping on loam soils instead of running a mixed farming stock/pasture phase in southern New South Wales (NSW). I also considered the potential to address labour efficiencies through use of unmanned farm machinery.

In continuous cropping cycles, weed resistance (e.g. rye grass) is generally the biggest hurdle in areas where summer cropping is not an option. It is most easily addressed by a pasture phase, which allows a wider use of chemicals for weed control and nutrient top up for future crops. However, there is often less return per hectare during the pasture phase than the cropping phase.

Robotics, in the form of unmanned farm machinery, offers potential for maximising labour efficiencies and reducing the cost of grain production per hectare. Unmanned farm machinery could be used for broad acre agriculture operations such as sowing, fertilizing, spreading, spraying and harvesting. Such machinery could result in an increase in scale and/or hours of use while staying within the ideal window for the operation. There was only limited information available about forthcoming commercial products due to the competitive nature of this developing industry.

This plough and plaque at the entrance of one of our properties
– highlights the changes in grain growing in the past 100 years.

Continuous Cropping

During the period February to August 2007 I studied aspects related to continuous cropping systems in Argentina, Brazil, Canada, France, the United Kingdom and the United States. I was interested in how other farmers balanced maximising returns against the high cost of land and production limitations (including increasing fertiliser costs).

I have divided the following discussion into segments: an introductory comment on land values and cropping practice in some other countries, the longer term viability of wheat as a primary crop, the emerging biofuels market, a brief comment on the complications of globalisation, and the potential of emerging genetics technology to support continuous cropping.

Owning & Farming versus Leasing & Farming

There was an interesting difference in approach in areas where farm land values were continuing to rise (for differing reasons in different regions) and arguably moving ahead at a faster rate than the returns received from the investment in grain production. In some countries there seemed to be a greater percentage of landholders leasing land to farmers for rent, rather than farming the land directly. For example, in Alberta, Canada, city based investors or owners appear to lease or rent the land at between 2.5% – 5% of land value, and factor in a capital gain to give a good investment return, while deriving an income from some other means. Managed funds and investment institutions seemed more interested in owning agriculture land than farming it, and would be hesitant to purchase unless they had someone to take on the day to day risk of the farming.

In the United Kingdom, increased urban pressure and continued rises in housing prices is affecting farm land values with city people finding better value or more affordability to buy a home in the countryside and commute to work. This is causing farmers to review how they can get a greater return from the land.

In Argentina, for example, land value reviews for leasing/renting periods were being shortened (e.g. from five to three years or even annually) to keep pace with changing land values, with farmers concerned about ever increasing rental costs. Researchers[1] noted that some farmers would be more inclined to reduce input costs and "mine" the soil.

[1] Facultad de Ciencias Agrarias Balcarce, Universidad Nacional de Mar de Plata

With regard to continuous cropping in Argentina, land rental costs, fertiliser costs and government taxes seemed to particularly influence cropping choices. The standard rotation of wheat-corn or wheat–soy beans in one year was changing to barley-soy beans, to allow more time to plant the soy bean crop in the optimum window. In the past wheat had been the priority crop with soy beans planted in a short window after harvest and often resulting in reduced yield due to late plantings. However, priority was increasingly being given to soy beans as the main crop. Soy beans are cheaper to grow due to the lower cost of nutrient inputs and also provide nutrient benefit for the following crop. Some were now choosing barley as a winter crop due to its shorter growing season.

Increased fertilizer costs (from US$360 to US$550 per ton by mid 2007) and limited availability were expected to force Argentinean farmers to move away from plantings of corn (a big user of nutrient). Argentina has a government tax on all export grains, from 0–24% depending on amount of processing or value adding involved before export. Wheat incurs a 20% tax on the FOB price (Free on Board) while soy beans which are mostly crushed for the oil have a 5% tax on the oil. Argentina is the number one country in the world for exporting soy bean oil and sunflower oil.

The big agriculture food state of California in the United States of America (US) is the number one irrigation state and grows 283 different crops. The San Joaquin valley is moving away from traditional crops, with the number one crop cotton reduced in acreage by 50% in the last ten years. It has been replaced by higher value almond and pistachio nuts, table and wine grapes and tomatoes, with issues over the best use of available water and increasing land values. The concept of "Pay back", a term for the amount of years needed to pay off land, was commonly used as a gauge of fair land values, and if the price would take more than five years to pay back, land was considered too expensive to purchase. In our business here in Australia, the price of land purchases reflect a 10 year pay back.

In comparison, in southern New South Wales, the traditional approach has been a mixed farming environment with stock and crop enterprises running together. This creates a more complicated business but tends to have a lower risk given our variable climate and a lower return. In a normal year, there can be lower costs on the livestock side of the operation, with the bonus of nutrient gains from the pasture phase, making problem weed management more easily addressed.

However, stock feed production can limit potentially more valuable grain production by using moisture and nutrient which could be carried over for the following crop. The reliance on grazing crops for winter feed, to fill the gap in pasture growth, can increase the amount of lower value grains grown, with the added cost of establishment and removal of the pasture.

Wheat

Australia is a wheat growing nation and relies heavily on exports. Wheat is the biggest winter crop grown and there is very good infrastructure in place to handle this from the paddock to the seaboard for export. With world production of 600 million tons, 100 million tons of this is traded annually, Australia averages 12% of this market from a domestic production of 20 to 25 million tons annually (weather permitting). All export wheat is handled by one authority called the Australian Wheat Board. This single seller system handles all of the grain and pays all producers the same amount per ton, with no preference on the amount of tons delivered. This single seller system is currently under review.

With the introduction of break crops (rotating between narrow and broad leaf plants) in the late 1970's, wheat yields increased and became more consistent to a stage where climatic conditions and genetics seem to be the limiting factor. The use of canola, lupins or field peas as break crops assured the grower a better wheat crop potential, due to disease break, weed control and soil structure improvements from nitrogen fixation or root penetration. This allowed maximum yield potential to be achieved more regularly, instead of the wheat following cereal systems of the past.

In Southern NSW and the southern states that farm on lighter or earth loam soils (which tend to be more acid than alkaline), farmers are more restricted in rotational options for wheat crops. Generally canola seems to win out over legume peas and lupins as a more profitable option, but this is not the case in all areas as some find the legume more reliable and profitable plant. With nutrient prices rising to record highs on the back of the ethanol maize frenzy, this will certainly affect the mix of crops grown in the future. Other broadleaf crops which have been tried but not widely accepted include chick peas and faba beans.

90% of Australian wheat varieties are derived from breeding conducted by the International Maize and Wheat Improvement Centre (CIMMYT) in Mexico. CIMMYT researchers are convinced that with everything being equal, rotating crops, stubble retention and minimum tillage give the best yield after a four year period.

International Maize and Wheat Improvement Centre

(Centro Internacional de Mejoramiento de Maiz e Trigo - CIMMYT)

Mexico

CIMMYT was established in the 1950's, with a mission to relieve hunger and poverty in the world. This organization is representing thirty countries in the breeding of better wheat and corn varieties, and also holds 160,000 samples in a seed bank. Utilising eighty scientists, nine thousand researchers world wide, and ship nearly 500,000 packets of seed per year. In 1970 Norman Borlauge received a Nobel Peace Prize for his success in breeding high yielding semi dwarf wheat varieties.

The gene and seed banks are housed on an eight hundred acre farm outside Mexico City. Trialling thirty two management systems since 1991, researchers are continually looking for improvements in tillage, rotations, water infiltration and stubble retention. Twenty five international guests are invited each year to add new ideas.

CIMMYT research on tillage and rotations – March 2007

Biofuels – grain for energy not food

"This is the biggest thing in agriculture since the industrial revolution "

Dr John Dunn – Director of Cooperative Resource Management – USDA

The changing face of agriculture is coming in the way of grain production for energy purposes and the ripples are being felt world wide. The US mandate to replace 50% of imported oil (20% of domestic usage) with biofuels by the year 2015 led to large planting increases in corn in 2007, which in turn drove fertilizer and chemical prices up. US Homeland Security is happy with energy supplies being more secure from risks related to international conflict. The green movement responded positively to the idea of less fossil fuels being removed from the earth, but may not have been fully aware that a lot of fertilizer would be needed to grow the crops, and that much of the environmental farm land in set aside programs (where farmers are paid to not crop) would be put back under corn. The biggest corn states in the US (Iowa & Illinois) are politically sensitive, with politicians trying very hard to win votes in these states.

World grain prices are expected to maintain higher averages in the future. With a new buyer in the market in the form of biofuels, the food and stock feed sector will have to compete with an industry that does not place as much importance on quality, and will pay more to secure product. The intensive livestock industry is likely to be the first to be impacted with increased grain prices, as chicken and pork are not able to use the waste products of the ethanol plants in these early days. The US Government is planning that no more than 25% of the expanded corn crop be used for ethanol, or it will have to put more support schemes in place to help the stock feed sector.

A Brazilian economist, Aercio Dos Santos Cunha[2], noted in March 2007 that the US had asked Brazil if it could help the US meet its target, as Brazil was self sufficient in energy and had been using sugar cane for ethanol since 1976. The 50% mandate equates to 200 billion litres of fuel per year, and is a moving target that will grow over the next eight years. 25% of the US corn crop would give 15 billion litres, with another 20 billion litres coming from cellulostics from wood chips, stubble and waste products, leaving a gap of around 165 billion litres.

[2] Dr Aércio dos Santos Cunha is a consultant on agricultural issues to the Brazilian Congress.

Some years ago apparently Japan had rejected a Brazilian proposal to supply ethanol to Japan for a 10% blend, as Brazil was the only supplier in the world resulting in limited negotiating power for Japan. However, with US biofuel commencing and other countries showing interest, the Japanese government had approached Brazil for supply of 200 billion litres, currently beyond Brazil's self-sufficient production of 17 billion litres per year. This emerging global market is likely to have a huge impact across many parts of agriculture.

Peter Ninnes, Contracts and Grant Officer at CIMMYT, is concern about the impact that the US mandate would have, and considered that all breeding programs world wide would go over to a focus on energy-related production in the next five years. This would likely include sugar cane varieties that could grow in the marginal climates of Africa and Australia.

Gary Hoard, a specialist lucerne (alfalfa) breeder, at Pioneer's Hi-Bred International Inc research centre in Des Moines in Iowa, expressed concern about potential loss of research funding. Lucerne was the fourth biggest crop grown in the state, and was used extensively by the dairy industry. With corn (maize) the number one crop grown, and big increases in plantings due to the forward prices being offered, this was directly impacting on the area available for growing soy beans (number two in the state) and lucerne. There was a risk of lucerne becoming an insignificant crop due to reduced acres planted and companies reviewing or stopping funding of research programs, with breeders becoming redundant. Therefore this research program was working towards stripping the leaf off the lucerne plant for the stock feed sector, and then harvesting the stalk for cellulostics (ethanol production).

Trialling of 16 corn varieties with stack traits (of which 14 are ethanol-related) at the Pioneer Hi-Bred International Inc Centre in Des Moines, Iowa – July 2007

Globalisation

Global free trade in agriculture could significantly change existing opportunities. Mexico is a country that has made changes over the last 20 years due it's involvement in the NAFTA (North American Free Trade Agreement) group, consisting of Canada, Mexico and the US. Mexico, originally a self sufficient grain producer and exporter, has been competitive in vegetables and livestock but not in grains, resulting in the demise of grain breeding programs. Mexico now imports soybeans (80% of domestic consumption), rice (60%), oats & barley (50%) and wheat (40%).

In considering the future of Australian grain production and the likely implications of global free trade one area in which Australia appears likely to retain a good future is that of wheat.

Genetics

Genetics is the area that farmers are looking towards for future improvements and productivity gains. Nearly all the other parts of growing, maintaining and harvesting of grain crops have already been evaluated and modernized. Unlike Mexico, for example, Australia has scale and mechanisation in the grains industry allowing competitiveness on a global stage.

Genetic modification (GM) and the value associated with Plant Breeders Rights (PBRs) is big business in today's changing world. Expensive testing and trials can take a number of years to get to the stage of commercial release, with many new varieties finding little or no grower acceptance, then increasing the on going costs of further breeding program. While farmers appreciate the need for more research and breeding programs, they are unlikely to spend money on varieties that do not give a commercial return.

There has been big planting of some genetically modified varieties (e.g. cotton, soy beans, corn, and canola) in some parts of the world. These genetically modified varieties (GMOs) have the ability to resist certain chemicals, with the biggest uptake by farmers of varieties for non-selective chemicals in the way of Glufosinate-ammonium (Basta) and Glyphosate (Roundup) or a combination of both (called "stacks" - which is becoming more common in the new varieties of corn being released). GMOs are promoted on the idea that the grower will receive multiple traits in one plant with chemical resistance, insect resistance, root disease resistance, leaf disease resistance and yield increases as the plant can make better utilisation of moisture and nutrients. In addition, growers can expect easier management with a wider range of chemical groups for problem weeds.

Canola in Australia has moved through from the standard canolas, which have limited chemical options, to Triazines (Simazine – Atrizine) chemical group, finishing with the Clearfield options (Imidazolinones) that allow group B chemicals to be applied. However, Canada continued to allow farmers to have access to the latest technology in the form of GMOs, with 90% of canola grown with the use of Basta or Roundup and most of the remaining 10% is Clearfield. The use of standard canola's is expected to rise, now that problem weeds that were unprofitable to compete with, have reduced in numbers enough or been totally removed.

The NSW government has had a moratorium in place to stop the growing of GM canola, but has lifted this to give farmers the option from February 2008.

Australian farmers have not been allowed to use GMOs, except for cotton and cut flowers. Debate about the use (or not) of GMOs includes concerns about potential loss of existing markets, corporate companies gaining monopolistic marketing power, direct and indirect implications for the food chain, organic industry concerns about contamination of their product in the supply chain and contamination/cross pollination, as well as potential for increased market opportunities, positive environmental impacts and yield increases.

Australia is being left behind to the amusement of other countries. Canadian farmers only wanted GM canola but rejected the GM wheat option, as this would need the use of more selective chemicals when killing volunteer wheat plants. The rejection of GM wheat is grower led and Canadian farmers did not appear willing to consider this option until the chemical companies could provide a cheap alternative for killing the volunteer wheat, especially in a canola crop.

US industry people considered Canada would be left behind (like Australia on canola) by not adopting wheat genetics which were planned to deliver 80% yield increases, on 50% of the nutrient, with release dates likely before 2012.

Kent McKay, Extension Officer with North Dakota Research & Extension Center, considered that with no Roundup Ready Wheat in Canada " they will not get the drought, yield, root and fungal traits - they will get left behind ".

On the canola front he considered 150 pounds of fertilizer was needed to grow 2000 pounds of canola per acre at the moment, with work being done on new generation varieties that would deliver 4-5 traits with the Basta and Roundup genes in place, and have a reduction of 100 pounds per acre of fertilizer to achieve the same yield.

In the early days of GMO releases, companies released varieties of corn, soy beans and canola with claims of many benefits, especially yield increases that were questioned at a grower level. Ten years down the track all industry people and growers agree there are definite gains and measurable progress in productivity. New varieties will not be released in the future until they do have the gains and traits to give greater returns to the grower with Kent considering no GM wheat varieties would be released before 2010.

I believe that using GM varieties with non-selective chemical traits, growers would be able to have continuous cropping as an achievable option, instead of being pressured into a pasture phase, hay production or buying expensive equipment for trash collection when harvesting or shielded sprayers and wider sowing rows. The reason for the pasture phase is to control problem or resistant weeds, and add nutrient for future crops. High nutrient levels have been difficult to manage in the drier years of this century, with not enough moisture to go with the high levels of nitrogen, often over cooking the crop grown, and giving a lesser or non return from the paddock.

Management of problem weeds would be so much easier using Roundup in crop when the chemical can be applied in the early stages of establishment, and then later before flowering to control late emerging weeds. Reducing weed populations greatly or eliminating them altogether, lessens the chance of resistance from the wider use of chemicals available in crop, and lessens weed numbers from which resistance develops.

40% of the Canadian canola crop uses the Bayer-Liberty lines, which use the chemical Basta for weed control. The chemical is considered not to be the best on grass weeds, and performs better in warm weather. It may be limited on the Australian market because canola is grown as a winter crop, compared with Canada growing canola in the warmer months. Farmers would more than likely favour the Roundup options of the two chemicals, but the best option would be a stack of both. The US corn growers use Basta early in the crop, then Roundup late to clean up any missed weeds. In Australia reversing the applications could be the better option with the use of Roundup early, and Basta later in the crop, when the day length and temperatures are increasing.

If nutrient input costs continue to remain high, there could be implications for choice of legumes and canola as rotation crops. New GM varieties with planned nutrient efficiencies would be greatly accepted by farmers. In response to sustained increases in global fertilizer pricing, farmers would be likely to move more towards legumes as a nutrient source in the short term.

I note, however, that lack of crop competition tends to bring on resistance to weeds at a faster rate. Non selective chemicals in legumes would greatly help with the control of late rye grass in these crops.

Legumes may be chosen instead of canola in crop rotation, especially if they became available with a wider range of chemical options, and more consistent markets are found. More legumes could go into the stock feed market replacing other grains destined for ethanol, and some consider a human consumption market could be developed in China in the future.

China has an ever increasing population that is ageing at a faster rate, due to the government's one child policy. When incomes increase people change their diet, as happened in Korea and Japan with more protein and meat included in diets. However, China has a unique age range with a higher percentage of older people that require different diets to younger people and there could be good future market potential providing pulse grains into China for this ageing population.[3]

One emerging area of scientific research which may offer interesting findings is that of light control of plant growth and development.[4]

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[3] See for example, studies on "China – Asian Agrifood Megamarket" published in August 2004 and "Agrifood Multinational Corporations in Asia" published in December 2001 by Judith Laffan, Executive Officer, Agriculture and Food Branch, Department of Foreign Affairs & Trade.

[4] See for example work of Dr Marcelo Yanovsky, at the Institute of Agricultural Plant Physiology and Ecology (IFEVA) at the University of Buenos Aires in Argentina – see http://www.ifeva.edu.ar/en/research/field3.htm.

Conclusion

I believe Australia has a great future in growing wheat and continues to need a rotation of some description (e.g. crops or pasture phase) to maximise wheat quality and yields. The introduction of non selective chemical traits in crops would deliver an option for continuous cropping (i.e. without pasture phase rotation), leading to better utilisation of expensive machinery and greater economies of scale. If varieties with non-selective chemical traits were too expensive, the uptake would be limited - if the grower could not cover costs or sell the product, they would not grow these varieties. Farmers may be more likely to favour end-point royalties given the climate risks in Australian agriculture.

Non-selective herbicide options on all crops would allow easier operational management and reduce or eliminate resistance to rye grass and black oats in the short to medium term, which is a common hurdle for continuous cropping. Access to varieties with stacks would be the best outcome as this would give a wider range of chemical groups to rotate with. Use of non-selective chemicals is the key to current weed issues. Of those available at the moment, glyphosate would be the preferred chemical for Australian conditions with its better range of weeds controlled and ease of management.

Continuous cropping would increase with the introduction of GM varieties, with future crops grown more likely to target the energy market, for example, sugar cane or bamboo being bred for non traditional climates. In the short term, grain would still go to food and the straw could be used for energy or stock feed replacements.

With regard to adaptation of GM varieties bred in other countries, it would of course take some time to adapt such varieties to Australian conditions, but overseas researchers suggested it would take significantly less time to adapt such varieties than it took for breeders to originally develop these varieties and see commercially viable productivity gains.

Owning (rather than leasing) the land and farming appears to be the most profitable option, giving the business a mix of capital gain and income potential to cover for variable climatic conditions in southern NSW. Farming has a good future in some areas from what I have seen in my travels.

The non-selective chemicals used in current breeding programs

Unmanned Farm Machinery (Robotics)

A shortage of labour in peak work periods, either skilled or unskilled is often an issue in agriculture. This can sometimes be attributed to lesser returns per hour, harsher work environments, distances to travel and inconsistencies in work due to seasonal or climatic conditions (e.g. drought, flood or fire). Both stock and cropping operations are affected. Returns for all labour can often be higher in other sectors, with greater reliability of work.

Grain production businesses who employ full time staff can sometimes find the non-peak work periods challenging to fill in regarding finding tasks for employees.

At the moment the mining sector, on the back of a world wide energy–mining boom, is drawing on workers and out competing other sectors including the farming sector. This is making it harder for agri-businesses to obtain seasonal or permanent staff, and also to hold existing staff in place.

This is also a factor in countries such as Canada, where the booming oil and gas sector was impacting heavily on available staff, especially in the state of Alberta. The capital, Calgary, was widely displaying staff wanted signs in shops windows. Edmonton based plant breeders working for Pioneer Brand Seeds have company accountants questioning them over the issue of paying casual staff $22.00 per hour (instead of the usual $12.00 per hour) when such staff could earn $30.00 per hour and bonuses in other sectors.

With the above in mind I researched the theory of driverless farm equipment to alleviate the seasonal pressure of labour. I have divided the following discussion into segments: with a basic overview of information technology, hydraulics and GPS, the developments in unmanned operations in aviation and mining, and the developments in agriculture covering issues or barriers before farmers obtain the option of autonomist vehicles.

Information Technology

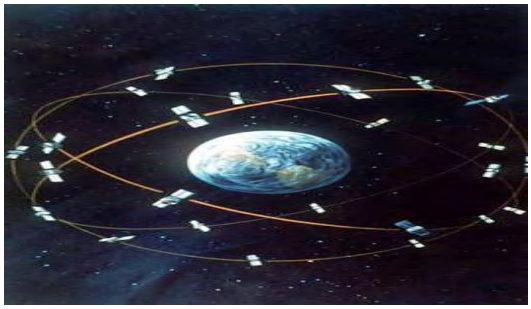
Over the last decade, the application of information technology developments in agricultural production has supported significant gains in knowledge (e.g. precision farming) and productivity. Computer technology, with its increasing memory and data management capacity, has supported repetition of increasingly complex, sophisticated tasks. Computers are a more affordable platform as once the program has been developed, it is cheaply copied or multiplied and does not have the expensive reproduction costs associated with manufacturing equipment. Information technology developments have been complemented by advances in hydraulics technology and in guidance and precision systems (e.g. GPS technology).

Hydraulics

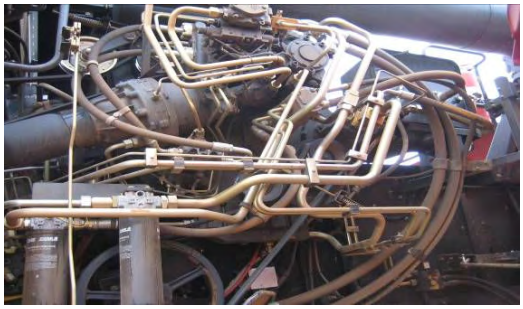
A significant factor in the development of more automated farm machinery systems has been advances in hydraulics technology. Hydraulics are being used in more areas of agricultural equipment today. In the past they were used for mainly lifting and folding equipment. Today's machinery has many hydraulic systems replacing belts, chains and power take off (PTO) drives. The hydraulics are controlled by the amount of flow through the hydraulic motor and this is easily adjusted manually or by computers.

MQ-9 Reaper Unmanned aerial Vehicle to replace troops in Afghanistan.

Typical mine with poor satellite coverage during different times of the day.



An artists impression of the GPS network.



Typical hydraulics on modern harvesting equipment.

GPS

Global Positioning System technology (GPS) became available in 1993 in the general aviation sector for guidance and positioning, and then in 1995 in agriculture in the form of guidance and yield mapping. Today with the use of fixed base stations in conjunction with satellites, the accuracy is much greater and systems are readily available for self-steering and recording information where the operator's only input can be as little as turning the machine at the ends and around any obstacles in the paddock.

Developments in unmanned operations

In the area of unmanned operations, aviation and mining are trialling and using systems. The military is promoting the use of planes (unmanned aviation vehicles - UAV) for high risk surveillance and operations where an unmanned drone has no pilot, eradicating risks for pilots if downed in unsafe territory and political issues related to loss of people in a conflict. These planes are controlled remotely by a person and can fly a pre determined path or do anything the controlling operator commands.

Mining is in the early stages on trialling driverless equipment with a view for use in unsafe work situations, such as excavators in Japanese furnaces, bulldozers on unsafe ground at Muswellbrook and dump trucks in the Kalgoorlie area. The earth moving company Komatsu is trialling unmanned dump trucks which climb out of pits on pre determined paths with obstacle avoidance systems that determine if the obstacle is stationary or moving, if it will clear the path and whether the truck will need to take evasive action.

Significant research has been done on systems to complement satellite guidance and positioning, given the restrictions of satellite coverage in mining situations (e.g. mine pitts). Technology such as lasers, pseudo satellites (expensive ground based satellites) and inertial measurement units (IMU's - gyros that track movement) are being used in conjunction with satellites to give the accuracy and reliability needed to keep these machines on the correct path.

The United States Department of Defence's central research department held a competition for autonomist vehicles in 2004 and 2005 with the aim of supporting technology in this area. Known as the DARPA (Defence Advanced Research Projects Agency) Challenge, it offered millions of dollars in prize money for the winner and defence contracts, attracting participation by numerous companies and universities. The first two competitions were held in a desert scene with mountainous terrain and tunnels to make satellite coverage an issue.

A third DARPA Grand Challenge was to be held in November 2007. This time it was to take place in a 96 km urban scene where vehicles would have to obey all traffic laws, making real time decisions on the actions of other vehicles. All auto manufacturers were expected to be involved or to closely follow the event to see what implications might emerge for smarter cars and safer highways in the future.

I understand that some golf courses use unmanned lawn mowers that work at night on pre determined patterns, which start and finish from where they are permanently stored.

I understand there is trialling of small unmanned helicopters (sized to one third scale) for spraying high value crops in urban areas. The helicopter is transported by trailer to the location desired. Before spraying commences, the operator drives around the paddock to assess and load boundary coordinates into the guidance system. Then the helicopter sprays the crop with no overspray or long banking runs associated with agriculture planes. This minimises impact on urban surrounds. The helicopter lands back on the trailer for transporting. This operation appears to be relatively cheap, flexible and precise with less impact to the surrounding environment.

Developments in agriculture

One early example of successful introduction of autonomist farm vehicles has been travelling or centre pivot irrigators, which have successfully overcome earlier problems with alignment. Auto-steering guidance systems under the GPS network have become increasingly common in Australian agriculture. They offer cost savings on inputs, repeatable results with less skilled labour and less down time due to driver fatigue. Uptake, which occurred first in the higher value row cropping sector and then in the lesser returning broad acre sector, has steadily increased on the back of the above and lower entry prices due to competition.

The next level of technology uptake could be for auto-steer guidance systems that do not just control the machine in a straight direction, or around curves, with the operator having to turn at the end of the runs and around obstacles, but to record all movements the machine does in a set paddock. This is achievable with computer technology - once the operation has been done once and saved in computer memory, it will automatically recognize the paddock you are in and repeat the task.

The cost of the systems needed to run the machinery could be offset by the removal of the cabin, which for a tractor is between 15 to 25% of the cost, depending on the size of the machine (air conditioner, lights, seat, radio, steering wheel, frame, glass and all hydraulic levers, buttons, gauges etc). New machines today have the brackets, wiring and components needed for auto steering as standard.

The space available from the removal of the cabin is being partly used for extra fuel, and the addition of cameras, antennas and a 30 cm square processing box 8cm high. Radar for obstacle avoidance with speeds up to 60 kph, lasers for greater speeds, is what is required for autonomist capabilities.

When purchasing a machine in the future, the purchaser could for instance have a choice of autonomous or standard at the same price. The most development work is being done with mid-sized higher horsepower tractors with basic roll over protection and a steering wheel. To move along a public thoroughfare or between properties, a lead vehicle is being trialled with the autonomist machines following and copying all movements.

Having agricultural equipment working in a paddock without an operator present has not been an option to date. While unmanned systems have been under development for a number of years, no company has made this a commercially available option. One company is developing the option for harvesting equipment to signal the chaser bin when it has a full load, which is being trialled with the view that an unmanned chaser bin could come out and position itself under the header to maintain a set speed, distance and direction until the transfer was completed, and then return back to the unloading area on the edge of the paddock.

I note that demand for unmanned systems is likely to be limited in farming and speculate that perhaps only 5-10% of farms in Australia, and only some countries would be likely to take up such technology. This is within the context that there is an abundant labour force in most countries of the world, and small farms would possibly face an excess labour capacity due to the small size of their operations, making unmanned machinery an uncommercial or undesirable option.

International machinery companies advised that they have been able to do unmanned operations for the past six years, but are not prepared to remove the steering wheel and the operator from the machine as then the companies would be totally responsible for litigation if the machine strayed or was seen to cause death or injury. There are also issues about ownership of intellectual property rights and allocation of related earnings, with various proposals such as partnerships between designers and manufacturers involving drip feed or percentage payments to the designer for all equipment sold, or where the designer receives a one off payment. This is still being sorted out and is a real barrier in the short term.

The more technology and complexity applied to an unmanned system the more expensive it becomes – e.g. obstacle recognition, avoidance and/or radar technology to cater for unplanned invasions of the field, and complications to vehicle operation when attachments are added or scale is expanded (e.g. more pivot points). Generally most manned equipment today has protection systems that will stop the vehicle if it gets too hot, low on oil or something is outside a set range. This concept of protection systems can of course be extended to unmanned equipment to protect from risks and/or overloading of an operation by more than a certain percentage (e.g. wandering off track). Technology now allows for unmanned systems to be monitored or adjusted from a distance with UHF radio, satellite technology or by the mobile phone network (depending on coverage), and with the use of fixed cameras, images can being monitored from any location.

Conclusion

There are concerns about the ability of the agriculture sector to afford unmanned farm machinery technology in comparison with the aviation and mining sectors. However, it should become more affordable over time as technologies developed for other sectors (e.g. aviation and mining) are adapted to agriculture. The market may also take into account the capacity of different sectors to pay for such technology – for example, the mining sector currently pays three to ten times more for exactly the same guidance systems used in agriculture.

Unmanned technology could lead to alternative approaches for large scale production, where instead of having larger machines moving faster and more efficiently, one person will monitor multiple smaller machines at the same time doing the same job or possibly doing complementary activities (e.g. sowing while the boomspray is working along side).

Leaving equipment to work for extended hours or to do a little more after you go home for the night would be a big efficiency. Working at slower speeds and having the ability to turn itself off independently or remotely should make for a safer environment.

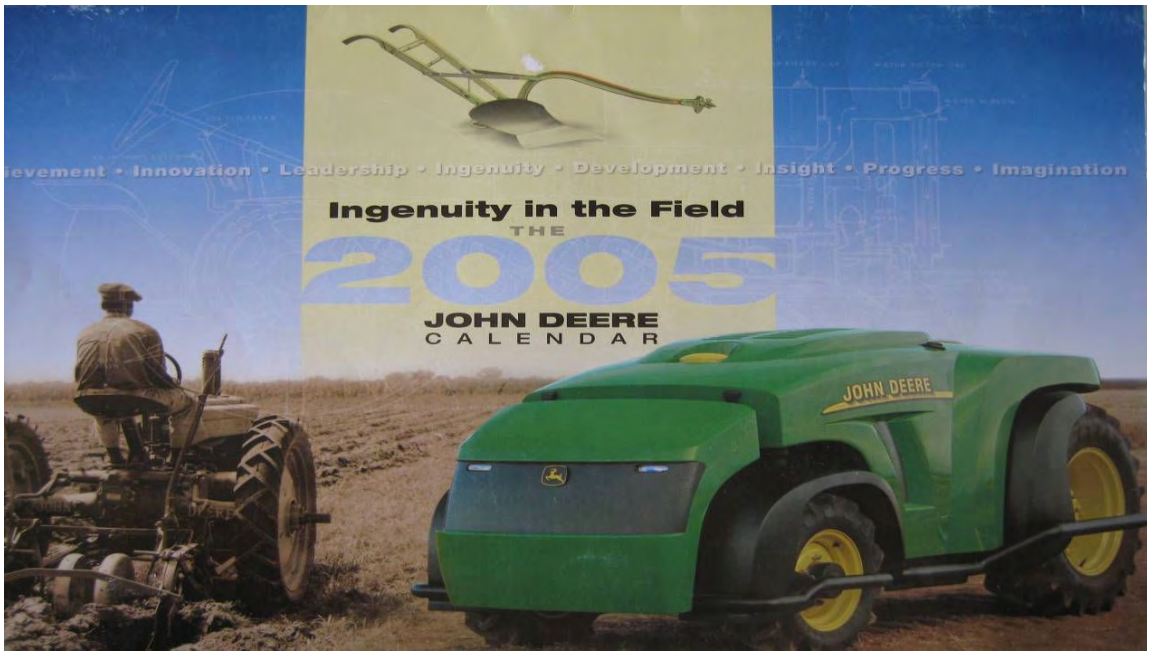
GPS technology with the use of satellites and RTK dual frequency base stations, giving positional information 60 times per minute to an accuracy as close as 2cm, is becoming more common in agriculture today. This system is good enough to instantly recognise if the machine attempts to leave the area of work, and alleviate any issues with machinery straying. Concerns about unmanned vehicle movement through public thorough fares could be to use manned lead vehicles which are being trialled.

There are concerns in Australia and elsewhere about the implications for country communities of further reduction in farm employment opportunities. The threat of losing employment was creating costly repair bills for farm owners in North Dakota and California, with staff sometimes damaging guidance hardware with the view it would eventually replace them in the work force. These issues are not new as machines and technology have been replacing staff in most sectors for years.

When discussing the future of Autonomist agricultural machinery with Mitch Torrie – Mechanical Engineering Lead for the company Autonomous Solutions Inc.

Mitch has systems currently working for the US army, mining companies, and has been working with the machinery company John Deere on autonomist tractors for 6 years. A major part of his work has been on tractors for the Mexico market, where there is not a labour shortage, but farmers are looking to operate the tractors 24 hrs per day, and only staffing them during daylight hours.

Mitch believes that the farming sector will buy these machines, and the time period will be greater than 5 years before there is a commercial release.



The 80hp tractor on the front right of this calendar was trialled for 1000hrs, and will give an idea of how tractors could appear in the future.

Annex A

Program of calls February to August 2007

During my year as a Nuffield scholar I met the following people in relation to my study of continuous cropping and unmanned farm machinery. I greatly appreciated the time they made available to meet with me.

Mark Argar: Austrade, Senior trade commissioner for Latin America, Sao Paulo, Brazil

Gerard Bange: Chairperson of Crop Forecasting, USDA, Washington, USA

Patricia Bergero, Rosario Board of Trade, Rosario, Santa Fe, Argentina

Clive Blacker: Nuffield Scholar, Precision Decisions Ltd, York, England

Hilda Buck: President, Buck Semillas S.A., La Dulce, Buenos Aires, Argentina

Dr Miguel Campos: - Co-ordinator Estratégico Agropecuario Jefatura de Gabinete de Ministros, Argentina

Canadian Wheat Board: Winnepeg, Manitoba, Canada

Dr Aércio dos Santos Cunha: Consultant on agricultural issues to the Brazilian Congress, Brasilia, Brazil.

Michael Darby: USDA, Canberra, Australia

Wally Doerksen: Nuffield Scholar, Steinbach, Manitoba, Canada

Dr John Dunn: Director of Cooperative Resource Management, USDA, Washington, USA

Justin Dutra: Stone Land Company, Lemoore, California, USA

Allen Ford: Farmer, Walla Walla, Washington State, USA

Ed Fry: Farmer, Marylands, USA

Jose Garcia: Product Development Specialist, BEELINE California, Fresno, USA

Greg Gingera: Pioneer Brand seeds, Saskatoon, Saskatchewan, Canada.

Alan Grombacher: Pioneer Brand Seeds, Edmonton, Alberta, Canada.

Goerge Hanna: Farmer, Milden, Saskatchewan, Canada

Jim Helford: Farmer and Conservapac Seeders, Indian Head, Saskatchewan, Canada

Javier Hernandez: Product Specialist for TOPCON, Fresno, California, USA

Gary Hoard: Research Manager, Pioneer Brand Seeds, Des Moines, Iowa, USA

Judith Laffan: Executive Officer Agriculture and Food Branch Department of Foreign Affairs and Trade Canberra, Australia

Kent McKay: Area Agronomy Specialist, North Dakota Research and Extension Center, Minot, North Dakota, USA

Judy McKell: Executive manager, Indian Head Ag Research Foundation, Saskatchewan, Canada

Kevin McNight: Bayer Crop Science, Lethbridge, Alberta, Canada

Peter Ninnes: Contracts & Grants Officer, CIMMYT, Mexico

Michael O'Connor: Novariant, San Francisco, California, USA

John Olivera: Farmer & Variable Rate Specialist, Fresno, California, USA

Abe Orbach: Senior Director Precision Farming & Guidance Platform, CaseIH, Burr Ridge, Illinois, USA

Harrold Perry: Nuffield Scholar, Lethbridge, Alberta, Canada

Julian Raine: Nuffield Scholar, Hinetai Hops, Stoke, NZ

John Stones: Nuffield Director, Market Harborough, England

Milton Suzuki: Bayer Crop Science, Ribeirao Preto, Brazil

Broc Taylor: Irrigation Specialist, Fresno, California, USA

Bill Taylor: Technical Support for Guidance, Fresno, California, USA

Titan Machinery: Fargo, North Dakota, USA

David Torrie: Farmer, Taber, Alberta, Canada.

Mitch Torrie: Mechanical Engineering Lead, Autonomous Solutions Inc, Utah, USA

Maarty Van Egmond, Australian Wheat Board, Grain Marketer, Temora, NSW, Australia

Dr Quin Zhang: Professor of Ag and Biological Engineering, University of Illinois, Champaign Urbana, Illinois, USA