"Precision Agriculture"

Final Report to the Australian Nuffield Farming Scholars Association[1]

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Executive Summary

I applied for a Nuffield Scholarship primarily to study precision agriculture and along the way I learnt that one of the benefits of being a Nuffield Scholar was learning from other Nuffield Scholars past and present about all aspects of farming, marketing and processing. The Nuffield network is amazing a life-long opportunity to learn and contribute. I see my future association with the Nuffield Scholars, world wide, as an opportunity to stay at the cutting edge of agriculture for life.

The majority of my study time, outside the six week organised tour, was spent on precision agriculture, to this end, the main countries I visited included the UK, France, Belgium, USA and Canada. Of the total sixteen weeks spent abroad, in two separate trips, over seven weeks was spent in the North America. I had a secondary objective to research marketing and purchasing opportunities by developing overseas networks. In pursuing this objective I visited Singapore, Malaysia, Thailand, India, Poland and Hungary. The most time I spent in any one country was in India for seven days, primarily in New Delhi looking at opportunities to develop strategic alliances to market primary produce to food processors.

In studying precision agriculture, I set out to familiarise myself with as many forms of precision agriculture as possible as well as meeting people involved in precision agriculture such as farmers, consultants, researchers and developers. I then to did some analysis of the potential benefits of these technologies as applied to our own broad-acre mixed farming operation at Nyngan and Nevertire, NSW Australia. I concluded that there are many economically beneficial precision agricultural technologies such as vehicle guidance, yield mapping, soil mapping, determining management zones and variable rate application of farm inputs. The adoption of precision agricultural technologies is a question of farm scale, the level at which these technologies become cost-effective for an individual farmer depends on the cost savings multiplied by the area applied.

One cautionary note with Precision Agriculture is there is a tremendous quantity of information to deal with and as yet software systems do not exist to seamlessly manage this data. It is important therefore that an individual farmer can get additional professional help with data management and interpretation if that farmer is to gain the largest financial benefit from precision agriculture.

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Acknowledgments

I would like to acknowledge the financial support of the Australian Nuffield Farming Scholars Association, Grains Research and Development Corporation (GRDC) and Grain Growers Association. I would also like to acknowledge the assistance given to me by former Nuffield Scholars, particularly Mr. Gary Naylor, of Worth Farms, UK. I am indeed indebted to Professor Stuart Pocknee from the University of Georgia, Tifton, USA, formerly of Brisbane, who made the onerous task of information gathering infinitely easier than I expected and finally I would also like to acknowledge the support of my family.

Objectives

The primary objective of this study was to make an assessment of the economic and physical benefits of precision agriculture with particular reference to broad-acre farming in New South Wales. A secondary objective was to research marketing and purchasing opportunities, primarily in precision agriculture related areas, by developing overseas networks.

The majority of my study time, outside the six week organized tour, was spent on precision agriculture, to this end, the main countries I visited included the UK, France, Belgium, USA and Canada. Of the total sixteen weeks spent abroad, in two separate trips, the majority of my time, over seven weeks, was spent in the North America. While in North America I visited 24 states and drove over 9,000 miles (14,400 kilometres). On my secondary objective, I visited Singapore, Malaysia, Thailand, India, Poland and Hungary. The most time I spent in any one country was in India for seven days, primarily in New Delhi looking at opportunities to develop strategic alliances to market primary produce to food processors.

In studying precision agriculture, my objective was to familiarise myself with as many forms of precision agriculture as possible as well as meeting people involved in precision agriculture such as farmers, consultants, researchers and developers. My idea was then to do some analysis of the potential benefits of these technologies as applied to our own broad-acre mixed farming operation at Nyngan and Nevertire, NSW Australia. In my travels I had the good fortune to come across two people, firstly Gary Naylor, Nuffield Scholar, managing Worth Farms in Holbeach, England. Gary had done some work on precision agriculture in his Nuffield studies and was a valuable contact in both the UK and in giving me my second contact Professor Stuart Pocknee from the University of Georgia based in Tifton, GA. Professor Pocknee was terrific in steering me to the leading precision agriculture conferences, researchers and farmers throughout the United States, my only problem was not having enough time to see more than about sixty percent of his contacts.

In this report I have outlined the major precision agriculture technologies I encountered, report on some of the experiences farmers and researchers have had overseas in implementing precision agriculture and look at adoption of the more promising technologies for my family's own farming operation and make some preliminary assessment of the likely economic and physical benefits of these technologies.

About the Author

Figure 1 - Benjamin W. Bootle

After completing a Bachelor's and Master's degree in Agricultural Economics at the University of Sydney, and working for the Department of Agriculture and Water Resources, Benjamin Bootle returned to full-time farming in 1996.

Ben is one of seven directors of his family's farming enterprise, trading as "Gargaloo", with farms at Nyngan and Nevertire in central-western New South Wales, Australia.

Gargaloo presently crops, using precision agriculture - zero tillage-control traffic farming methods, between 6 and 8,000 hectares of grains. The primary winter dry-land crops are wheat, durum, barley, oats, canola, chick and field peas. Summer irrigated crops include up to 550 hectares of cotton, lucerne and corn. "Gargaloo" also runs 600 breeding cows and their progeny and 3,500 sheep for lean lamb production.

What is Precision Agriculture?

Precision agric ulture (PA) has many definitions, if you refer to the literature, definitions are plentiful one of the least confusing is:

> "Precision agriculture is a catch-all term for techniques, technologies, and management strategies aimed at addressing within-field variability of parameters that affect crop growth. These parameters may include soil type, soil organic matter, plant nutrient levels, topography, water availability, weed pressure, insect pressure, etc"[1]

McBratney and Whelan add an additional purpose, that of environmental protection, to precision agriculture's definition by defining it as:

> "Precision Agriculture (PA) attempts to develop integrated information and production-based agricultural systems to optimize long-term, site-specific and whole-farm productivity and minimize impacts on the environment… (Precision Agriculture) will develop as a more visionary approach to farm management"[2]

When you ask farmers what precision agriculture means to them you get a number of different answers depending on their perspective. These include, but are by no means limited to:

Replacing foam marker with DGPS,
Yield monitoring,
Control traffic farming,
Zero/minimum tillage farming,
Quality assurance schemes,
Variable rate fertilising,
Grid soil sampling, and
Tractor guidance.

All of these answers are indeed part of precision agriculture and valid because what an individual farm manager wants from precision agriculture depends primarily on the economic

or management pressures motivating them to strive for more control of their farming enterprise.
Precision agriculture assists a farmer to gain more control and to manage complexity, therefore my definition of Precision Agriculture is:

> "Precision Agriculture is the physical and financial management of farming operations in a site-specific manner, which returns more control, repeatability and certainty to the farming enterprise; resulting in lower costs and less variable and more predictable returns."

A farmer's focus on PA rightly depends on their perception on what the most limiting management factor is. Some examples of these include:

1. Vehicle guidance – using Global Positioning Systems (GPS) or Differential GPS for higher accuracy

Where machine overlap is perceived to be costing a farmer or where a farm is using tram-lining farming systems to improve productivity.

2. Mapping and Remote Sensing - soil, yield, compaction, crop scouting, topography and many other land based criteria

Where soil property constraints are viewed as most limiting output, mapping these constraints so that differing management or inputs can be applied to them can lead to beneficial results.

3. Variable rate technology (VRT)

The next step in precision agriculture, once some form of remote sensing or mapping has identified management zones within a field or farm then the next logical step is applying differential rates of inputs, in a site-specific manner, to ameliorate problems and generate output more efficiently.

4. Site specific financial management

A logical progression from VRT is knowing the financial performance of land management units, allowing a farmer to understand the profitability of site specific management and apply management and financial resources accordingly.

Figure 2 - Where am I?

One of the most important concepts within the field of PA is Site Specific Management (SSM). Once a farmer is able to locate an area that is to be 'managed' that area or site can be treated in a specific manner particular to its requirements. This is the most important single concept within precision agriculture, the component which makes it precise is ***knowing exactly where you are***. This enables you to be precise and specific in your operation of your farm.

How do we know exactly where we are?

For centuries navigators and surveyors have been aware of the importance of knowing exactly where they were, they used traditional methods such as the stars, the sun and the moon to determine, using triangulation, precisely their position on the surface of the planet.

Knowing where you are, in relation to where your enemies are gives you a strategic advantage, a system which made all this possible without the need for surveyors or navigators was initially sought by the United States Department of Defence (DOD). Thus the DOD developed an amazing new navigation technology called Global Positioning System or GPS, the US government supported the extraordinary initial cost of the GPS network conditionally based on it being available to both civilian and military users. The first of the GPS satellites was launched in February 1978, the satellites have a life of approximately 10 years with replacements constantly being launched. The way it works is presented in a stylised manner in Figure 1 below.

Figure 3 - GPS Satellite Orbits

GPS is based on a constellation of 24 satellites orbiting the earth over twenty thousand kilometres up. These satellites act as reference points from which receivers on the ground trilaterate their position (like triangulation only it doesn't use bearings but distance measurements).[3] Satellites can act as reference points because their orbits are very accurately monitored by ground stations on earth which measure the travel time of signals transmitted from the satellites, a GPS receiver on the ground can then determine its distance from each satellite. It only requires distance measurements from four satellites, and some maths, for a GPS receiver to calculate its latitude, longitude, altitude, course and speed. Using GPS signals a good receiver can do this to an accuracy of better than one hundred meters and do this more than once per second.

The GPS is a free service, one catch with the system used to be that the DOD built in a signal distortion called "selective availability". The argument for this deliberate degradation of signal accuracy was that being a world-wide system the USA did not want their military enemies to use GPS to target the USA. So this meant we had a pretty good idea of roughly where we were, give or take 100 metres. Early in 2001 the DOD turned off "selective availability" and a good GPS receiver's accuracy was improved to +-20 metres.

A farmer, and most commercial users of GPS, require significantly greater accuracy than +-20 metres. This led to the development of differential GPS (DGPS). The differential works by cancelling out errors in GPS measurements, the basis of the differential is having an additional receiver. This receiver is placed on a spot whose position is known exactly. The second receiver calculates its position from the GPS satellites and compares this theoretical position to its actual position, the difference (thus differential) is an error factor. Because satellite errors change continually due to a number of factors including atmospheric conditions, this differential is constantly updated and broadcast to a differential receiver, giving the error data by which to adjust the theoretical GPS position calculated by the GPS receiver. Depending on the quality and speed of refresh of this signal accuracy is improved to sub-metre, and for special application like surveying or vehicle control down to less than 2 centimetres.

There are a number of sources of differential signals, some free and some requiring subscription. These include radio beacons such as the coast guard beacon and some FM radio beacons (such as one broadcast on ABC JJJ network) both free and proprietary subscriptions satellite systems such as John Deere's Starfire™ satellite, Omnistar™ (both broadcast signals from Aussat). In the USA there is also a free satellite system, launched in September 1999 by the Federal Aviation Administration to augment GPS accuracy to allow GPS to be used for landing planes known as WASS (wide Area Augmentation System). The WASS signal can be used for all differential applications, including agriculture.

DGPS - Who else uses it?

The uses of DGPS are continuing to grow and presently include, coast guard and shipping, the original user the military, aviation, natural resource managers, miners, land-based and offshore exploration for minerals and petroleum, archaeologists, geologists, surveyors, transport (including ground, sea, rail and air) and fleet managers, utilities (electric, gas, phone) and public safety (police, ambulance and fire).

The GPS system is also making it into more mainstream life every day. Recreational uses are the latest to see the benefits of know and exact global position. Some of the recreational uses are in boating, mountain climbing, bushwalking/hiking and even a golfers hand-held GPS guide that tells you exactly how far it is from where your ball is to the green. (http://www.skyhawke.com/) below is a description of how the "Sky Golf GPS™" works:

Figure 4 - SkyGolf GPS™

SkyHawke Technologies fired the first shot in the digital revolution of golf with the introduction of SkyGolf GPS™. SkyGolf GPS is a handheld GPS receiver that works with Palm™ V/Vx and Handspring™ Visor™ handheld computers. It puts precise measurements in the palm of your hand-from your ball to all critical targets on each hole. Targets that you designate.

Professional golfers rely on their caddies for precise measurements to all of the points on a hole critical to scoring: not just the landing area or pin position, but to all of the hazards around the target as well. Amateur golfers have never had access to the same kind of information before. At best, the only measurements available were from sprinkler heads and generic markers to the center of the green… until now.

SkyGolf GPS gives any golfer the same information that tour caddies give their players. It's like having a personal digital caddie. With better information, golfers can make better club selections and better strategic decisions on the golf course. They can stop pacing off distances, triangulating points off of the fairway, stop guessing how far they are to the target. In short, SkyGolf GPS helps golfers play smarter, play better, play faster and have more fun. It will help most golfers shoot lower scores without forcing major swing changes.

Another recent novel use of GPS technology was recently reported in Toronto, Canada and involves the use of GPS based marketing in Taxi cabs in that city. Below is a report from the Canadian Globe and Mail (http://rtnews.globetechnology.com) outlining the system:

"**Taxi technology delivers captive ad audience**" *By JACK KAPICA,*

Globe and Mail Update

There's nothing an advertiser likes more than a captive audience. And a new Toronto company is promising to deliver them in the millions.

ToMarket Inc., a company started by six Torontonians, has developed a thin touchscreen that can be mounted in taxis and provide a number of services, including music, news and ads, to riders.

The screens, mounted on the back of the front passenger seat, are controlled by a small computer located in the trunk. They use the car's sound system to play MP3 music recorded (legally) by local radio stations.

The screens will also display listings of events and attractions going on in the city, including sports schedules.

But the heart of the system is a sophisticated combination of the Global Positioning System (GPS), which can locate a taxi to within five metres on a map displayed on the screen, and ads that appear automatically on the map when the cab approaches the advertiser's area.

"It's a pretty cool service, especially if you're a tourist," said Adam O'Byrne, one of toMarket's founders.

Cab drivers are enthusiastic about it, Mr. O'Byrne said. A prototype version has been installed in 25 cars belonging to Beck Taxi, and "all are saying they have five or six buddies who want the system in their cars too," he said.

So far, cabs must report to a local car-radio installation company to update their programs every two weeks, and toMarket is paying the cabs "a generous amount" to do this. But after Oct. 1, when the finished product is expected to be installed in 250 cabs belonging to Beck Taxi, Mr. O'Byrne said that content — ads as well as music — will be sent to the cabs wirelessly.

The system is activated only when the cab's meter is on, and the passengers can select whichever stream of music they wish by touching the appropriate spots on a rugged brass-bevelled screen. Ads for various establishments — night clubs, restaurants — will pop up in a corner of the screen while the advertiser's logo appears at the appropriate place on the map as the cab approaches the advertisers' locations.

The passengers can also turn the system off if they like.

One of the benefits of toMarket, Mr. O'Byrne said, is the GPS system, which passengers can use to make sure the cab doesn't take the scenic route instead of a more direct one.

But drivers who do this should not be concerned, Mr. O'Byrne said; the cabs receive revenue from the system whether they take the shortest route or not.

The system is expected to be run entirely on advertising, Mr. O'Byrne said. ToMarket has contracted 35 sales people.

There are 3,477 cabs in Toronto, the company's advertising pitch says, accounting for 57 million fares each year. Each cab averages 16,388 riders per year. So even if the system finds it way into only 500 cabs, toMarket figures it will reach almost 8.2 million people.

Mr. O'Byrne said the system is attractive "because you're influencing the behaviour of the customer right at the point of sale." But, he admitted, it may take a little bit of getting used to. "It's a little creepy at first," he said, "but after a while, it's pretty cool."

The uses of the GPS system are endless, in fact anyone who needs to know exactly where they are or anyone who needs to know exactly where something of interest is will find a DGPS useful. It is here that many agriculturalists be they researchers or farmers can see a growing number of application for DGPS. Some of these are explained below.

Precision agriculture technologies

Vehicle Guidance

A. DGPS Guidance

Why have DGPS vehicle guidance? Because GPS/DGPS vehicle guidance:

i. Using a light bar – or auto-track system is more reliable than foam or marker arms
ii. Allows fading light and night -time operations
iii. Works in any field conditions (such as hot or low humidity)
iv. Reduces operator fatigue and eye strain
v. Reduces set-up time
vi. Is chemical free
vii. Guidance provides the operator with accurate field areas, this reduces wastage
viii. Virtually eliminates operator overlap - Saving $

ix. Where recorded, ensures compliance with EPA regulations.

B. Non DGPS Guidance

Guidance does not necessarily have to be GPS assisted. Researchers at Silsoe Research Institute in the UK have developed a image analysis computer that uses "line of best fit" algorithms to compute precisely where to guide an application based on computer image analysis of plant row location.

Guidance lenses focus forward on the plant line to give the hydraulically positioned tool bar a precise location eliminating cultivation losses. The operator drives the tractor to follow his best guess of the plant line.

Figure 5 - Silsoe Research Institute's Precision Cultivator

Two of the machines they have used this system on to date include a robotic spray rig which selectively sprays only the plant, saving chemical and labour. The robotic spray rig can phone its owners when it needs to be refilled or encounters any problems. The second machine is a precision cultivator capable of inter-row cultivating on 7 inch (17.7 cm) row spacings. The operator just drives his tractor to follow the planter direction and the toolbar is hydraulically controlled to stay between the plant rows regardless of the drivers position.

Yield Monitoring

Crop Yield Monitoring

There are many types of yield monitors available, some commercially, some in development, crops such as potato, peanuts, grain, cotton, turf, vegetables, citrus, and oil palms all have yield monitors developed. In time virtually any type of crop will be able to have yield monitors developed. All that is required is some measure of weight or volume of material being harvested. Figure 6 below illustrated a simplified grain yield monitor.

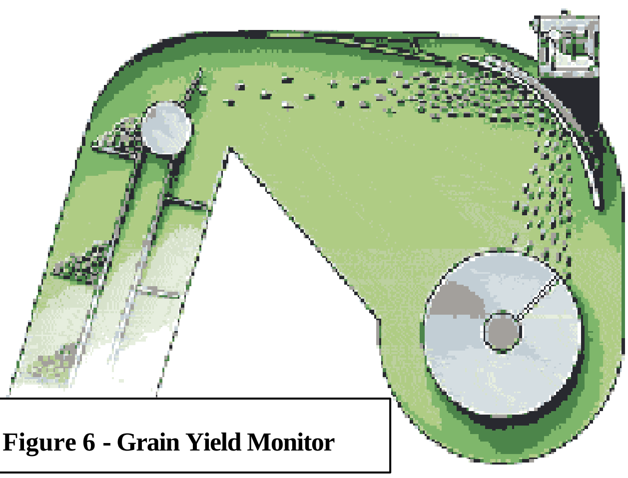


Figure 6 - Grain Yield Monitor

Grain from the main elevator hits a sensor before entering the grain tank cross-auger. The volume of grain hitting the monitor varies with crop yield. The fact that the yield monitor is ordinarily situated just before the grain tank on a header means the are usually some seconds delay between actual crop yield and sensed crop yield

A yield-monitoring system[4] allows a farmer to measure the yield and moisture of a crop as it is being harvested. In the USA alone more than 50 million acres were yield monitored in the 2001[5].

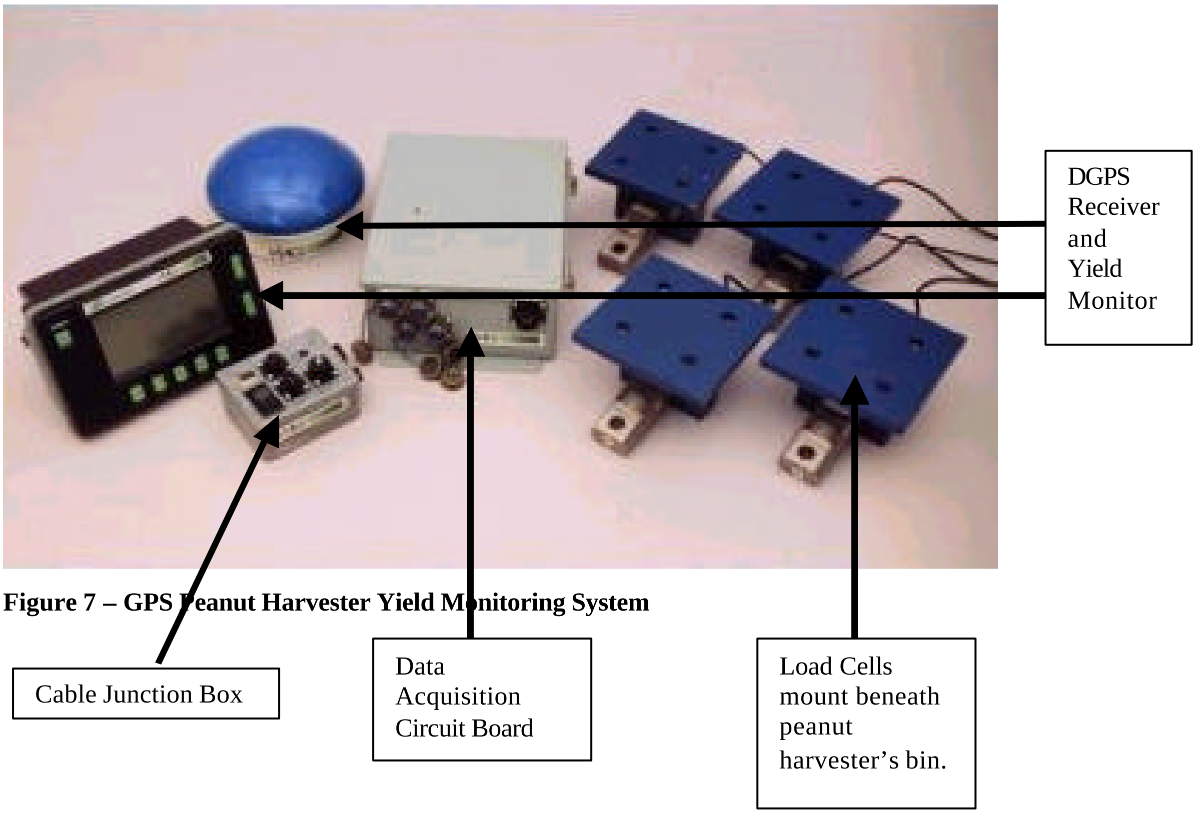


Figure 7 – GPS Peanut Harvester Yield Monitoring System

The Figure 7 contains the components of a peanut harvester's yield monitoring system[6], the same principle can be applied to a number of crops such as green vining peas, potatoes, grapes, fruit and any other crop that harvests into a bin or tank capable of being weighed. See http://farmscan.net/news.aspx for some of the available yield monitors in this area.

In Figure 8 below a cotton picker is shown, yield information is calculated from the flow of cotton past sensors inserted in the delivery chutes before the basket.

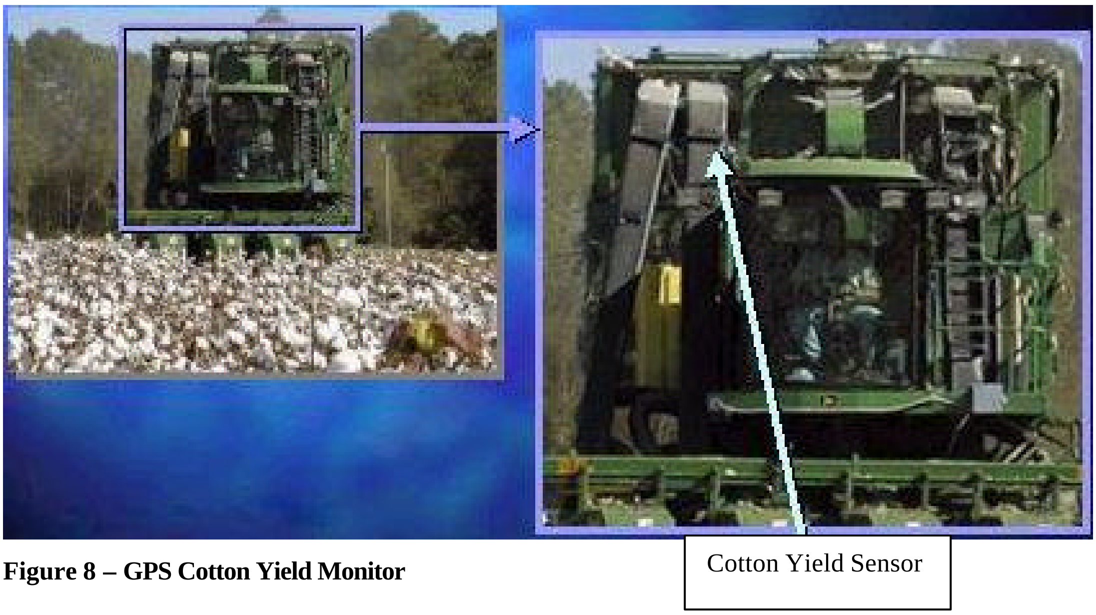


Figure 8 – GPS Cotton Yield Monitor

Gargaloo Yield Maps 2001/2.

The Legend used in each of the following yield maps varies between farms and crops. The same colour code is used however even though the absolute values vary. To illustrate this the legend shown below applies to the soil types example (number 3 below).

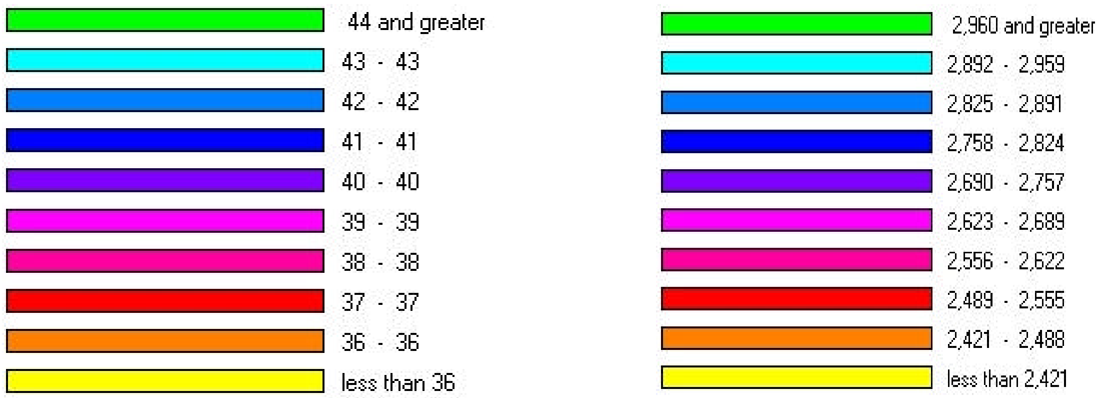


Figure 9 - Legend Showing Yield in Bushels/Acre and Kilograms per Hectare

Figure 9 contains two legends from the John Deere Yield Mapping Program (JD Map 4.2 ™). The legend on the left illustrates yield measured in bushels per acre, the legend on the right, yield measured in kilograms per hectare. For example any area showing yellow is yielding less than 36 bushels or 2,421 tonnes. You can adjust the range over which the legend applies quite simply, you set the range to illustrate the phenomenon or feature you are interested in.

To better understand yield maps, it's important to recognize that many things affect yield. Some examples from our on farming operation are shown below.

1. Weather

In Australia the most limiting of crop yield factors is the weather. Often lack of rain limits crops achieving their maximum yield potential. But the weather's affect on crop yield is not limited to rainfall. The yield maps above illustrates the track of a hail storm in September 2001. The two adjacent fields are approximately 160 hectares each, the storm's path was over 480 metres wide and damaged wheat yields were reduced to less than 600 kilograms per hectare (kg/ha). Damaged area in the northern field exceed 70 hectares. The average yield in the undamaged area was approximately 1800 kg/ha, thus the losses from the hail were in the order of 1,200 kg/ha or 84 tonnes of Australian Hard wheat (average 12% protein) valued at $200 on-farm, a loss of $16,800.

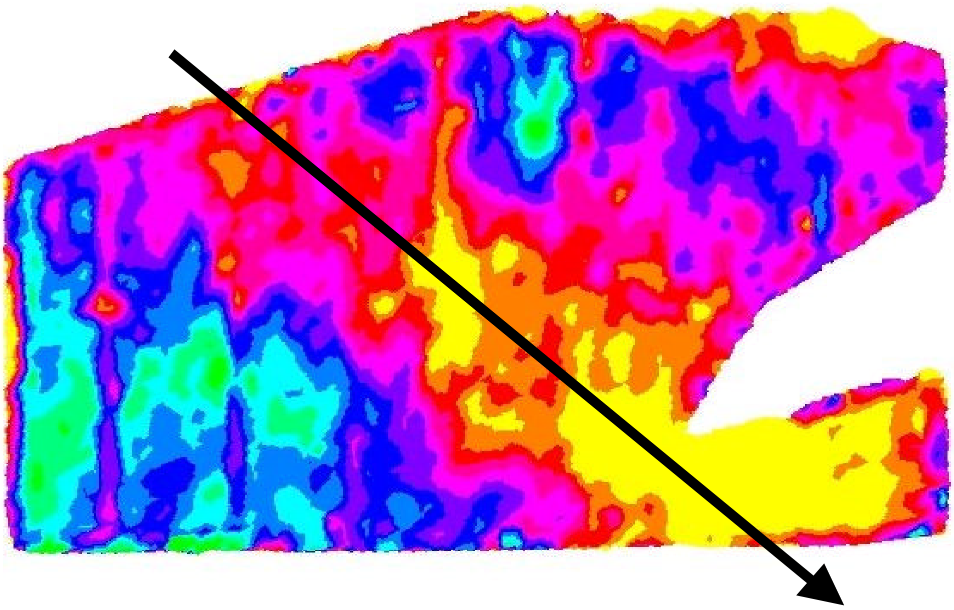
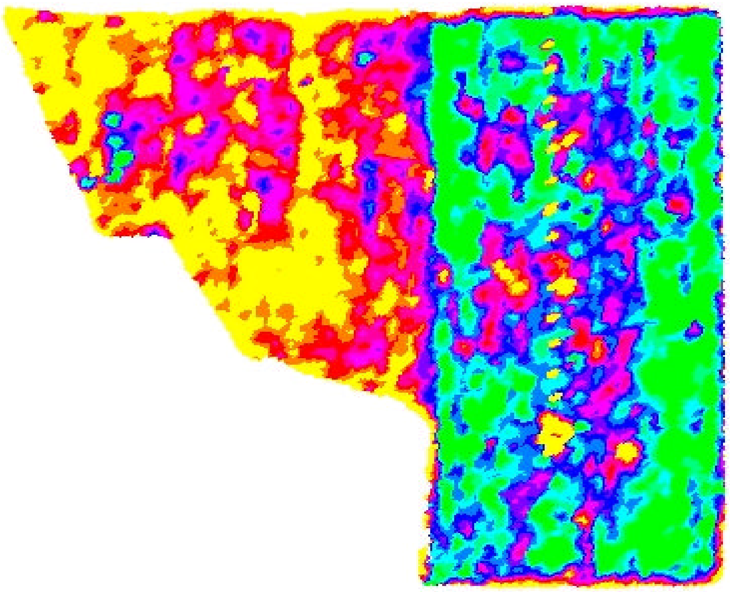


Figure 10 – Track of a Hail Storm

2. Seedling Emergence

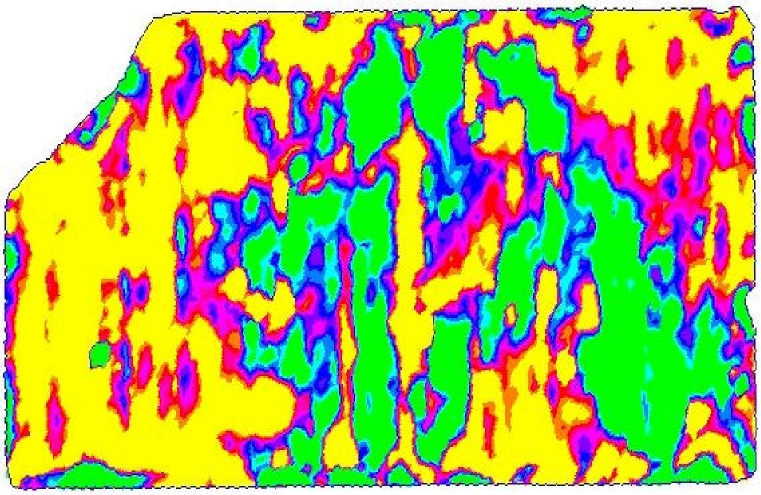


The field on the left illustrates the effect of seedling emergence and varietal difference on yield in canola. The area on the right was planted first with good soil moisture. The area on the left (although a different variety – the effect is mainly due to emergence) was planted after a machinery breakdown delay, into marginal moisture conditions resulting in poor and patchy plant populations (4-6 plants per square metre) resulting in significantly lower yields.

Figure 11 - Seedling Emergence

3. Soil Types

a. Sandy loam versus Clay loam soil

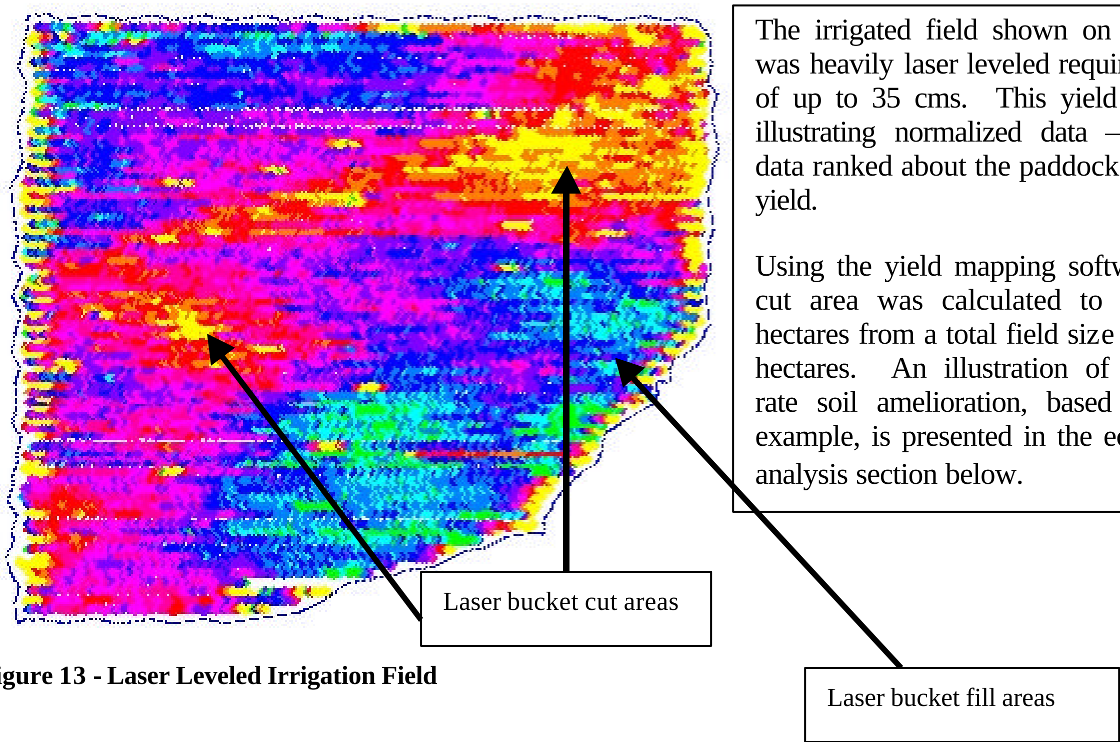


In this field soils vary from red-clay loams to sandy loams. The sandy loams have a much lower water holding capacity due to lower clay content and in a year where rainfall is limited the crop simply hasn’t the moisture reserves to finish.

In terms of management there may not at first sight be much that can be done to remediate this problem, it would be prohibitively expensive to add clay for example. What can be done though is recognise there is a lower yield potential in the yellow areas and use lower fertiliser inputs.

Figure 12 - Sandy Loam V's Clay Loam Soils

b. Laser Levelled Irrigation Field – Year 1



The irrigated field shown on the left was heavily laser leveled requiring cuts of up to 35 cms. This yield map is illustrating normalized data – that is data ranked about the paddock average yield.

Using the yield mapping software the cut area was calculated to be 9.78 hectares from a total field size of 27.65 hectares. An illustration of variable rate soil amelioration, based on this example, is presented in the economic analysis section below.

Figure 13 - Laser Leveled Irrigation Field

This method highlights the areas better than (blue through to green), and worse than (pink through to yellow) the field average (represented by light blue).

4. Pest Pressure/isolated paddock trees and poor drainage.

This field shows the effects of pest pressure and the effect of isolated timber within the field.

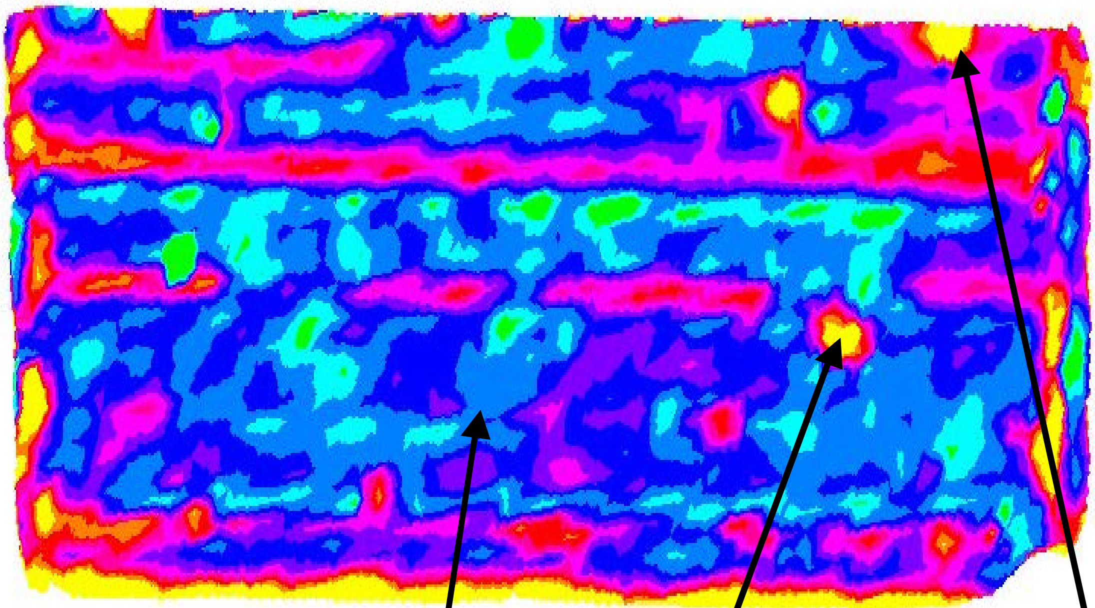


Figure 14 - Multiple Effects on Yield

The yellow edge effect on the lower and left hand boundary show grazing pressure from kangaroos on the wheat.

The single yellow points in the field are areas where timber is present.

This area of lower yield is poorly drained due to water build up along a road.

5. Weed Infestation/ Compaction

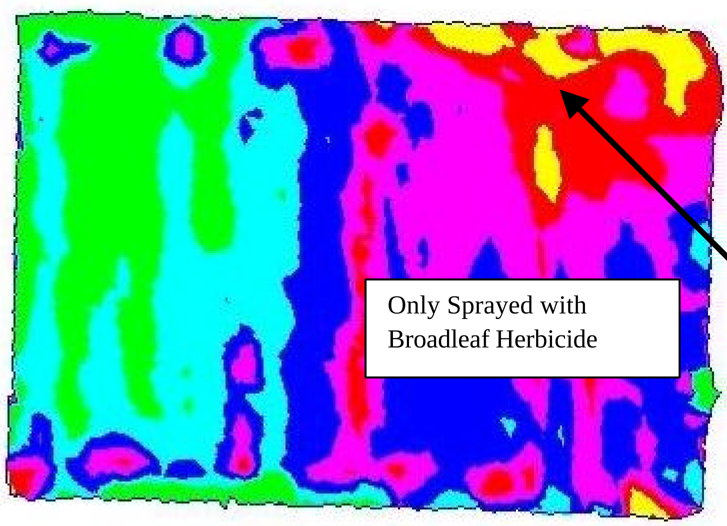


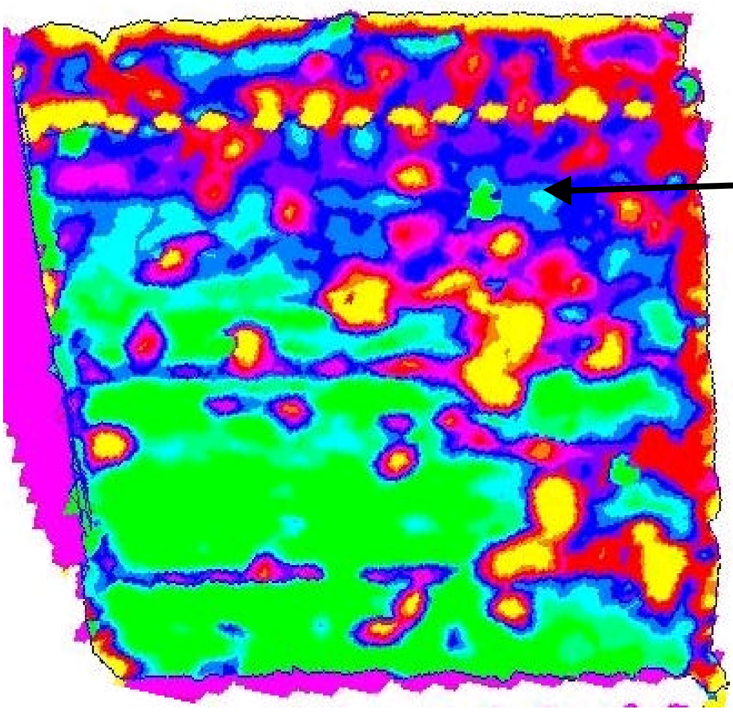
Figure 15 - Weeds and Compaction

The field on the left was sprayed for broadleaf weeds only on the right hand side and sprayed for both broadleaf and grass weeds on the left hand 1/3.

The yellow area here illustrates low yield compounded by compaction causing poor rainfall infiltration and low seedling emergence.

The yield here ranges from less than 6 bags per acre (yellow) to greater than 11 bags per acres (green).

6. Operator Error/Machinery Breakdown



Yield in the top half of this field was generally lower, between 1,400 and 1,700 kilograms per hectare, because of a broken fertilizer drive at sowing time, this problem wasn't picked up by the operator.

At change of shift the following operator noticed the broken drive and a different seeder was used to finish the field. The yield in the following section of the field was greater than 2,000 kg/ha. This represented a 25% reduction in yield, mapping of protein would also show a reduction in protein, further exacerbating the financial loss.

The line of yellow in the top 1/3 of the field was due to one header's gps unit failing.

Figure 16 - Machinery Breakdown Not Noticed

7. Experimenting Using Variety Trials using Yield Monitoring

In Figure 17 four different canola varieties were sown, they were all long season varieties, sown in Mid April 2001, and windrowed as they ripened. Variety 1 yielded 20%+ below the normalised yield for the paddock, Variety 2 yielded 20%+ above the normalised yield, and variety 3 yield between 5 and 20% above the normalised yield. There was very little yield penalty evident from using the TT (triazine tolerant) version of variety 3.

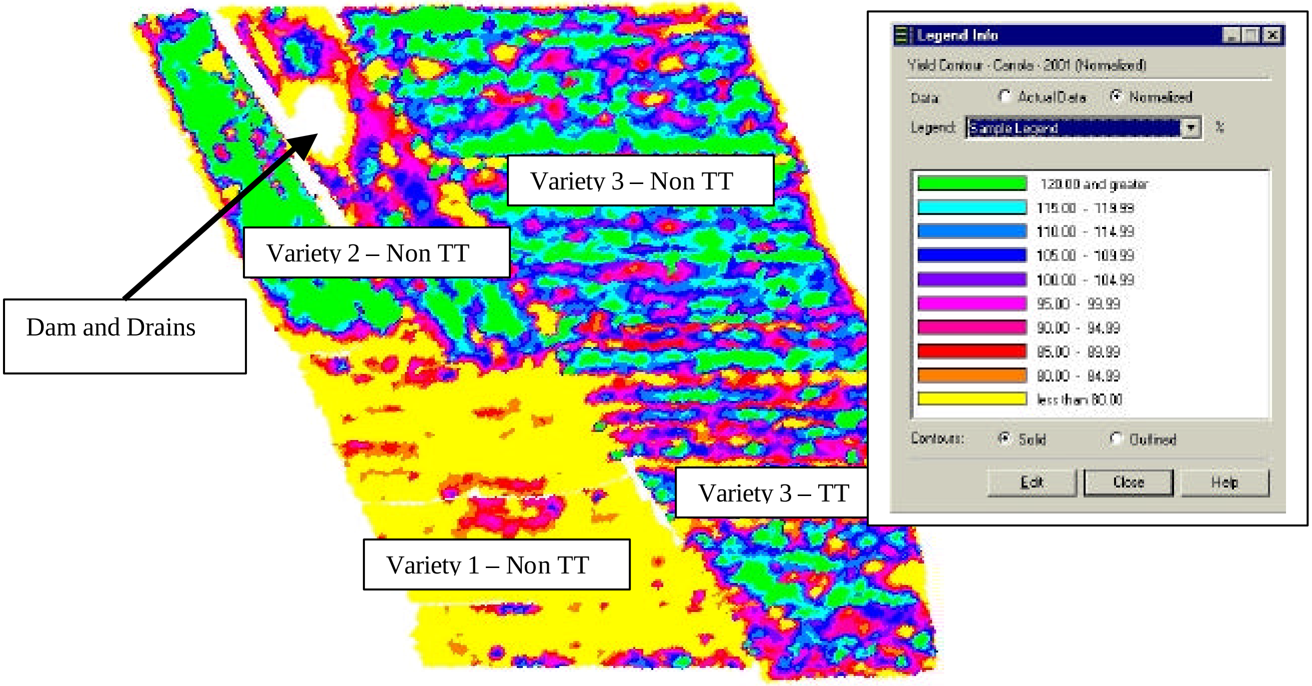


Figure 17 - Canola Variety Trial

Pasture Yield Monitoring

CSIRO Livestock Industries, Agriculture Western Australia and the Department of Land Administration WA[7], have developed pasture growth analysis using a satellite (NOAA AVHRR) that passes overhead daily. Instruments on board measure the reflectance of both visible and invisible light from the earth's surface, including vegetation such as pastures. The satellite imagery is converted into a Normalised Difference Vegetation Index (NDVI), which essentially shows how green the pastures are. This is then combined with climate information to give estimates of pasture growth rate. The technology is being verified across southern Australia, with test sites in South Australia, Victoria and New South Wales.

The collaborators believe this pasture information can assist farmers with management decisions such as grazing rotations, feed budgeting, fertiliser application and other "precision agriculture" techniques for the grazing industry. Agribusiness, regional shires, government, banking and finance may also be able to use the technology to assist them with rural strategic planning, land valuation and assessment, insurance, and futures forecasting.

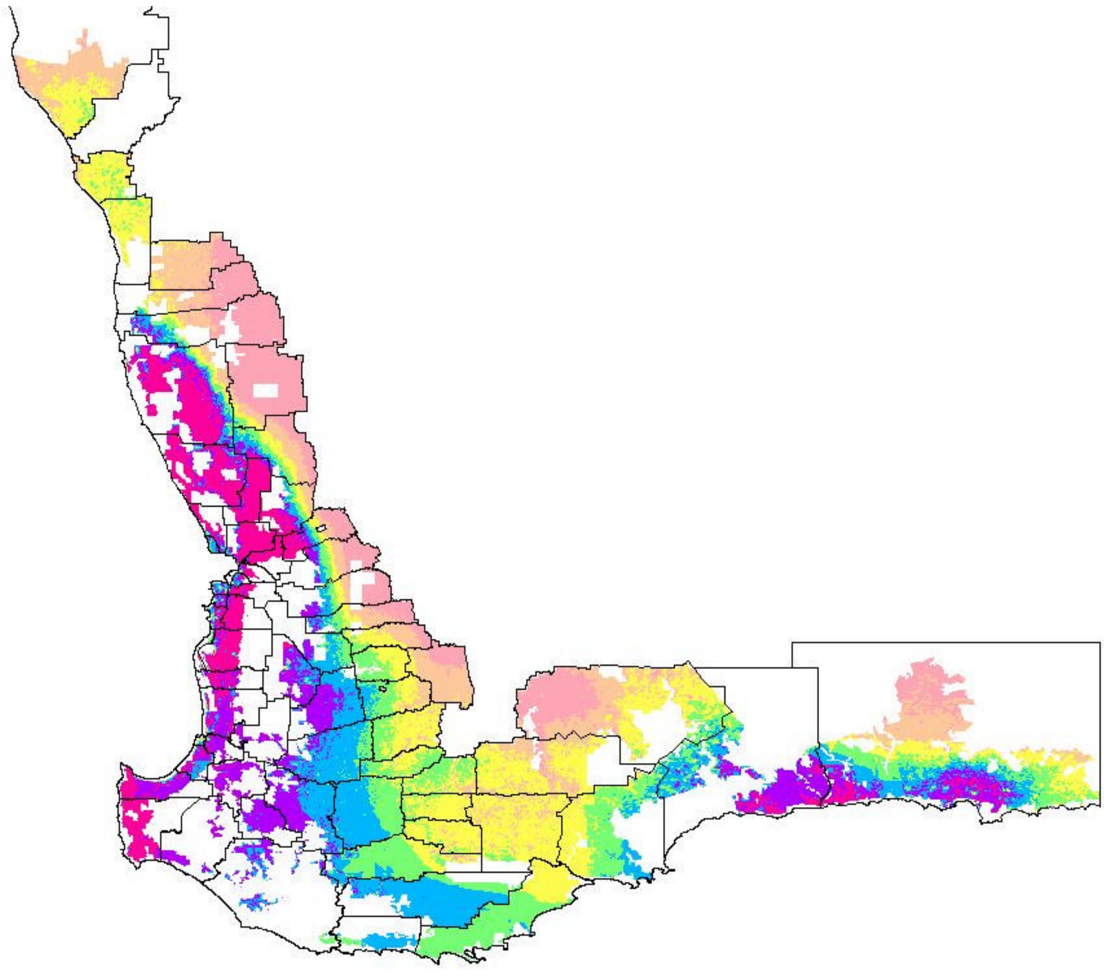


Figure 18 - Pasture Biomass Estimates for Western Australian Agricultural Regions

Figure 18 above, and 19 below, show satellite technology being used to measure the Feed-On-Offer (biomass) of pastures. Figure 18 show the biomass on a state-wide basis, the white areas represent cloud cover or crown land, while Figure 4 is a close up of a an individual property. Satellite imagery with a resolution of around 30m is used to produce these colour indicative maps. This satellite resolution allows researchers to instantly get estimates within individual paddocks and across the entire farm, district or region. Research is still in developmental stages and eventually collaborators hope to be able to produce individual farm maps showing the distribution of Feed-On-Offer, such as in the Figure 19 example below. Users will then be able to zoom into individual paddocks to see within-paddock variation.

A farmer can then use this data to make decisions about stocking rates, look at historical data to see pasture responses to treatments and do some serious cost-benefit analysis of improving pasture production.

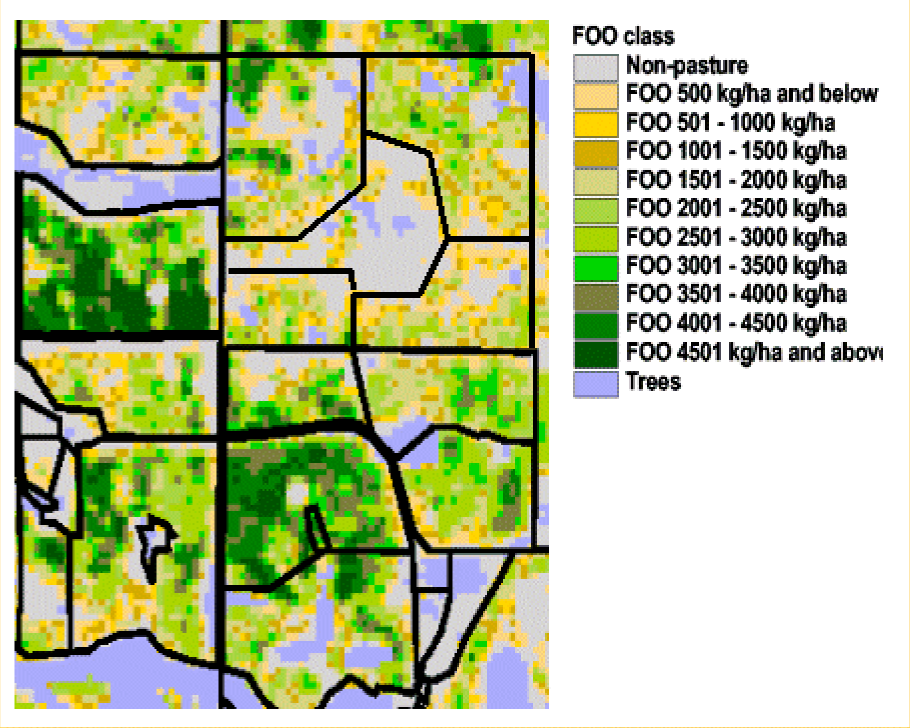


Figure 19 - Feed on Offer (kg/ha.)

Precision Crop Scouting

"Crop Scouting" is the term used by agronomists to describe in-paddock or in-field tests of crops for any number of agronomic factors. Crop Scouting in a PA environment simply links accurate co-ordinates or location information to the crop scouting information. Precision crop scouting has many benefits, for example, pest and weed numbers can be identified and mapped using GPS co-ordinates and printed out for decision makers onto farm or paddock maps. Precision crop scouting is carried out using hand held or laptop computers connected to (usually inexpensive) GPS receivers. Agronomists or managers can record pest or weed numbers and any other information that they may need, to make more informed management decisions as they routinely inspect the farm. The hand held devices are small enough to fit conveniently into a farm vehicle's glove box and consequently are always available to make instant reports. This information can be downloaded or e-mailed at the office and displayed on a GIS (geographic information system) giving a visual display of exactly where the crop scouting has occurred and identifying any problems and enabling more sound and economic management decisions to be made. This also eliminates the problem of scouts scouting in the same position in the paddock.

Figure 20 - Compaq™ Ipaq™ with SST's Stratus™ Software

Crop scouting by consultants should be made using GPS data as a matter of course to demonstrate due diligence to clients as well as to avoid costly litigation. Consultants using hand-held GPS-based reporting should be able to negotiate with insurance companies for lower professional indemnity rates.

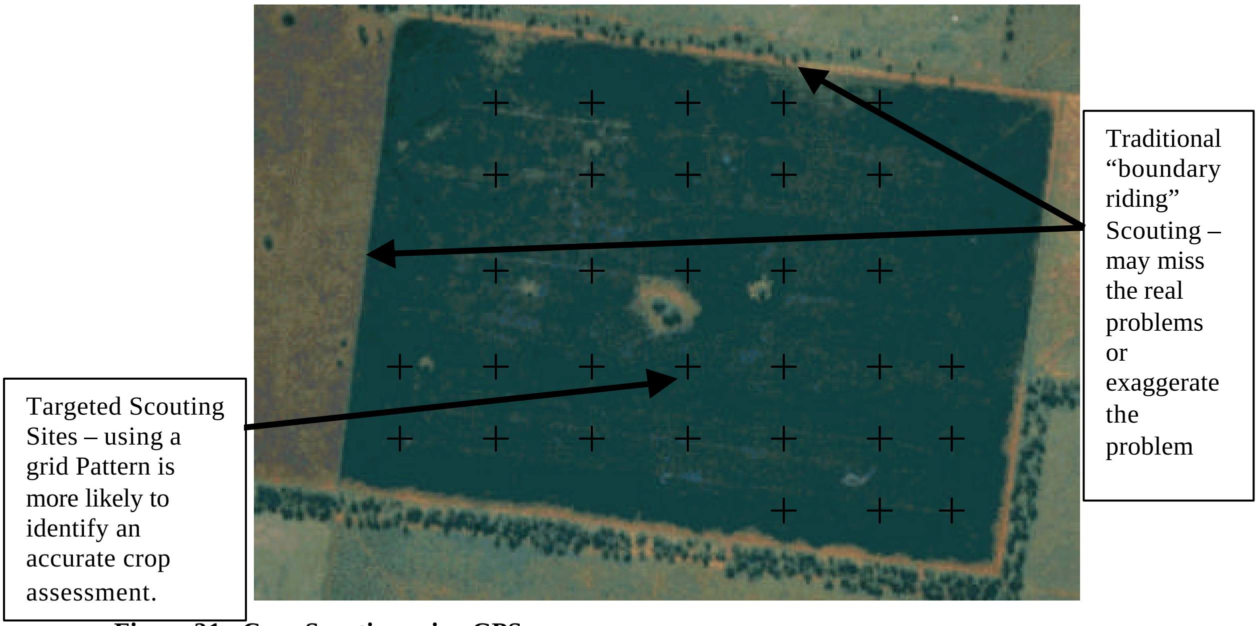


Figure 21 - Crop Scouting using GPS

Site-Specific Management (SSM)

Site specific management is about managing specific variations within a paddock as a management unit. Some examples of this are already mentioned above, some additional examples that may be more common in the future are:

1. Variable tillage by soil type/relief
2. Adjusting seed variety and rates "on-the-go"
3. Adjusting fertiliser rates and types "on-the-go"

4. Adjusting pesticide rates and types “on-the-go”
5. Precision crop scouting based on remote sensed images
6. Remote sensing used for scouting, nutrients, yield, drainage, irrigation
7. Yield maps showing variation based on geo-referenced maps.

SSM is 10 years old and PA pre-dates this by 15 years, it was the adoption of GPS that was the catalyst of the main drive and uptake of PA in the USA in 1993/4. Adoption has now plateaued - of 210 m acres farmed in USA, 50 m acres yield monitored. This is a level much greater than the adoption of PA in Australia.

Remote Sensing and Geographical Information Systems (GIS)[8]

Remote sensing: The measuring or estimation of properties from a distance.

The technology underlining remote yield sensing was developed at the height of the Cold War when the US wanted to estimate grain production around the world - and especially in the Soviet Union. Driving around on the ground, the traditional means of gathering production estimates, was hardly an option so researchers began to explore other methods.
To this end, NASA, the USDA and NOAA joined forces and investigated the use of aerial or satellite imagery to estimate cropping areas and yield on a large scale (and by large, we mean country by country).

One legacy of this project is the scientific basis for yield estimates from satellite and aerial imagery, another is the satellites themselves (LANDSAT and its descendants). But though nation-wide estimates might have value as corporate and national intelligence, they have little relevance to a farmer - especially when you consider the yield variability that can occur within a single paddock in Australia.

To provide the enormous detail needed for the in-field estimates a farmer needs, the original technique has been significantly refined. It is now possible to use these satellite-based remote images to give on-ground estimates of a variety of crop and or soil conditions.

Figures 22 and 23 below show a bare-field and NIR aerial image of a corn field in Kansas, USA. Soil types are identified from the bare field image and tested, these soil types can subsequently be seen to affect crop health I the NIR image in Figure 23.

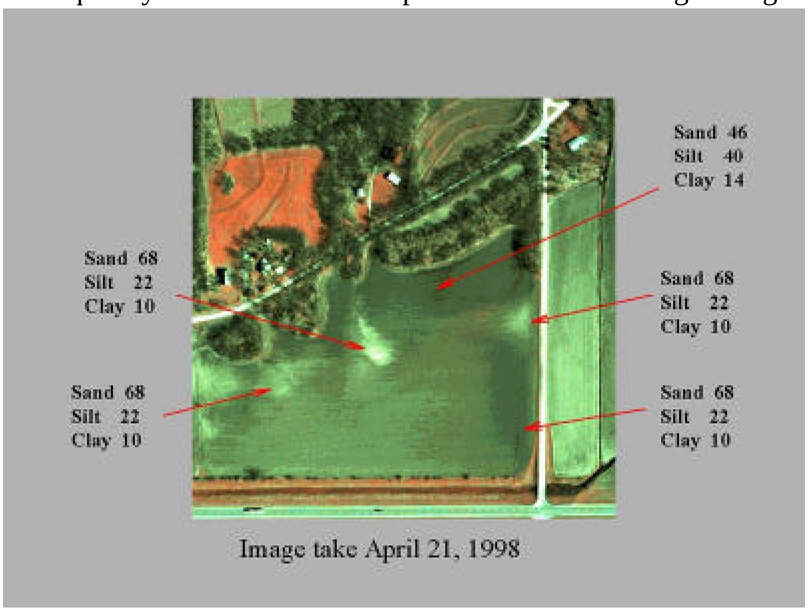


Figure 22 – Bare-Field Photo Showing Soil Colours (Kansas State University)

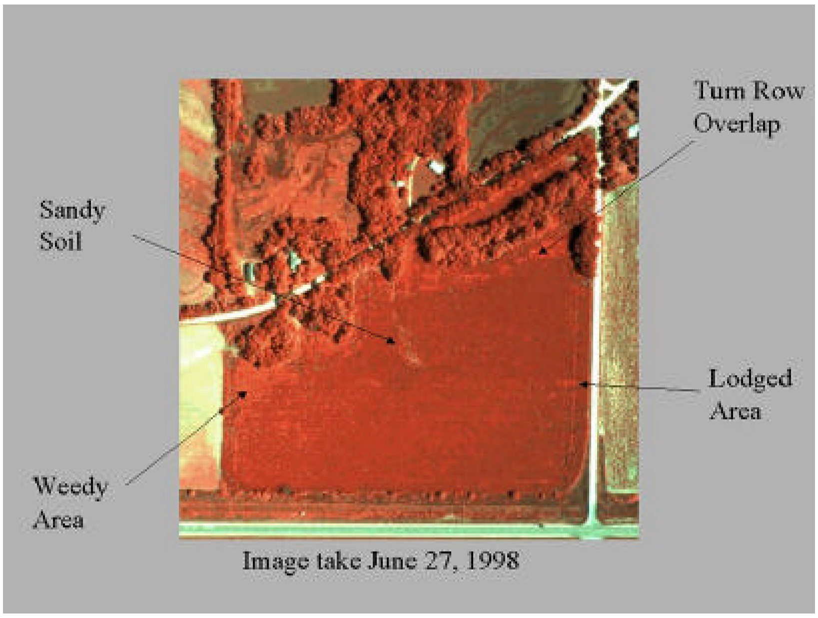


Figure 23 - NIR Aerial Image Showing Crop Stress Areas.

Defining Management Zones

Historically, management zones have been around for a long time, farmers apply more or less inputs to good or bad areas of a paddock, it is the formal definition of these that allows VRT for most farm inputs.

"A Management Zone is a sub-region of a field that expresses a homogenous combination of yield-limiting factors for which a single rate of specific crop input is appropriate" Tom Doerge, Pioneer Hi-Bred International.

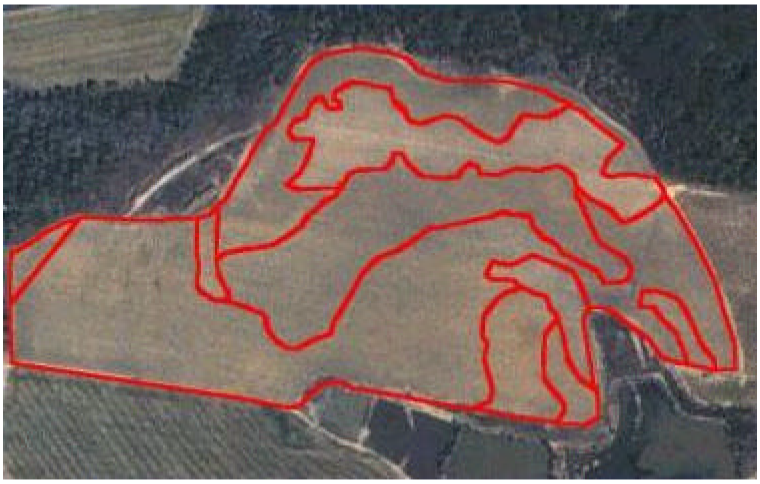


Figure 24 - Farmer Defined Management Zones[9]

Variable Rate Technology (VRT)

The "holy grail" for some PA farmers.

The idea is to apply crop inputs based on the management zones identified for that specific location and crop, not on an average paddock need.

Silsoe Research Institute in Bedfordshire, UK has been working on a variable rate on-the-go foliar nitrogen applicator.

Figure 25 - VRT Foliar Nitrogen Applicator (NIR)

Figure 25 above is a close up of the boom on an experimental VRT “on-the-go” foliar nitrogen spray rig. The Spray rig is a standard design except that it has dual wet lines and electronic solenoid activated spray nozzles, the rig also has a NIR (near infa red) camera mounted in front of the spray nozzles which passes information about the colour of the crop canopy to a computer, this computer uses GPS data to log where the camera is located and thus enables a nitrogen rate to be calculated based on this. At the moment the rig is in developmental stages and requires two passes of the paddock to complete an operation, one to acquire the NIR data and the second pass to apply the foliar nitrogen. It is envisaged that in time this will be a one-pass system.

Farmers at a precision agriculture conference in Indianapolis, IN, USA in 2001 identified some of the best economic responses to VRT in the USA have been from the application of lime and seed, particularly in soy-bean crops.

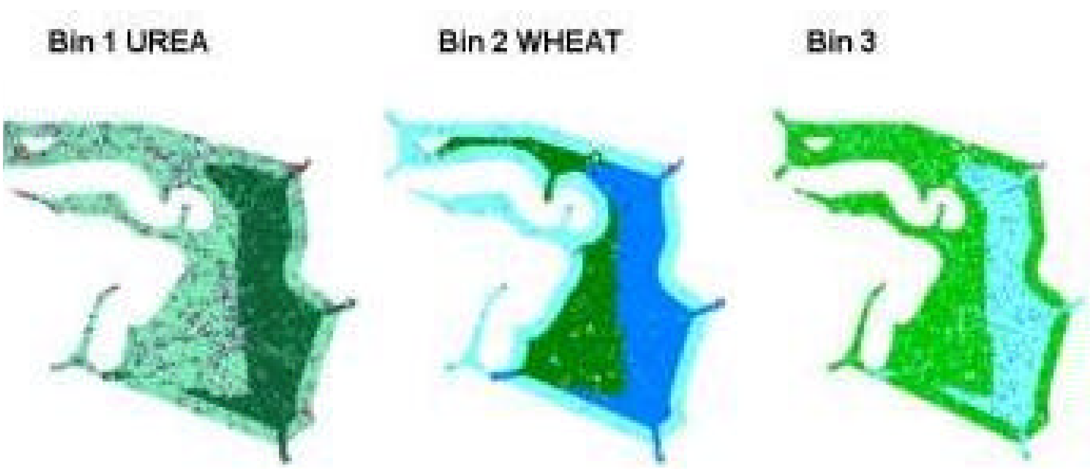
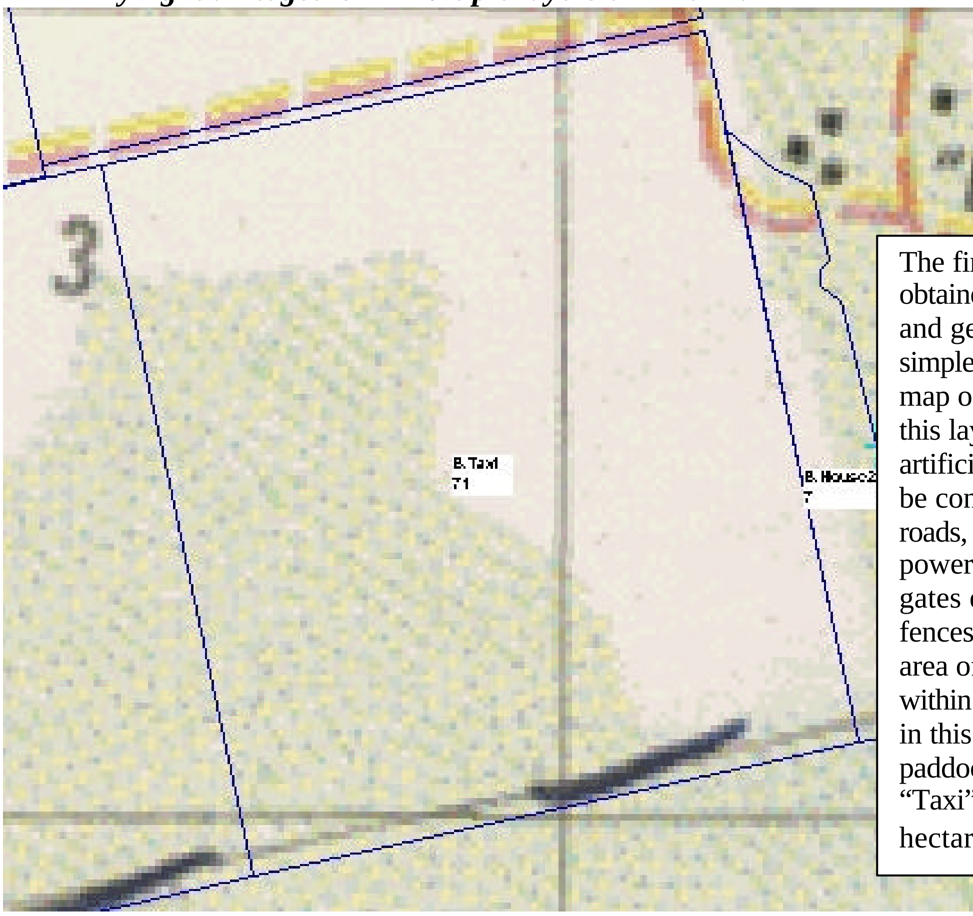


Figure 26 - Prescription Maps for a Triple Bin Air-seeder

Precision Agriculture, Conservation Farming and Control Traffic

Tying it all together – Multiple layers on "Bonna"



The first layer is obtained by scanning and geo-referencing a simple topographical map of the farm. Onto this layer a number of artificial images can be constructed such as roads, pipelines, power-lines, fences, gates etc. Once the fences are outlined the area of the paddock within is determined, in this case the paddock name is "Taxi" and it is 71 hectares.

Figure 27 - "Bonna" Map Layer 1 - Topographical Map

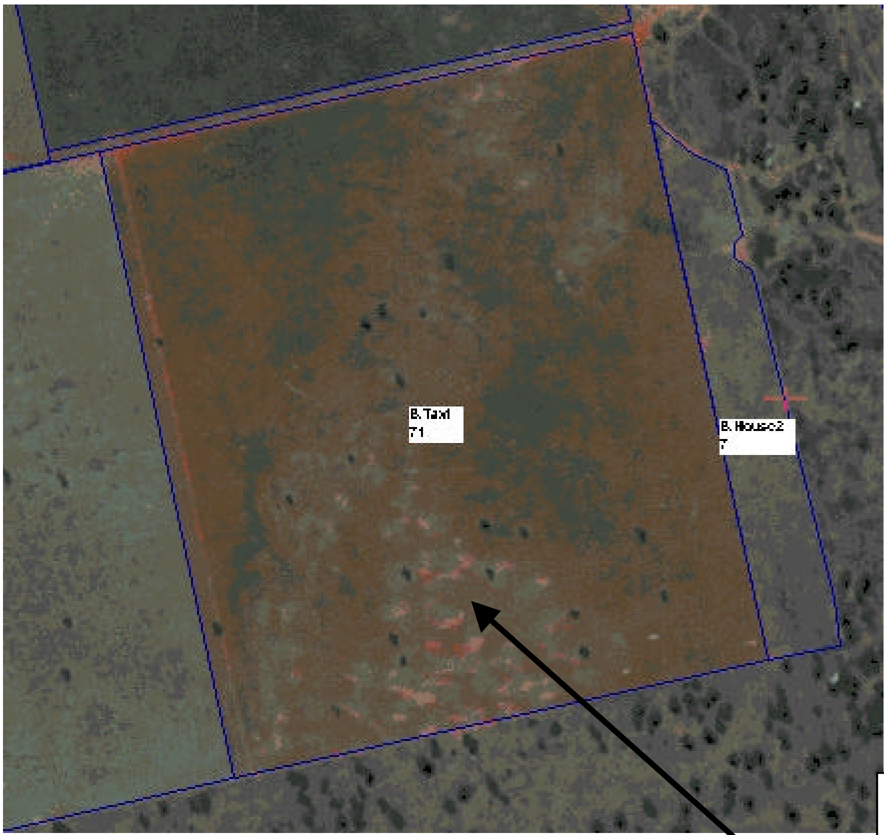


Figure 28 - "Bonna" Map Layer 2 & 3 - Aerial Photo and Fences

Gilgais (melon holes) and associated heavier gray soils are easily seen in the aerial photo in Figure 26.

Looking at the same areas on the yield map in Figure 27 we can see that yield in these heavier soil types was significantly lower.

What we do not know from one year of yield data is if this is a one-off effect, such as water-logging, or if the soils are perpetually less productive. More yield maps over a number of years will provide more clarity.

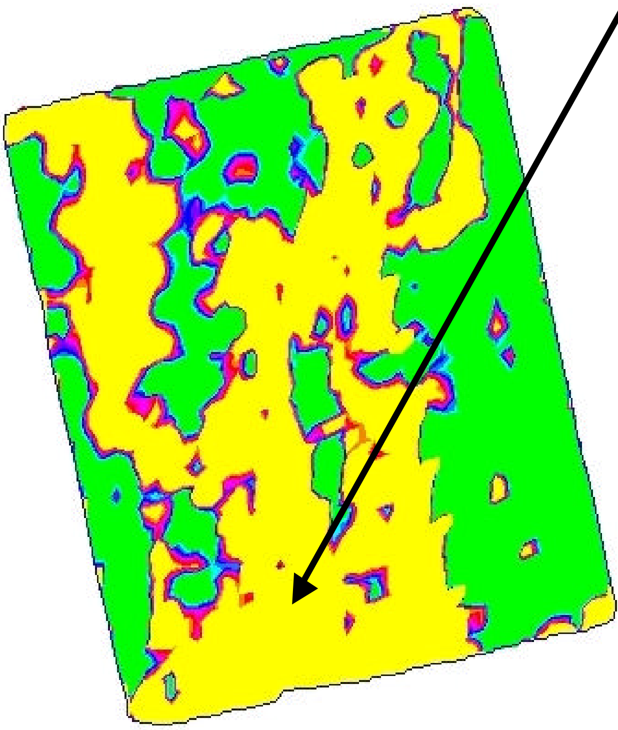


Figure 29 - "Bonna" Map Layer 4 - Yield Map from 2001 harvest (Barley)

Precision Agriculture Data Analysis

A cautionary note with Precision Agriculture is there is a tremendous quantity of information to deal with and as yet software systems do not exist to seamlessly manage this data. It is important therefore that an individual farmer can get additional professional help with data management and interpretation if that farmer is to gain the largest financial benefit from precision agriculture. Professional help can be either training in PA analysis or using PA consultants to undertake PA analysis on their behalf, much like an agronomist is called in for specific agronomic advice rather than the farmer learn some specialist area such as cotton entomology for example.

Pocknee[10] refers to two classes of precision agriculture data analysis, 'rigorous' versus 'quick and dirty'. Rigorous analysis, is quantitative analysis and includes classical statistics and geostatistics, these methods are capable of getting the most information out of a data set and can discriminate between dissimilar results to a very precise level. Some examples of rigorous analysis include regression analysis.

Quick and dirty analysis on the other hand encompasses a wide range of qualitative techniques. Visual observations of field conditions are a type of analysis. Statements such as "that corn looks taller this years than last year" or "the yield in this corner of the field seems to be down this year" are qualitative observations that may be correct do not confer exact magnitudes. It is often difficult to prove or disprove such observations hence there is a definite uncertainty inherent and an increase in risk. A farmer can often not communicate the reasons for an observation in any convincing manner. This does not mean that the observation is incorrect although it does make it difficult for others to repeat and learn from the observation.

Data archiving and maintenance:

- Software and analysis techniques change but data is constant
- Data may have to be collected over several seasons before it can be translated into information
- Data archiving is non-trivial and can be expensive

The data is a crucial commodity. You will not always be able to use it when it is collected. It may take the collection of other data over time before some of your data can be utilised. For this reason it is important to ensure that your data is stored methodically and in a safe environment.

Some Farmer Experiences with PA

Kent Brewer, Frankfort, Indiana, USA.

Farming since 1979, 2 FTE, 1,500 acres crops / 500 sow piggery
Got into PA from the cost side of it not for increased yield.
His yield is 7 bu/acre corn and 16 bu/acres soybeans better than conventional neighbour BUT expenses much lower.
VRT Chemical Application - Chemical Injection triple nozzle sprayer.
VRT Anhydrous Ammonia.
Has 7 different management zones which relate to soil types.
Says VRT with Soybeans gives his quickest return.

Doug Hartford, Mazon, Illinois, USA.

To get value from PA you need to define Value:

"Value from PA is the ability to gain control"
Began soil sampling in 1976, drainage in 1980, 1983 No-till.
1992 Yield monitor in Header, first map 1993
1997 Began remote sensing - still trying to "figure it out"
PA allowed him to find out what can be controlled, and taught him to stop chasing that last bushel

Kim and Joe Townsend – Agricultural Consultants, Mississippi, USA.

Joe Townsend is an agricultural consultant working for his own consultancy business "Townsend Consultants", Joe is working with a company which is introducing NASA technology. This is leading edge technology and is one of the first in the world doing this and his two farmer clients are the first farmers doing this commercially. The technology theoretically it works like this (they are still getting bugs out of the computer/gps/email side of things). A photo is taken at 12,000 feet – near infrared spectrum (NIR), stressed cotton is brown, unstressed is green. Fields have already been marked out using actual GPS co-ordinates so an image is taken only of the cotton fields that Joe is interested in. Joe walks out in the field with his handheld Compaq Ipaq™ connected to the GPS and looks at the screen (image has been wireless emailed to him) until he's in the middle of the green area. He does a crop scout taking bug samples within this area and then proceeds to the brown area. If there are significant differences between the crop scouting report that require different chemicals to be used, the field is then divided up into different spray categories. The recommendations for the different spray categories are emailed (wireless phone line) to the clients. The NASA guys write a "prescription" card for the application of the pesticide and the spray rig with the GPS spray system puts the chemicals out differentially depending on where they are in the field.

They use the latest Compaq Ipaq™ also use Navman GPS™ which the Compaq Ipaq™ slides into Joe's just trialing (well actually he hasn't put it into trial yet) a program called Fieldbook™ from Farmworks (www.farmworks.com)/SST (Site Specific Technologies Group) (www.sstdevgroup.com) for laptop, which we saw and looks excellent. The only problem is it needs a laptop. The handheld version is Stratus™.

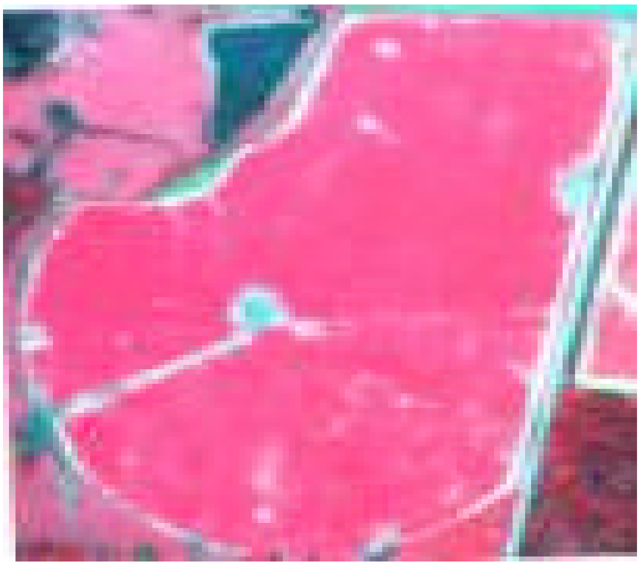
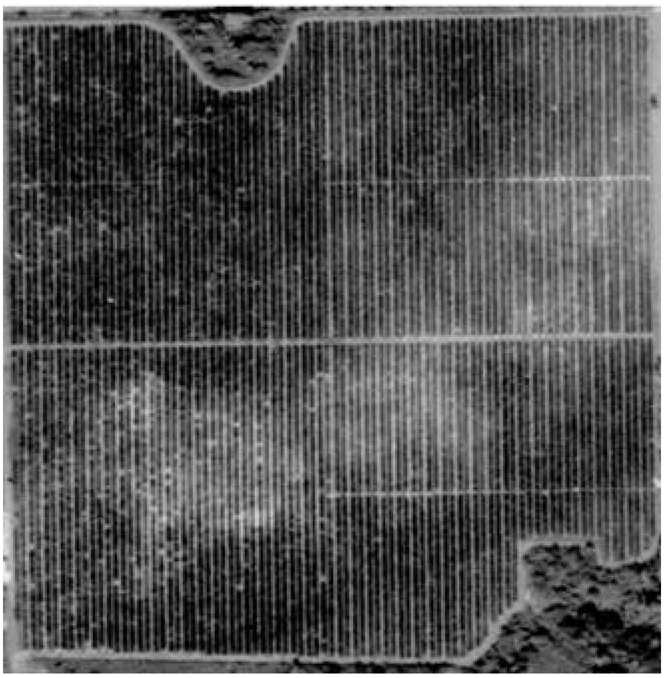


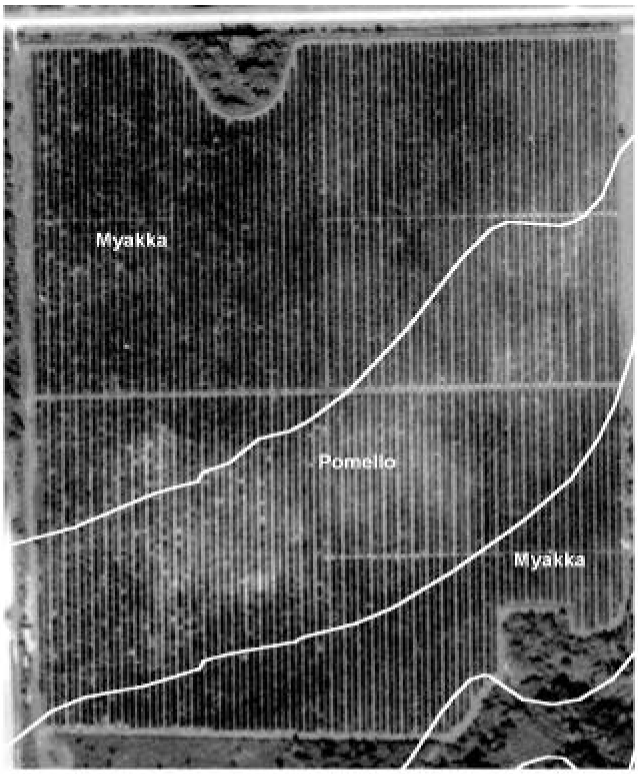
Figure 30 - Example of a Near Infrared (NIR) Aerial Image of a Crop of Corn

What Joe actually does is walk out in the field, work out the percentages in his head of the different insects attacking the cotton, work out the spray recommendations then goes back to his vehicle and dictates his recommendations as he drives along to one of his workers who types it into a word file on the Compaq Ipaq™. They print it out via infrared port to a Cannon ™ Bubblejet™ BJC85™. Printboy™ software enables printing from the Compaq Ipaq™ to the Cannon ™ BJC85™.

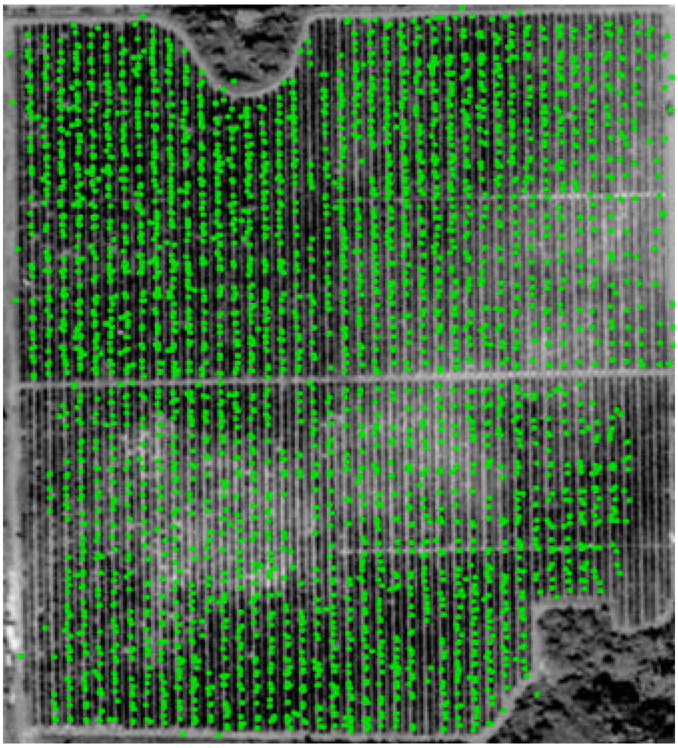
University of Florida – Citrus Research Project[11]



This picture is an aerial view of citrus grove showing spatial variation in tree size or condition. The darker areas represent more foliage and consequently are areas of better tree size and condition. In the lighter areas less tree canopy is visable and more of the soil can be seen in the photo.

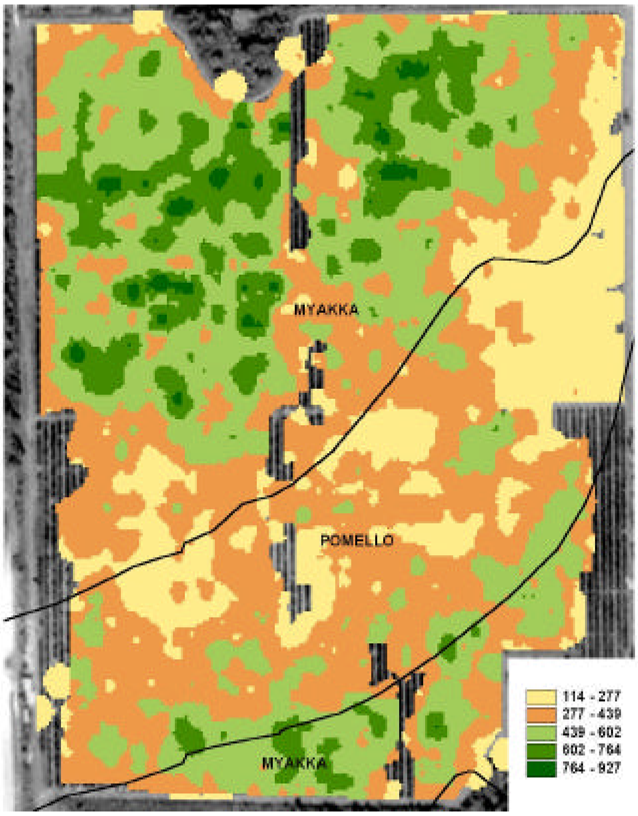


The orchard was then soil sampled to try to identify the reason for the differing tree size and conditions. The picture on the left show a soil types outlined over the original aerial photo. The two main soil types appear to account for the variation in tree condition. The Pomello soil type is a lighter sand with sodic properties.



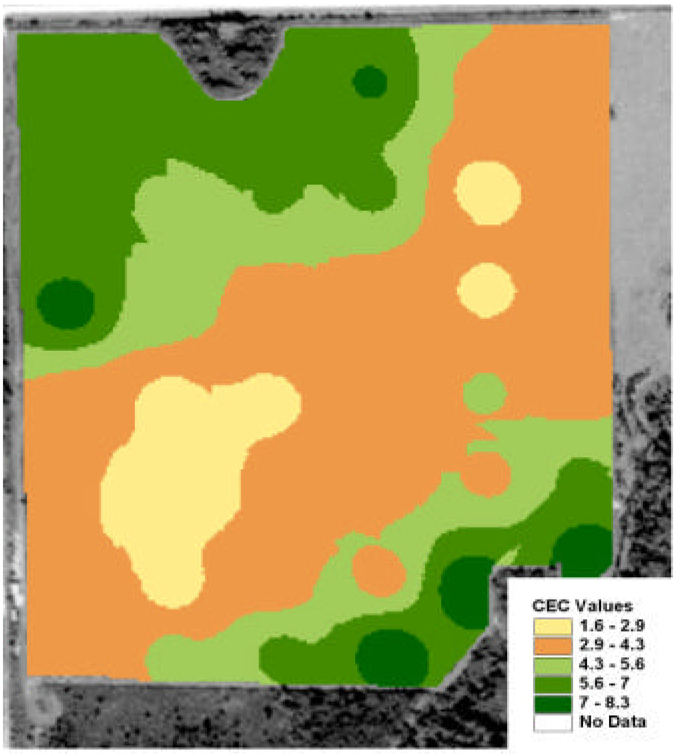
This photo has had citrus crop yield plotted over the original aerial photo. Citrus yield was obtained by placing a green dot to represent each box of fruit picked, the box was geo-referenced using DGPS data to identify the specific location of the box and illustrate the location of the citrus tree's yield. The more containers per unit area (higher density) where tree condition is better indicates higher yield per acre.

Note that citrus yield can be seen to closely mirror tree canopy density.



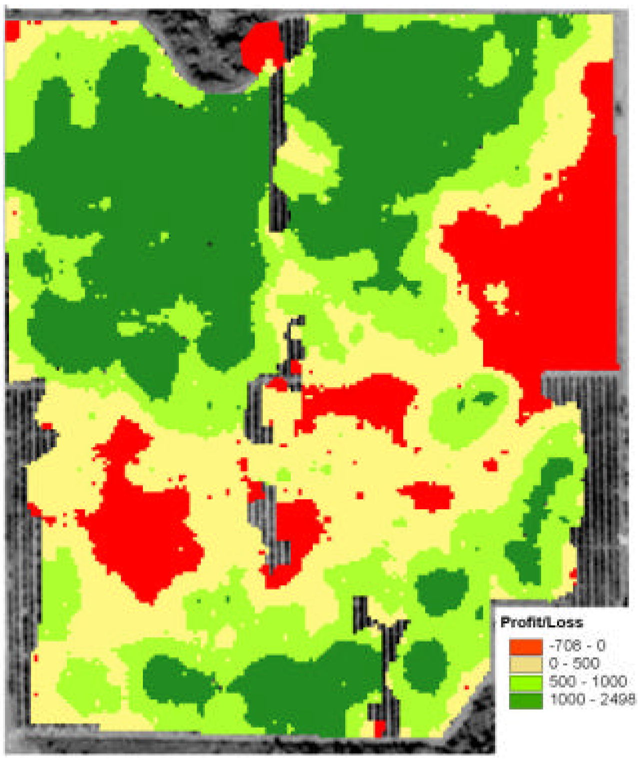
The photo on the left here has had an interpolated yield map based on the container density overlaid on the original aerial photo, as well as the soil type layer. The yield is plotted in Florida boxes/acre, this needs to be divided by 10 for approx metric tons/ha.

This map of the orchard now is presenting multiple layers of information to the orchardist who can interpret that information into management decisions.



One of the important soil amelioration strategies in Florida Sands soils is Cation Exchange Capacity (CEC), this is a reflection of sodicity and soil quality. Once again it is possible to see a high correlation between CEC and crop yield.

This type of information is most important when setting up an orchard, the orchardist in this example is dealing with a mature orchard, with little chance of altering crop yields in the short term. A far better strategy is to locate the orchard on better soils in the beginning.



The final picture in this series plots profit and loss per acre. This presents a stark reality to the orchardist, almost one third of his orchard (total area 200 acres) is losing money, and not just a bit, the worst ranging from a loss per acre of US$708 to Breakeven. Averaged out this loss is approximately US$14,200 for the worst area, per annum.

When this is compared with his profit in the better soil type of up to US$2408 per acre per annum the decision to bulldoze the middle section of this orchard becomes clear. Amelioration not being a realistic option for this tree crop.

Financial Analysis of some Selected PA Technologies

Below are outlined a number of basic economic analyses of different aspects of Precision Agriculture technologies.

Precision Agriculture Technology Evaluator[2]

The aim of the spreadsheet was to evaluate simply the purchase of new precision agriculture technologies, using farmer input on their own farm and financial circumstances. The spreadsheet required information on costs of the PA technology, expected benefits of the technology in terms of reduced overlap and expected gains in productivity.

An example of a PA technology is presented below, the new technology being considered by our hypothetical farmer is a proprietary DGPS Guidance System. The DGPS guidance system is used to guide a machinery operator in a straight line, or race-track style guidance. It is expected to cost $13,500, and has a annual subscription for GPS signal of $1,404.

Precision Agriculture Technology Evaluator

Precision Agriculture (PA) Equipment:	DGPS Guidance	Benefit-Cost Crop Budget	
Purchase Price	$13,500	Increased Annual Income from Cropping	$ 7,500
Percentage Financed:	100%	Reduced Annual Variable Costs	$ 10,000
New (N) or Used (U)	N	Reduced Annual Labour Costs	$ 750
Finance Period (Years)	2	**Annual Benefit of PA Investment**	**$ 18,250**
Interest Rate (%)	7.75		
Depreciation Period (Years) Max is 5	4	**Annual Cost of PA Investment**	**$ 4,673**
Expected Ownership Period (yrs)	4		
Marginal Tax Rate:	30%	**Net Benefit of PA Investment**	**$ 13,577**
Expected Average Inflation Rate (%)	3.50	**Accumulated Benefit Life of PA**	**$ 54,309**
Precision Agriculture Costs		**Per Hectare Benefit of PA Investment**	**$ 54.31**
Personal Computer Cost	$4,000		
% of Time Allocated to PA	33%	**Running Costs Data**	
Annual Area Cropped:	1000 ha.	Consultant Labour Hours per year	0
Number of PA Operations	5	R&M as a % of Capital Cost (3.5%)	3.50%
Hours Used per Annum	500 hours	Materials (Disks Paper Etc)	$675
% Area Farmed by this Unit	100%	Consultant Labour ($/hr)	$150.00
Crop Budgets:		Differential GPS Signal Subscription	$1,404
Annual Income from Cropping	$250,000		
Annual Variable Costs (ex. Labour)	$100,000		
Reduced Overlap from PA	10%		
Expected Gain in Productivity from PA	3%		
Labour Cost ($/Hour)	$15.00 per hr.		
Annual Labour Costs for PA Activities	$7,500		

[2] A spreadsheet developed by the author and is available by email upon request.

After the farmer inputs all the information marked in shaded yellow, the spreadsheet calculates a series of costs and benefits from the PA technology. The benefits are:

1.	Increased Annual Income from Cropping	$7,500
2.	Reduced Annual Variable Costs (ex. Labour)	$10,000
3.	Reduced Annual Labour Costs	$750
4.	Total Annual Benefit of PA Investment	$18,250

From this Total Annual ($18,250) which is based on the farmer's marginal tax rate, method of equipment finance, calculated based on the expected period of ownership of the PA technology. This gives a Net Annual Benefit (Cost) of the PA technology, which as can be seen from the above table, of $13,577. This is also calculated based on the Life of the technology to be $54,309, and per hectare of cropping to be $54.31 per hectare.

So from the example presented here a farmer with an annual cropping income of $250,000, with variable costs of $100,000 and cropping 1,000 hectares can expect to return an additional profit of approximately $54,309 over the life of a new PA guidance system.

We can compare this with a more expensive system of machinery guidance such as an Auto-track system which allows hands free operation of the machine, this will allow the hypothetical farm manager to compare the costs and benefits of the two systems. So in this second example the cost of the new technology is $48,500, the expected reduction in overlap is increased from the first system from 10% to 15% as there is very little overlap at all with the auto-track systems, the resulting improvement in tram-lining ability and associated reduction in compaction and increased crop production is increased from the first example from 1% productivity gain to 2% productivity gain. Using the auto-track system can, depending on the system also negate the cost of differential signal saving $1404 per annum. Consequently, inn the second example, keeping all other costs constant, the benefits are:

1.	Increased Annual Income from Cropping	$15,000
2.	Reduced Annual Variable Costs (ex. Labour)	$15,000
3.	Reduced Annual Labour Costs	$1,150
4.	Total Annual Benefit of PA Investment	$31,125

From this we deduct the tax effective Annual Cost of the PA technology investment which is $13,321. This gives a Net Annual Benefit (Cost) of the PA technology of $17,804. Over the Life of the auto-track technology the total net benefit is $71,217, and per hectare of cropping to be $71.22 per hectare.

So from our hypothetical examples above the farm manager can compare a net total benefit of $54,309 for the DGSP guidance system versus a net total benefit of $71,217 for the auto track system. This is a net difference of $16,908 or $4,227 per annum. Obviously the technologies both are positive investments and the farm manager can decide which one suits his own farming situation best.

VRT of Ameliorants for Irrigated Field following Laser Leveling

Figure 13 above illustrated the yield map of a corn crop harvested in May 2002 from an irrigation field laser-leveled in 2000. Laser leveling is used to obtain more uniform irrigation of a furrow irrigated field. The down-side of this is that higher areas of land have their topsoil cut away and used as fill in lower lying areas of the field. Figure 13 clearly shows the effect of this cutting, correlating highly with the lower yielding areas of the paddock.

Using VRT application of both zinc and gypsum as soil conditioners, following recommendations from consultants and site specific soil sampling. The cut area of the field, suffering from yields less than the paddock mean yield was 9.8 hectares out of a total field area of 27.65 hectares. Table 1 below shows the area, yield (as a percentage of mean), and suggested ameliorants in tonnes per hectare.

Table 1 - Soil Ameliorants on a Laser Leveled Corn Field

Area of Field	Mean Yield	Gypsum per Hectare	Total Gypsum	Zinc per Hectare	Total Zinc
1.7	<100%	4	6.8	5	8.5
2.3	<90%	5	11.5	6	13.8
2.2	<80%	5	11	7	15.4
2.4	<70%	6	14.4	8	19.2
1.2	<60%	10	12	10	12
9.8			55.7		68.9
		Average	5.7	Average	7.0

Compare the quantities of ameliorants used in Table 1 with what would have been used if a whole of field approach was used. The 55.7 tonnes of gypsum and 68.9 kilograms of zinc would have been used over the entire area giving an average rate of 2.01 tonnes per hectare of gypsum and 2.5 kilograms per hectare of zinc over the 27.65 hectare field.

Alternatively if an average rate of 5.7 tonnes of Gypsum and 7 kilograms of zinc were applied to the entire field an additional 101 tonnes of gypsum and 125 kilograms of zinc would have been required costing approximately $9,100 after spreading costs were included. Using this whole of field approach to applying nutrients/ameliorants would still leave 3.6 hectares or 13% of the field with not enough ameliorants applied to return to full production level.

Foam Marker vs. DGPS guidance

Another simple use of the Precision Agriculture Technology evaluator assesses the use of a foam market versus a cheap light-bar guidance system. The foam marker can only be used in good conditions, hot or poor light conditions result in increased overlap. Even under ideal conditions the foam marker still results in an overlap of 1-2 metres in 18, plus the overlap at the end of a paddock from not driving straight, add another 5%, giving a total overlap of 10-15%. The light-bar guidance system results in a reduction to approximately 50 cms in overlap, plus because you can drive in a straight line there is not overlap (or triangle in a square field) to finish off. Conservatively the overlap would be reduced by 7.5 %. Taking this into account as well as the ability to night spray and spray in adverse conditions, timeliness of operations can be expected to be improved, this would certainly result in better productivity, assumed to be a 1% gain.

The net benefit of light bar guidance over foam marker would be, for our hypothetical farm described above, in the order $6,839 per annum. Over the life of the light bar guidance system, assumed to be 4 years, the net gain would be $27,356 or $27,36 per hectare. Thus there is a good argument for investing in this precision agriculture technology.

General Observations - North American Experience

Some aspects of precision farming will become standard practice for North American agriculture, but as yet which aspects will prove most practical and profitable is unclear. The most durable investment that farmers and agribusiness can make in this area is the development of management skill and databases. Hardware and software are sure to change, but site specific data bases and the capacity to use precision management tools profitably will provide a long run competitive advantage.

Future Direction for PA in Australia

Some of the most promising aspects of PA seem to be the use of PA technologies to conduct on-farm research, and the environmental benefits of PA. Both of these have the potential to provide real benefits both on a farm-level and on an environmental level. At a farm-level the farmer is able to more easily document and demonstrate the advantages of certain varieties, pesticide strategies or nutrient applications. The environment is the beneficiary because of a more targeted approach to the application of nutrients and pesticides ensuring that there is less off-target application and less leaching to groundwater and surface water and in general lower level of externalities.

Adoption Levels in The USA seem to have plateaued in the last 2 years but it is unclear whether this is a result of poor commodity prices or a wider lack of interest in PA, some farmers have held off adoption preferring to wait until the technologies are "proven" economic winners..

"Identity Preserved(IP)" – Quality Assurance Production[12] is another area for excitement, this combines the more rigorous approach of farming using PA with a documentation trail and quality assurance benefit to marketing of products. The table below illustrates the differences between traditional and IP production methods.

Table 3 - Differences between IP and Traditional Production

Identity Preserved	Traditional
• Contracted	• Open market
• Quality specifications	• Volume focus
• Rules	• No rules
• "Extra" work required	• No "extra" work
• Receives premium for grain	• Receives market price for grain

Conclusion

In conclusion, the use of precision techniques in agriculture heralds the beginning of a paradigm change, one which arguably, will have as large an effect on the economics and productivity of agriculture as previous paradigms such as the use of pesticides, "green revolution" dwarf cereal varieties or the use of fertilizer, even the use of machinery.

History has taught the it is the early adopting farmers who were at the start of previous paradigm changes that have been the ones who have gained the most benefit from the new technology. Late adopters of new technology are usually forced into the adoption by economic pressures and the continual cost-price squeeze affecting agriculture. Late adopters usually have to bear the cost of new technology just to stay competitive and gain very little economically from the adoption.

To put this conclusion into perspective, the precision agriculture paradigm change has already begun, farmers in the USA have been using PA techniques routinely now for almost a decade, farmers in Australia are, in general, a few years behind this. Ask yourself the question where are you up to in the adoption of the next paradigm change to affect agriculture?

Some Useful Precision Agriculture Links for the Internet:

CSIRO Pasture Yield Monitoring:
http://www.pgr.csiro.au/

Crop Scouting Software and Hardware:
http://www.farmworks.com/

University of Sydney, Australia.:
http://www.usyd.edu.au/su/agric/acpa/

University of Georgia, USA.
http://nespal.cpes.peachnet.edu/PrecAg/

Variable Rate Irrigation
http://nespal.cpes.peachnet.edu/vri/home/

Precision Agriculture Learning Site
http://nespal.cpes.peachnet.edu/pa/home/

Kansas State University, KS, USA
http://www.oznet.ksu.edu/precisionag/

Purdue University, Indiana, USA
http://mollisol.agry.purdue.edu/SSMC/

FarmScan Precision Agriculture Software
http://farmscan.net/news.aspx

Site Specific Development Group (SST)
http://www.sstdevgroup.com

Red-Hen Software
http://www.redhensystems.com

Search Engines:

http://www.google.com

http://www.yahoo.com

http://www.agrisurf.com

Appendix 1 - Precision Agriculture - Equipment Purchase Benefit-Cost Budgeter

Precision Agriculture (PA) Equiupment:	DGPS Guidance
Purchase Price	$13,500
Percentage Financed:	100%
New (N) or Used (U)	N
Finance Period (Years)	2
Interest Rate (%)	7.75
Depreciation Period (Years) Max is 5	4
Expected Ownership Period (yrs)	4
Marginal Tax Rate:	30%
Expected Average Inflation Rate (%)	3.50

Precision Agriculture Costs

Personal Computer Cost	$ 4,000
% of Time Allocated to PA	33%
Annual Area Cropped:	1000 ha.
Number of PA Operations	5
Hours Used per Annum	500 hours
% Area Farmed by this Unit	100%

Crop Budgets:

Annual Income from Cropping	$ 250,000
Annual Variable Costs (ex. Labour)	$ 100,000
Reduced Overlap from PA	10%
Expected Gain in Productivity from PA	1.00%
Labour Cost ($ / Hour)	$15.00 per hr.
Annual Labour Costs for PA related Activities	$ 7,500

Capital Costs

Amount Financed	$13,500
Market Value at Disposal	$4,000
Depreciation Over Ownership Period	$13,500
Written Down Value at Disposal	$-
Recouped Depreciation (Profit on sale)	$4,000
Opportunity Cost Factor (%)	7.75
Opportunity Cost	$ 2,884
Finance Cost (Interest over period)	$1,589
Inflation	$531

Benefit-Cost Crop Budget

Increased Annual Income from Cropping	**$ 2,500**
Reduced Annual Variable Costs (ex. Labour)	**$ 10,000**
Reduced Annual Labour Costs	**$ 750**
Annual Benefit of PA Investment	**$ 13,250**
Annual Cost of PA Investment	**$ 4,673**
Net Benefit of PA Investment	**$ 8,577**
Accumulated Benefit Over Life of PA	**$ 34,309**
Per Hectare Benefit of PA Investment	**$ 34.31**

Running Costs Data

Consultant Labour Hours per year	0
R&M as a % of Capital Cost (3.5%)	3.50%
Materials (Disks Paper Etc)	$ 675
Consultant Labour ($ / hr)	$ 150.00
Differential GPS Signal Subscription	$ 1,404
R&M ($ / pa)	$ 473

Total Running Costs

Repairs, Maintenance & DGPS Subs.	$ 7,504
Materials (Disks Paper Etc)	$ 2,700
Labour	$ -
Sub-total Running Costs	**$ 10,204**
Less Tax Deduction on running costs	$3,061

Insurance (2.5%)	$245
Storage Costs Per Annum $50.00	$200
Tax Payable on Recouped Depreciation	1,200
Less Tax Deduction on Interest	477
Less Tax Deduction on Depreciation	4,050
Less Tax Deduction on Insurance	74
Less Cash From Sale at Disposal	4,000

Total Ownership Costs of PA Equipment	**$ 11,548**	**Total Operating Costs Computer**	$ 7,143
Ownership Costs Per Year	**$ 2,887**	**Ownership Costs Per Hour**	**$ 9.35**
Computer Ownership Costs Per Year	**$ 1,786**	**Operating Costs Per Hour**	**$ 14.29**
Total Ownership Costs per Year	**$ 4,673**		

Annual Costs	**$4,673**
Hourly Costs	**$23.63**

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