Use of remote sensing and GNSS in precision agriculture

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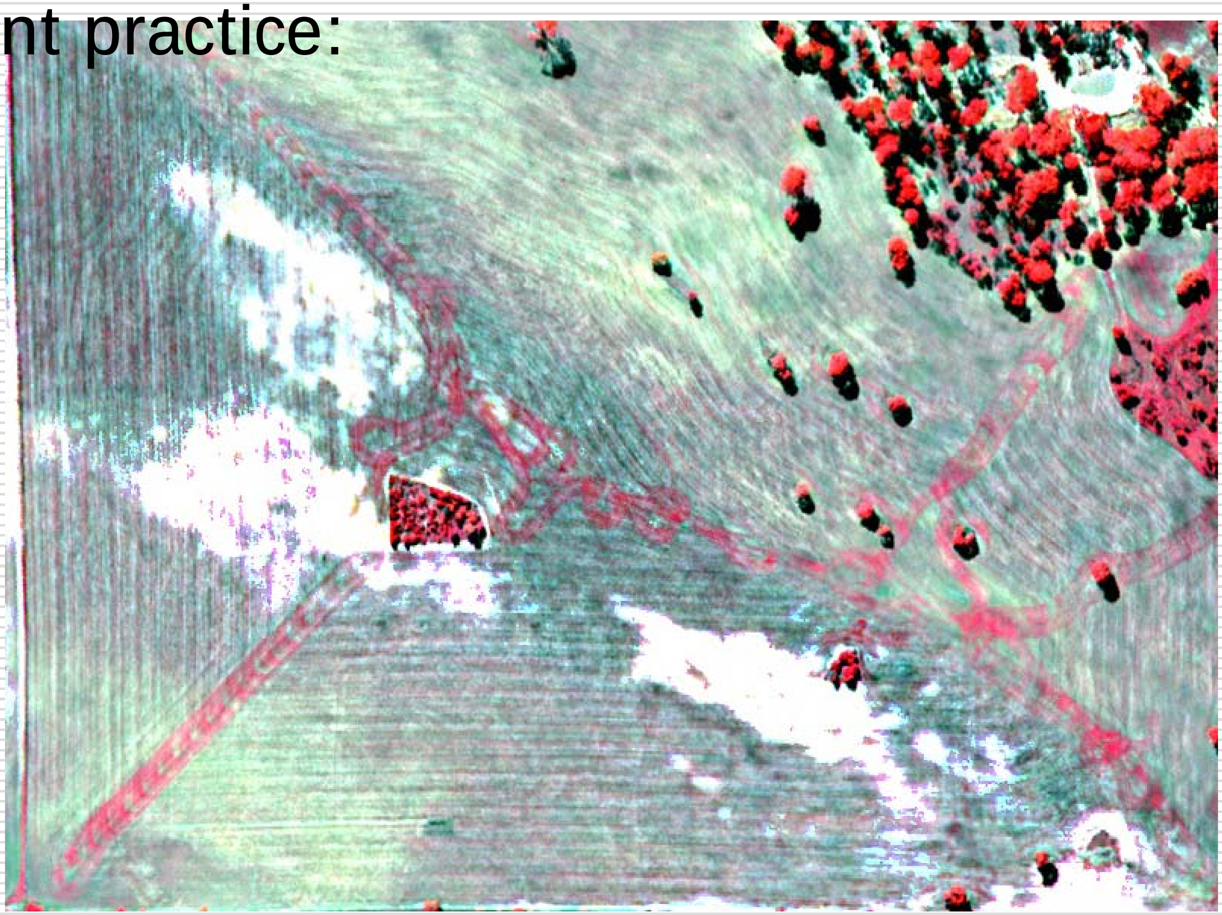
Traditional management practices' assumptions:

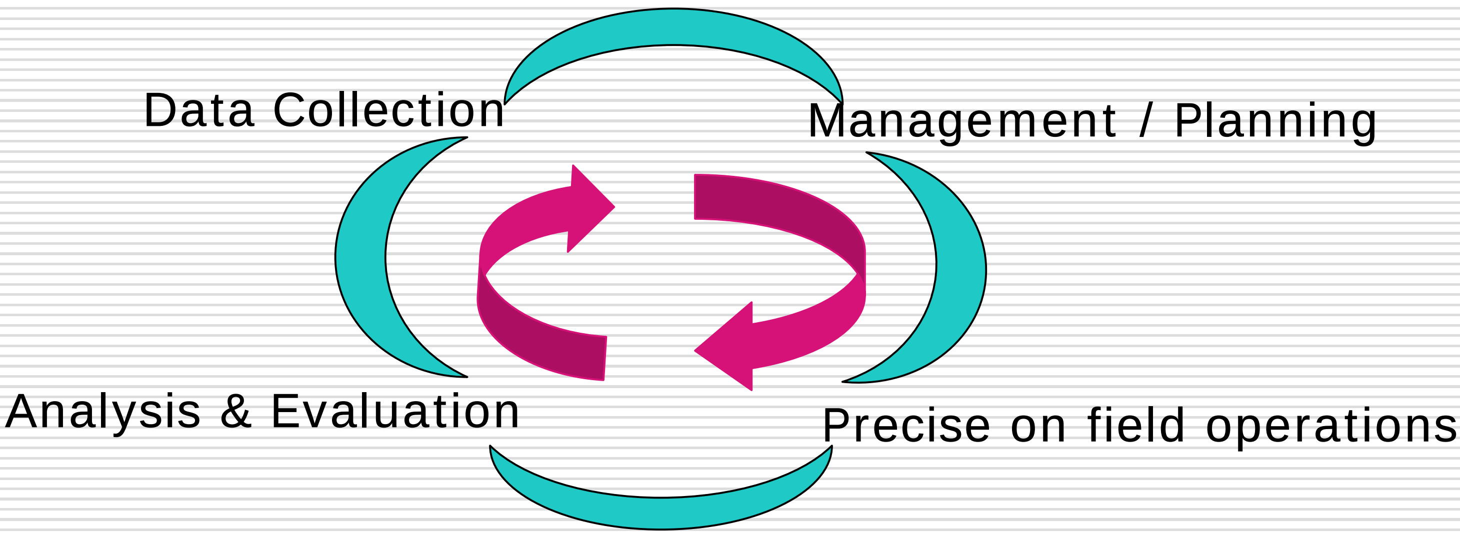
- One soil type over the entire field
- One management practice:
  - fertilisers
  - herbicide
  - seed volume



Precision farming

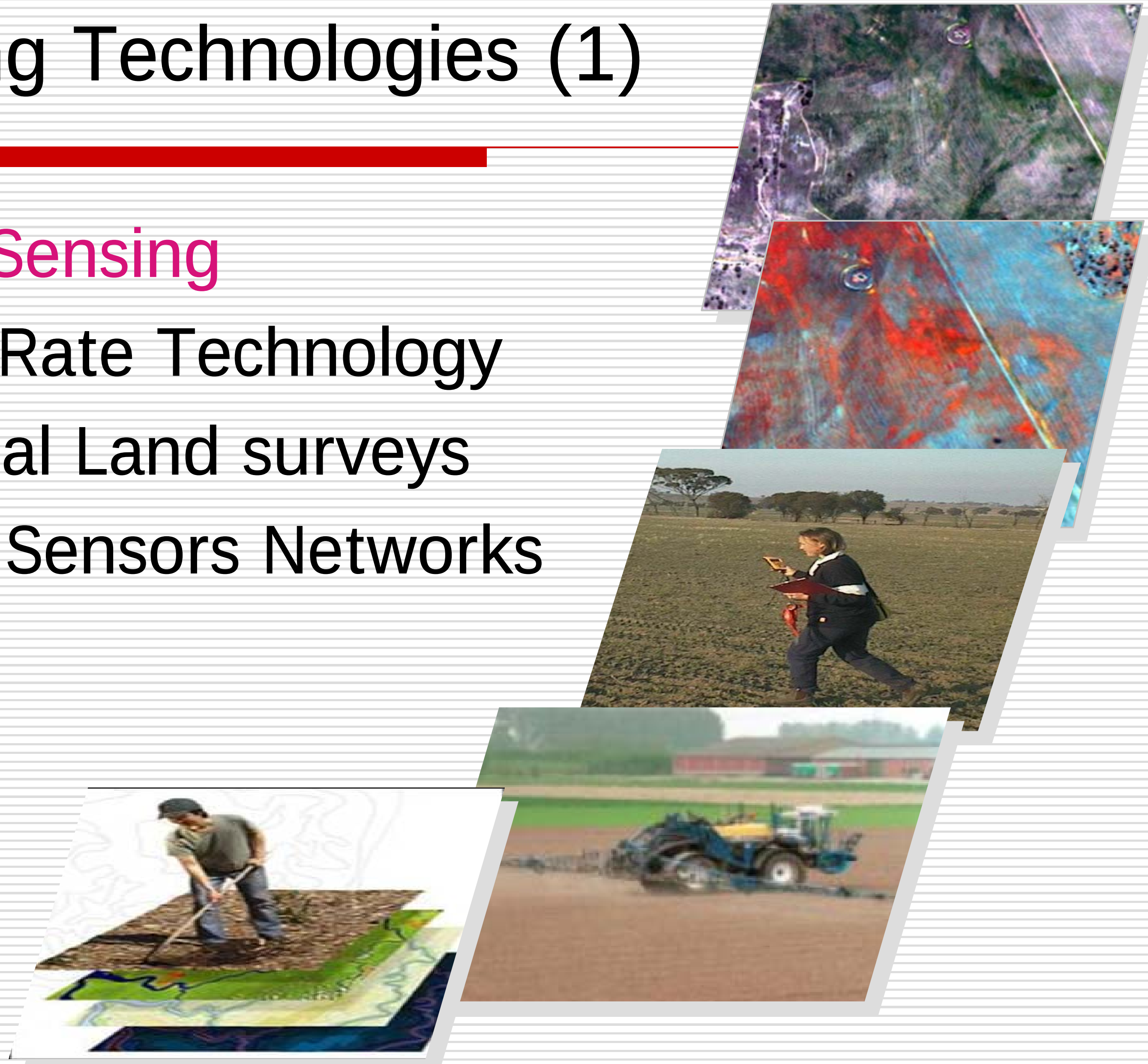
Information and technology-based agricultural management system to improve crop production efficiency by adjusting farming inputs to specific conditions within each area of a field.

PA as a cyclic optimisation process



PA Enabling Technologies (1)

- Remote Sensing
- Variable Rate Technology
- Traditional Land surveys
- Wireless Sensors Networks
- GIS

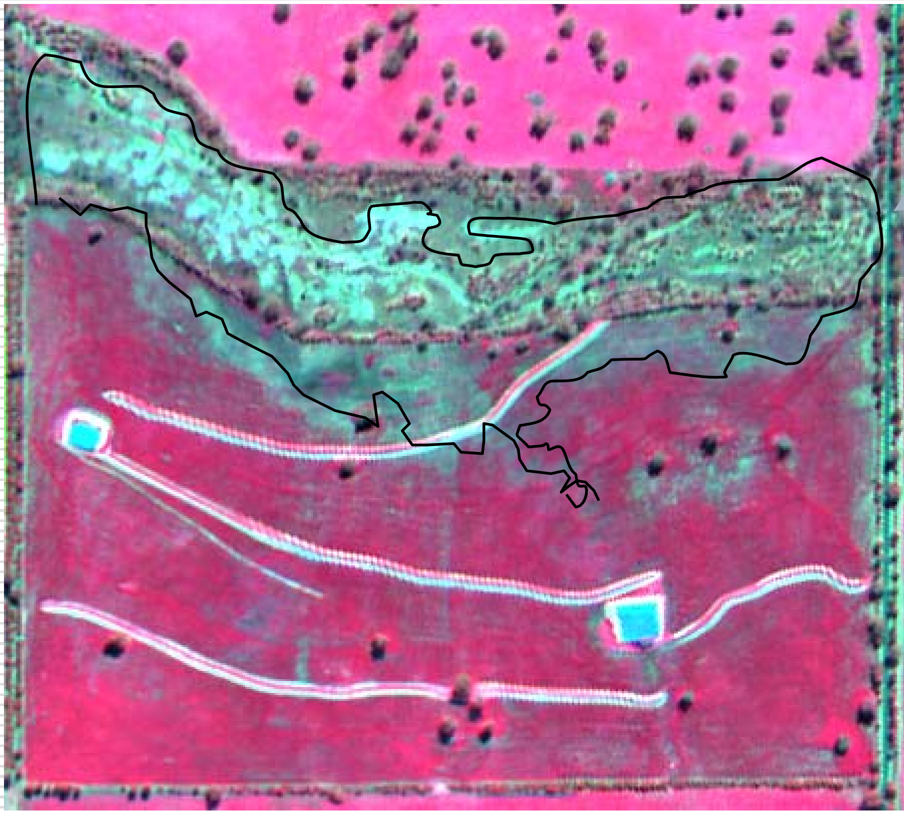


PA Enabling Technologies (2)

- Variable Rate Technologies. Main areas:
  - Tillage
  - Fertilizer or lime applications
  - Planting
  - Spraying
  - Irrigation
  - Harvesting and yield mapping

- Traditional Land Surveys
  - Scouting (GPS-based, guided by remote sensing derived products)
  - Soil testing (grid based, stratified)

Precision farming: sites are exploited according to their capability



Fields are divided into management zones

Techniques

continuos sensors to map crop yield

intensive soil sampling

Time consuming!!

Remote sensing

Information required for crop precision management

- Seasonally stable conditions
  - crop yield, soil variability
- Seasonally variable conditions
  - soil moisture
  - crop phenology
  - crop nutrient deficiencies
  - crop disease
  - Pests (weeds or insects)
- determining the *cause* of soil/crop variability

Considerations for a spatial mission "Agriculture"

- ✓ satellite revisit frequency ?
- ✓ spatial resolution ?
- ✓ spectral bands ?

to fulfil farmers' information needs, at an affordable price

Requirements for image-based precision farming:

- **Spatial resolution**: 5 meters or better, as management units of 10x10 m (0.01 ha) are generally adopted.
- **Spectral resolution**: most applications require multi-spectral data. Number of bands and band resolution are variables determining the type of features that can be discriminated.
- **Timeliness**: rapid image turnaround (for fertilisers or herbicide applications).
- **Frequency of coverage**: crucial times of crop development.

Satellite Remote Sensing Technology

Optical/Infrared Remote Sensing Satellites

Low Resolution

- Geostationary Satellites
- Polar Orbiting Meteorological Satellites
  - NOAA-AVHRR
  - DMSP-OLS
- Orbview2-SeaWiFS
- SPOT4-Vegetation
- ADEOS-OCTS

Medium Resolution

- TERRA-MODIS
- ENVISAT-MERIS
- ADEOS2-GLI

High Resolution

- LANDSAT
- SPOT1,2,4
- MOS
- EO1
- IRS
- RESURS

Very High Resolution

- IKONOS2
- EROS-A1
- Quickbird2
- Orbview3
- SPOT5

Microwave Remote Sensing Satellites

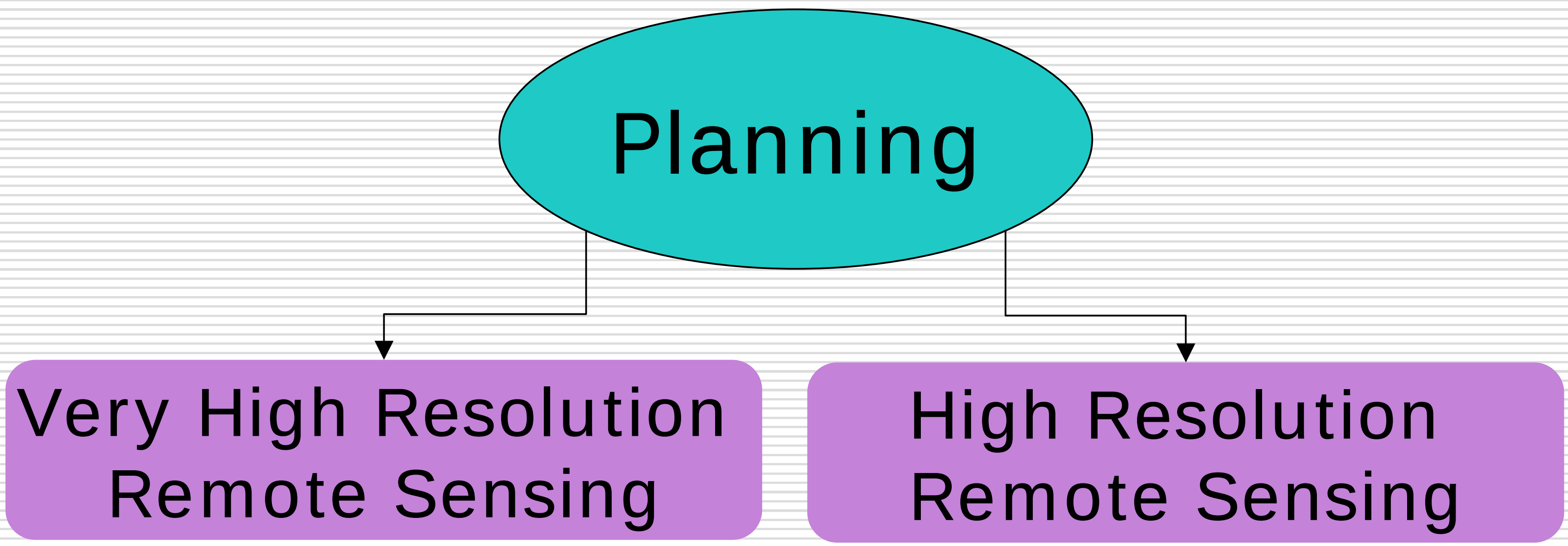
- ERS-SAR
- JERS-SAR
- RADARSAT-SAR
- ENVISAT-ASAR
- Space Shuttles
  - Shuttle Imaging Radar
  - Shuttle Radar Topography Mission

Opportunities for Remote Sensing of Agriculture

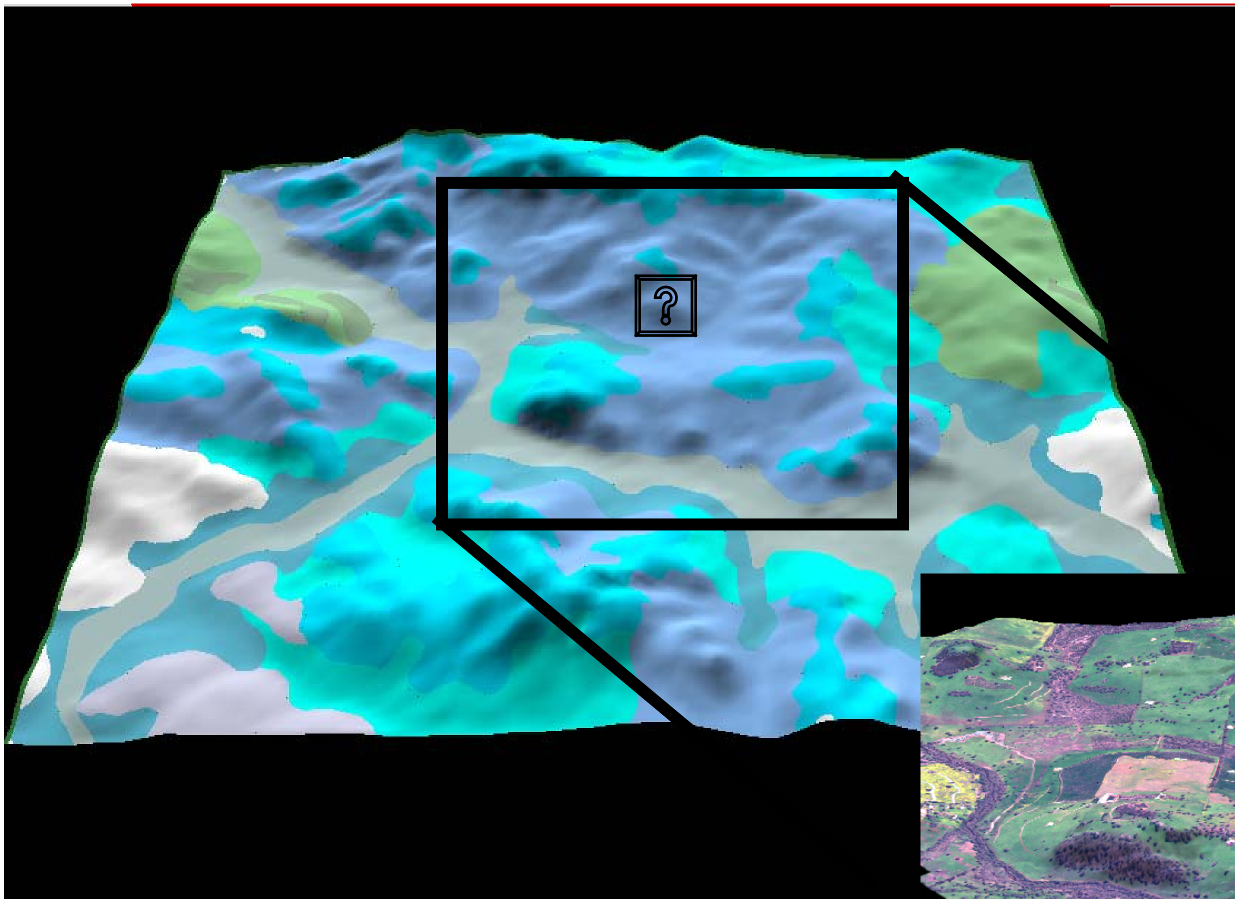
Planning | **Monitoring**

- Mapping and Monitoring Crop and Soil Variability;
- Efficient way of mapping and monitoring the effects of any condition that affects plant health, yield, or quality of a crop.
- The Imagery can be applied to:
  - Monitor within/between field variability;
  - Map soil variations;
  - Investigate crop management practices;
  - Detect and map weed and pest infestations;
  - Optimise crop inputs;
  - Pasture growth rate.

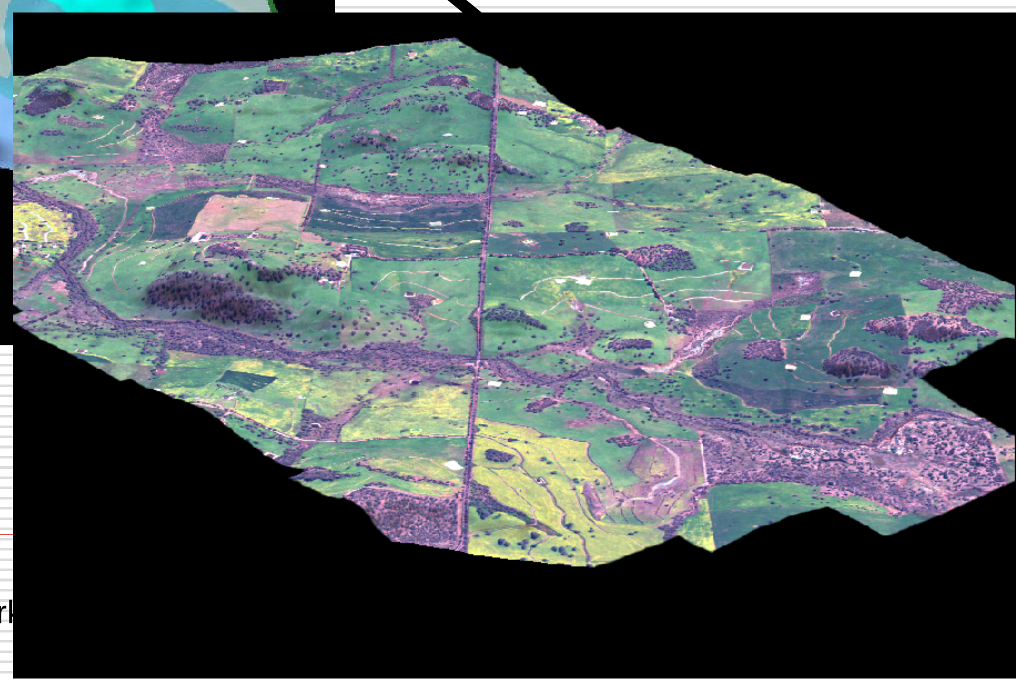
Developing value-added products



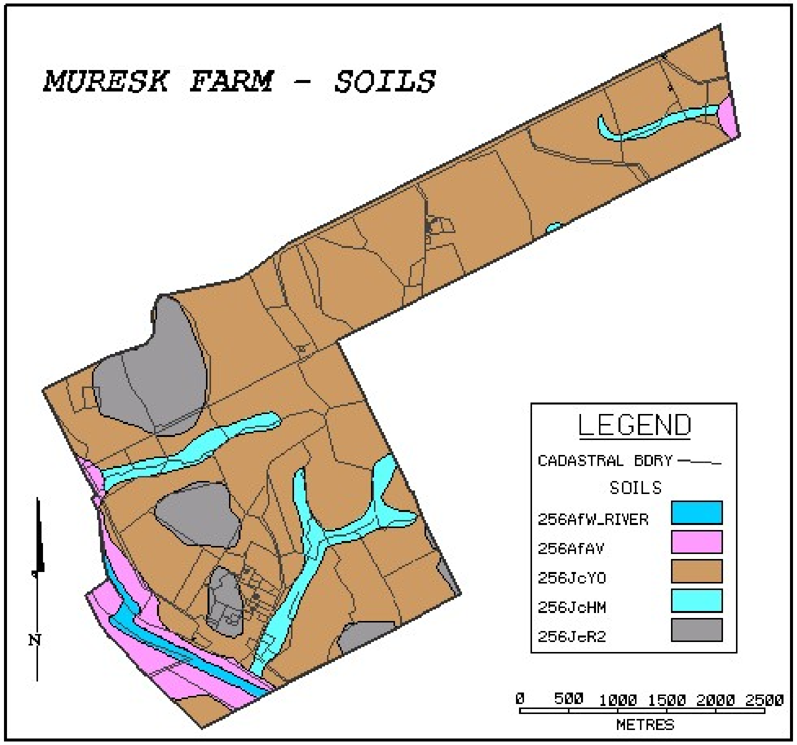
Combining terrain information, existing soil maps and Remote Sensing data:

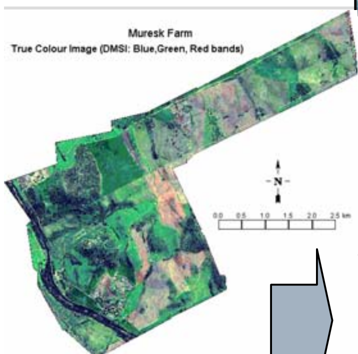


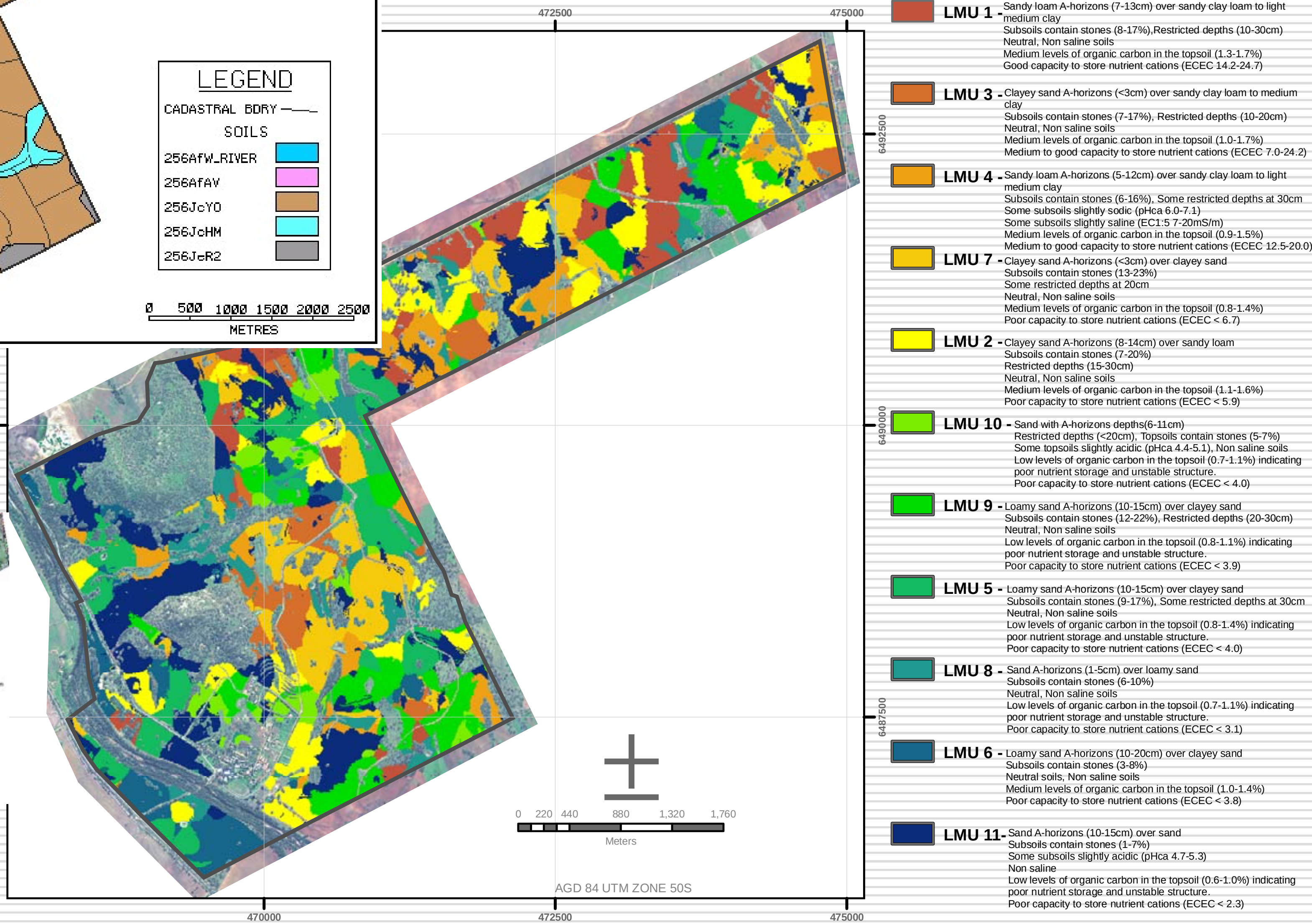
- Map soil variability
- Improve existing soil maps



Improving soil information for PA



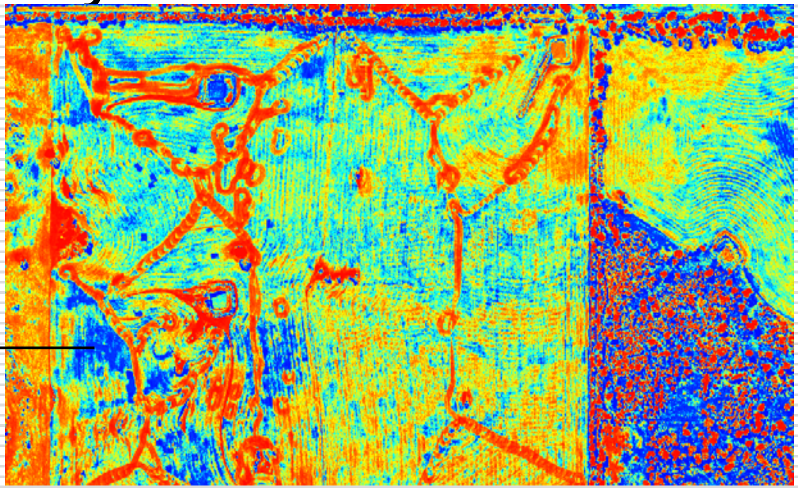




Assisting to determine the *cause* of variability in crop production:

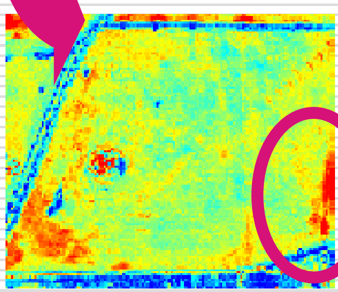
- Problem areas on the ground can be identified and located on the enhanced imagery, or multi-temporal analysis;
- Sites are visited (portable GPS) to identify the causes of site variability => soil testing may be required.
- Information can be integrated within a GIS, for further temporal and spatial analysis.

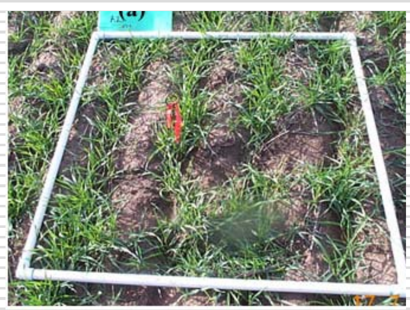
X= 545
y= 6777

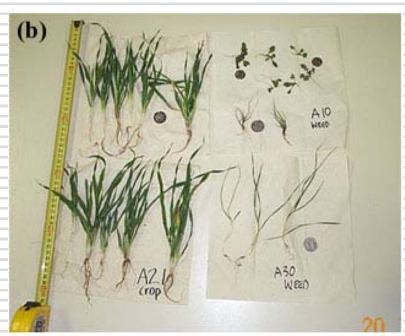


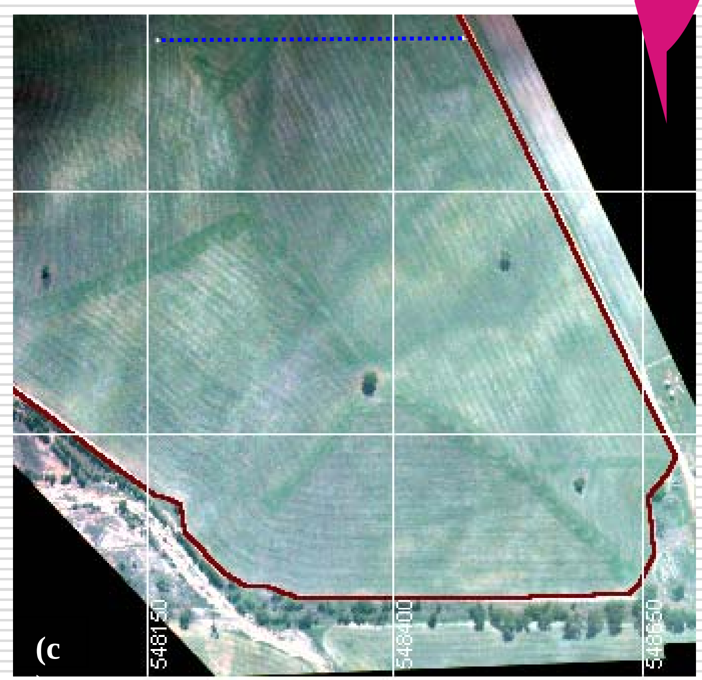
Detect and map weed infestations

- Mapping excessive weed pressure on paddocks. Our investigations found weak correlations between DMSI data and weed density in early season canola seedlings
- Good results were achieved in detecting weed infested areas in fallow pasture paddocks;
- Weed detection is a function of weeds' amount and shape.



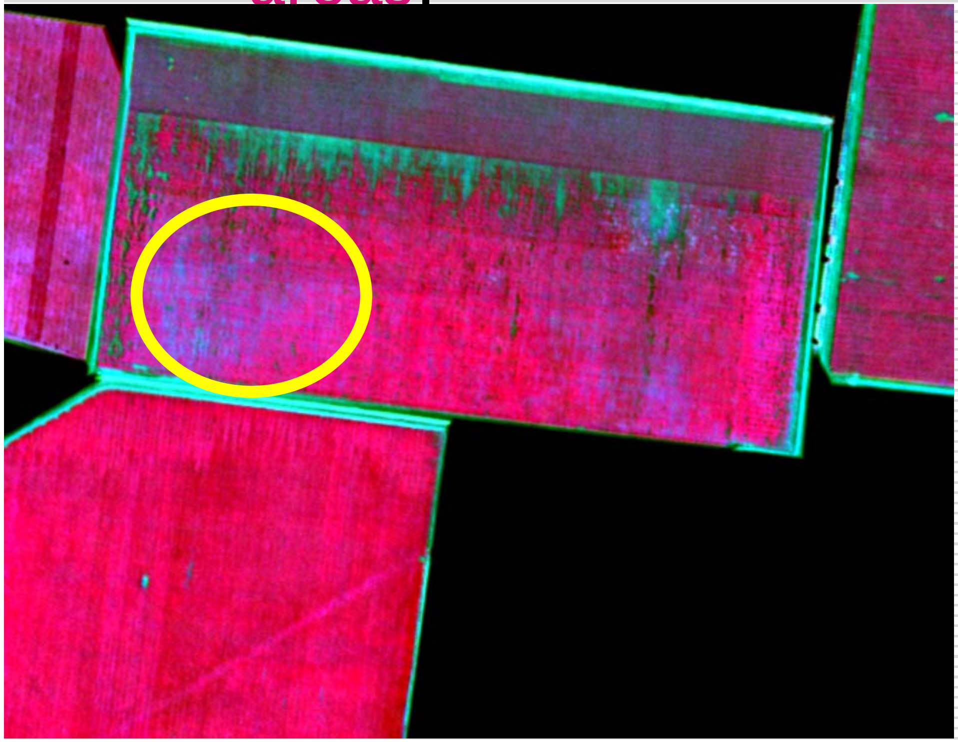


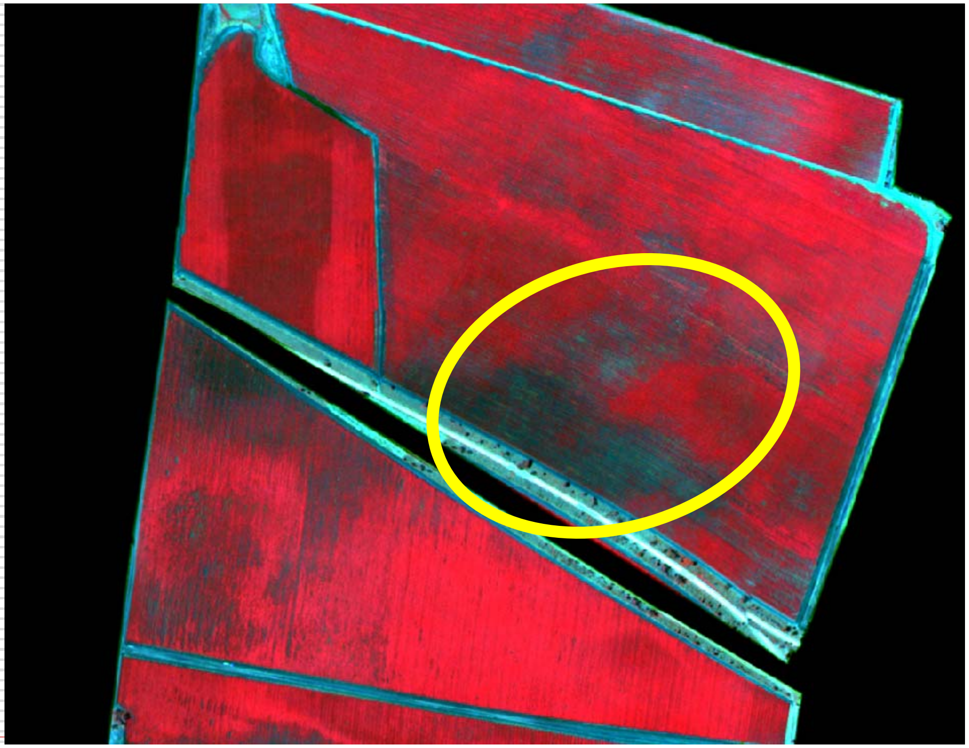




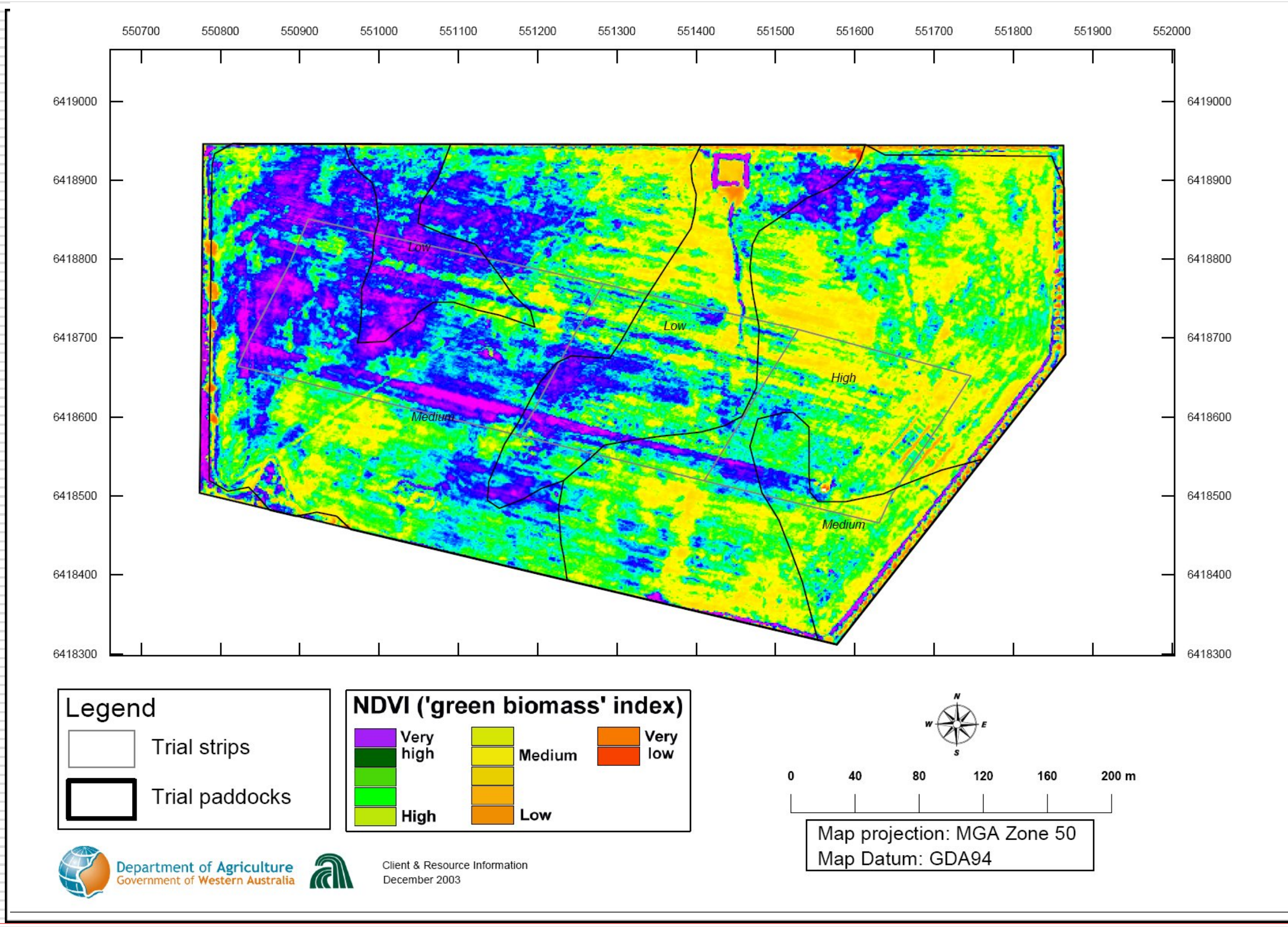
Remote Sensing supporting VRT: fertilizers

- Knowing the causes and spatial extent of variability, the images can support variable rate applications, to apply fertilizers at higher rates on lower producing areas:

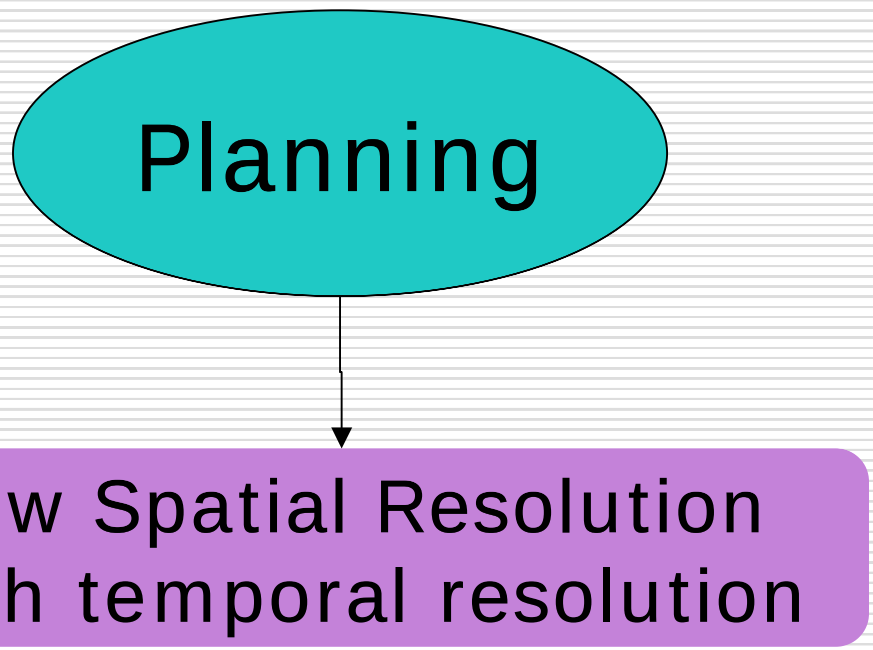




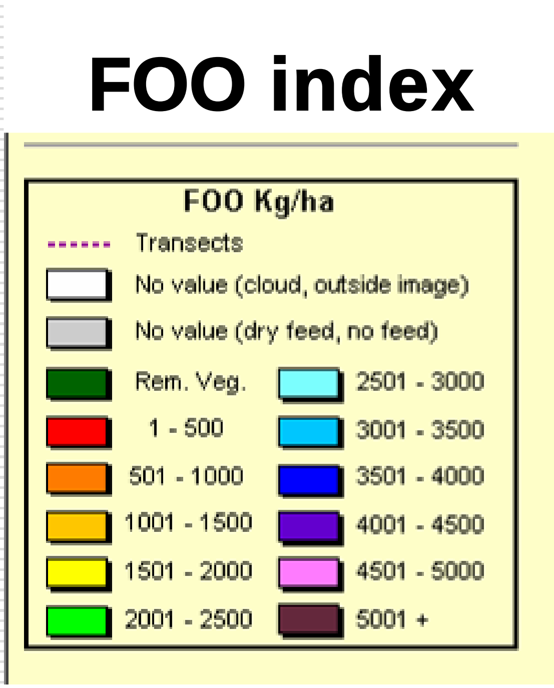
Looking at crop responses in paddock strip trials

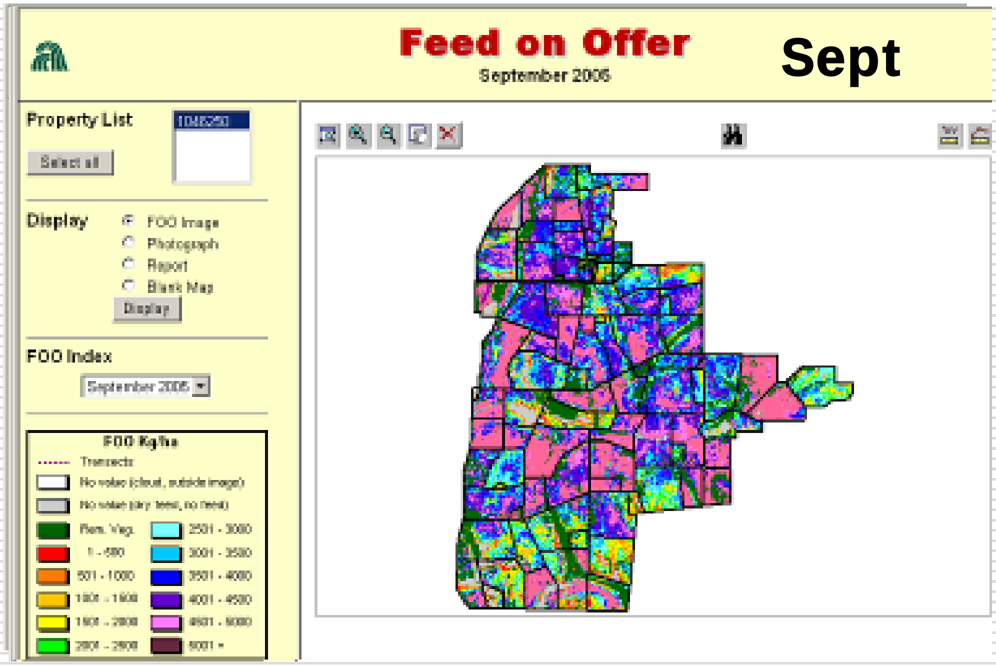


Developing value-added products



Remote Sensing for grazing management of sheep: Pasture from Space program





- Feed on offer (FOO) is the amount of pasture in front of an animal at any one time, measured in kilograms of dry matter per hectare (kg DM/ha).
- Its a balance between pasture growth and the removal of pasture by grazing animals.
- Pastures from Space uses satellite images (MODIS) and field data to estimate pasture biomass with 97 % accuracy.

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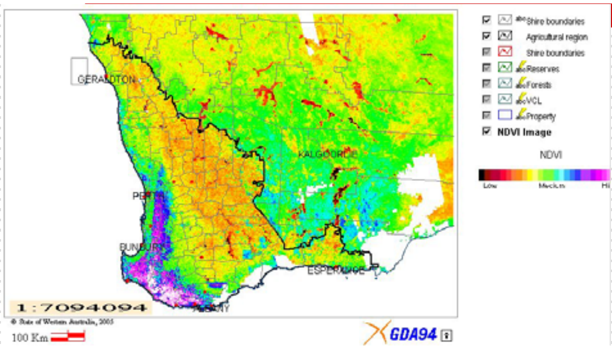
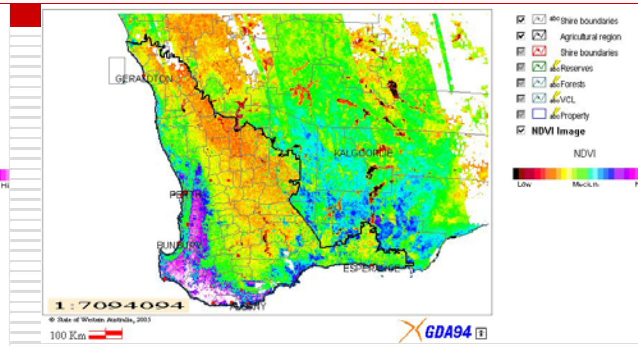
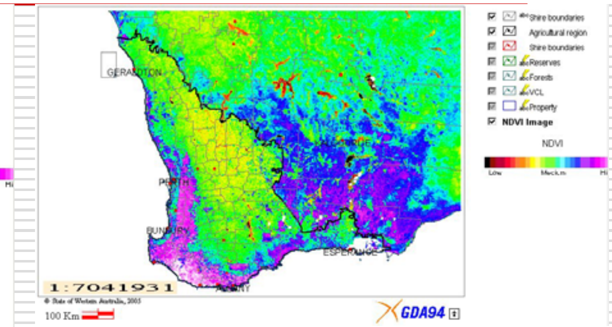
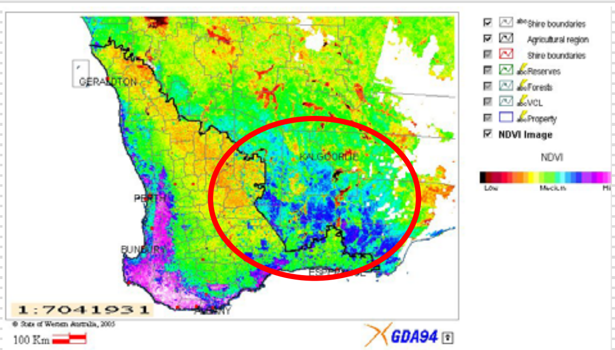
Prediction potential locust invasion (1):

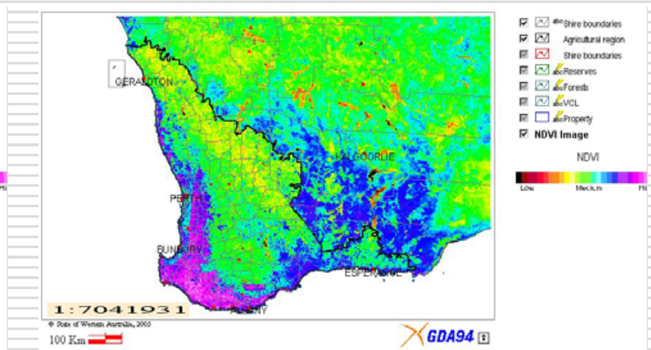


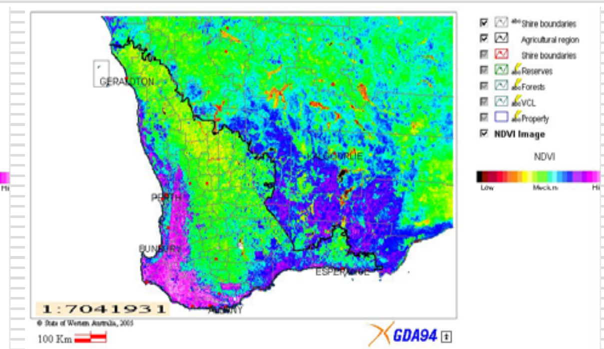




January 2004 February 2004 March 2004



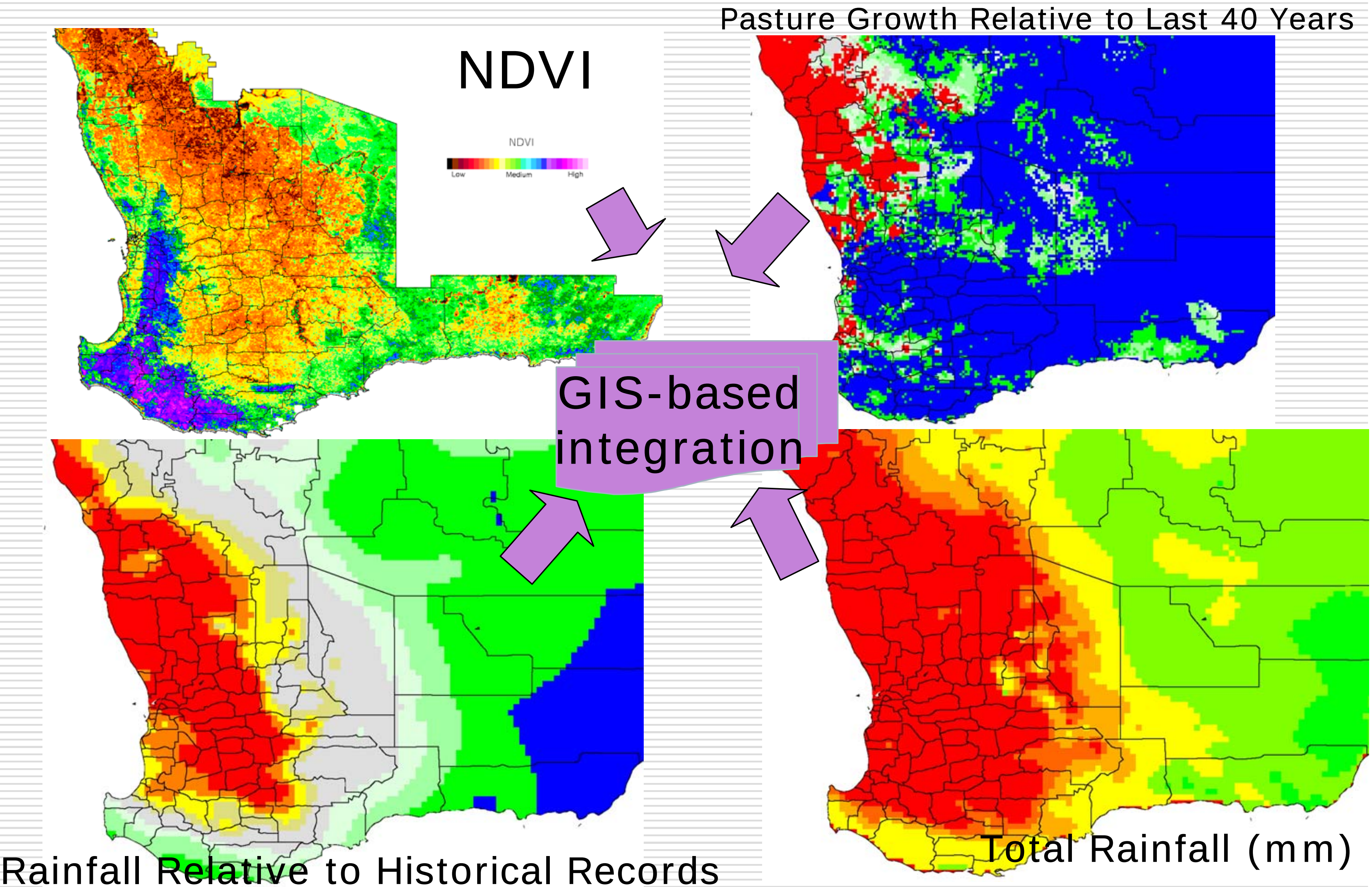




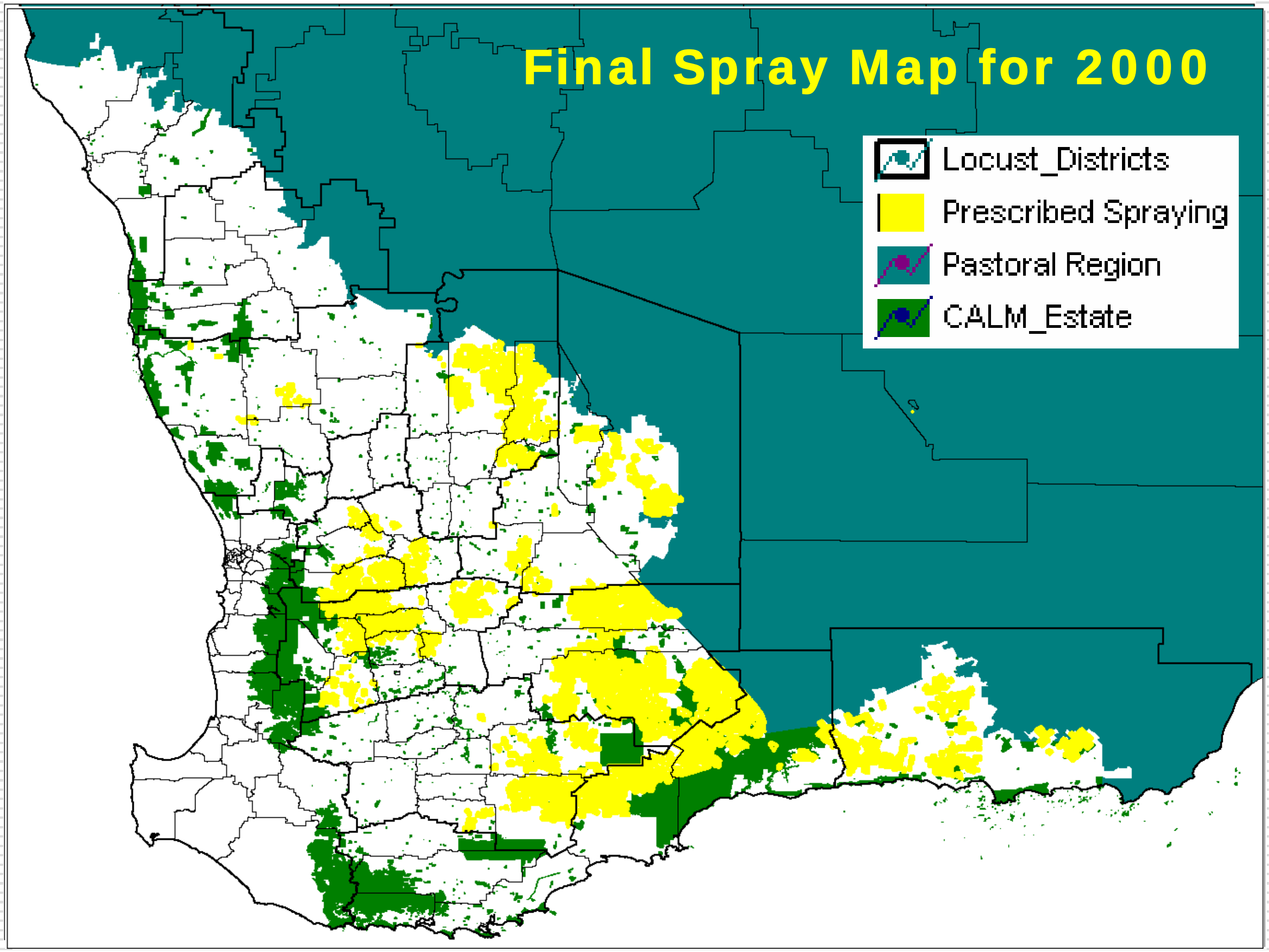
January 2006 February 2006 March 2006

Relatively wet summer 2005/06 (compare with 2004) results in potentially suitable habitat areas close adjacent to south-west agricultural area.

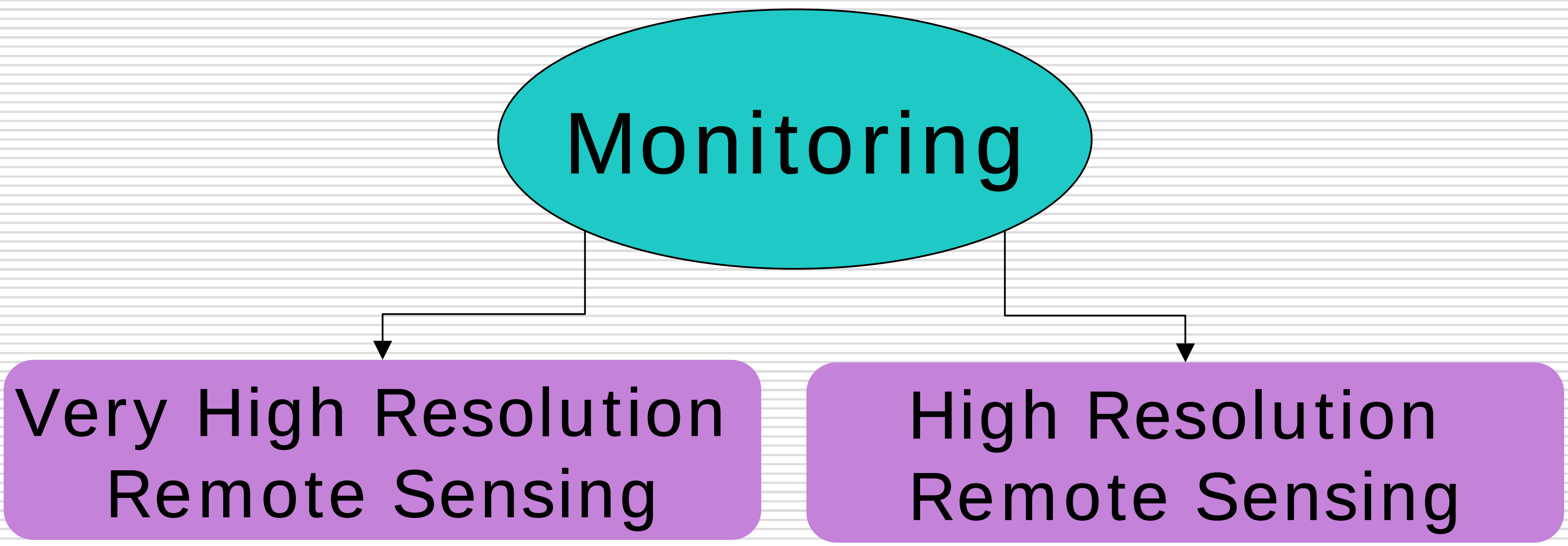
Prediction potential locust invasion (2):



Prediction potential locust invasion (3):



Developing value-added products

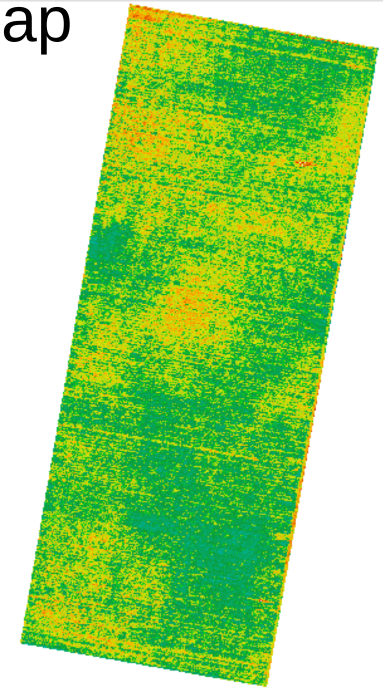


Monitoring Plant Establishment (Cotton)

Base image acquired within a week of seeding.

Second image acquired 4 weeks post seeding.

Change in PCD Map

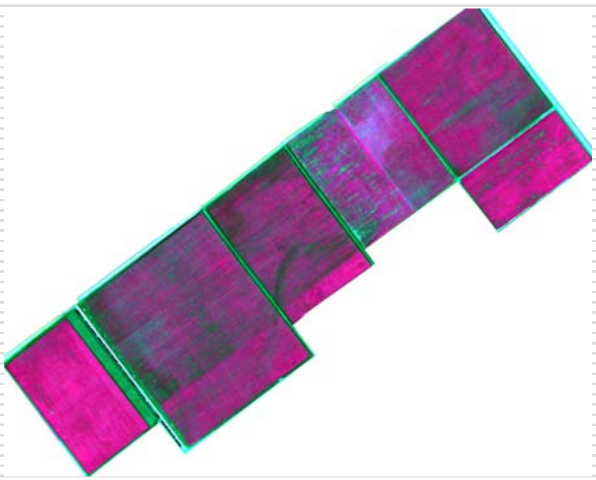


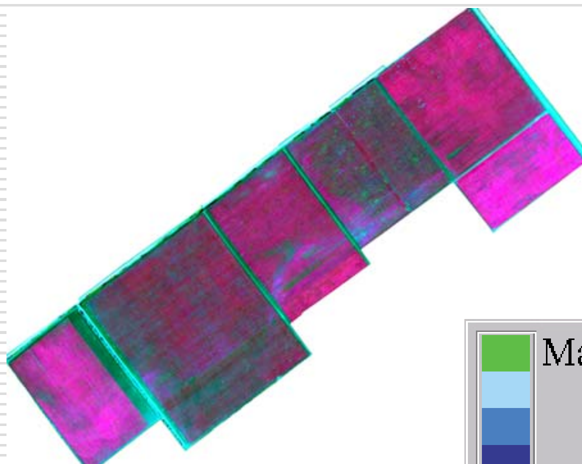
The "Bare Soil" image serves as a base from which levels of subtle vegetation gain can be detected.

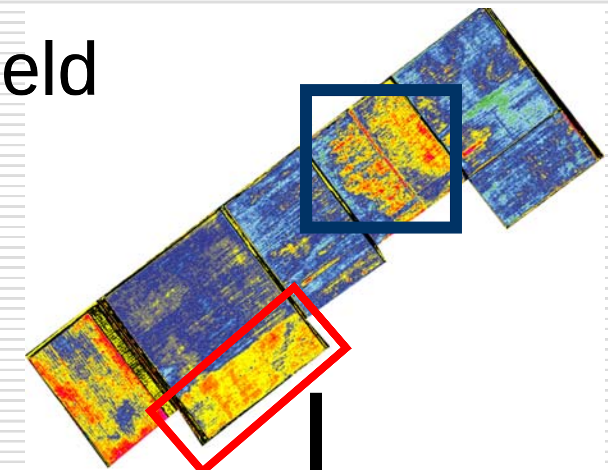
Blue areas represent a 2% gain in total vegetation ground cover. Red areas represent 0% gain, or no cotton emergence.

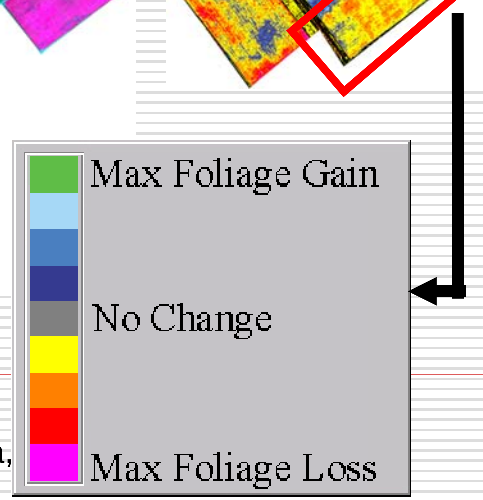
Monitoring crop growth

- Qualitative monitoring of crop growth, and variations in crop conditions within a paddock (e.g. density, canopy vigour or biomass);
- Identify critical crop stages;
- Monitoring within- & between-field variability.





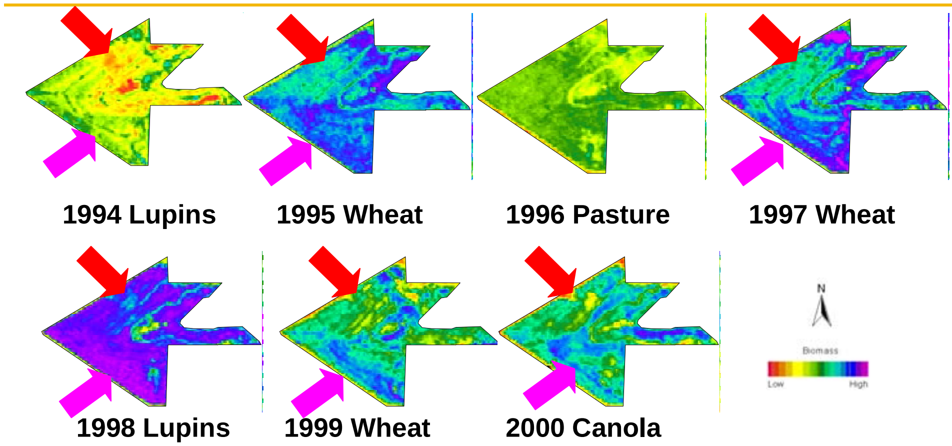




Remote identification of variation within paddocks using multi-temporal imagery (Skyplan):

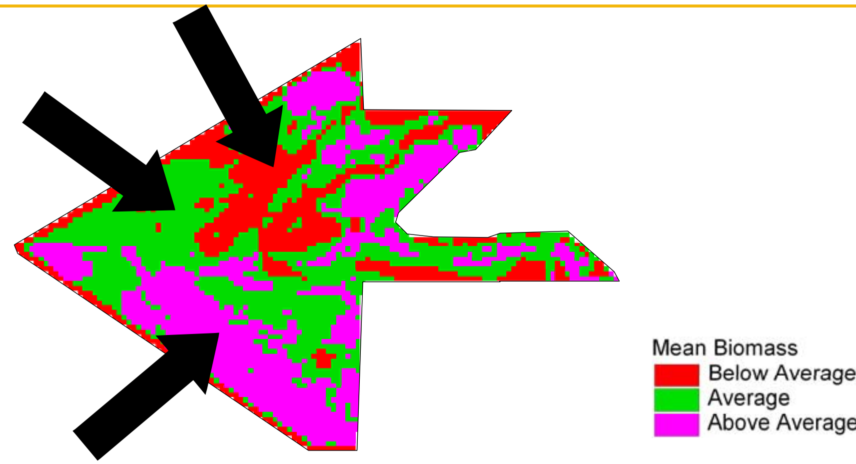
futurefarm. SKY+PLAN

Biomass Images (1994 to 2000)



futurefarm. SKY+PLAN

Mean Biomass Image - 1994 - 1995, 1997 - 2000



- Retrospective, provides ‘areas’ of variation within paddock using historical data.
- Data: Landsat TM
- Enables farmers to isolate good from bad yielding areas.
- Yield maps: based on biomass from imagery.

Developing value-added products

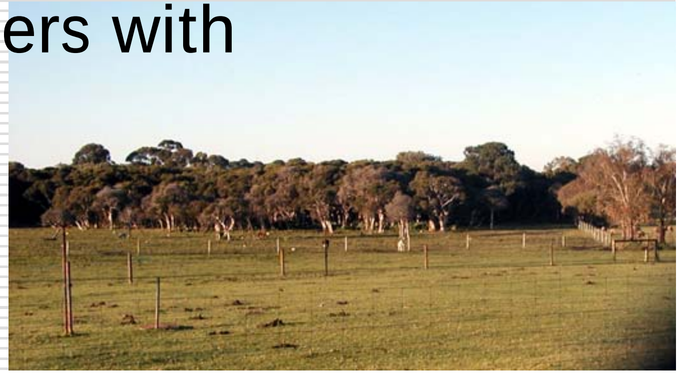
Monitoring

↓

Low Spatial Resolution
High temporal resolution

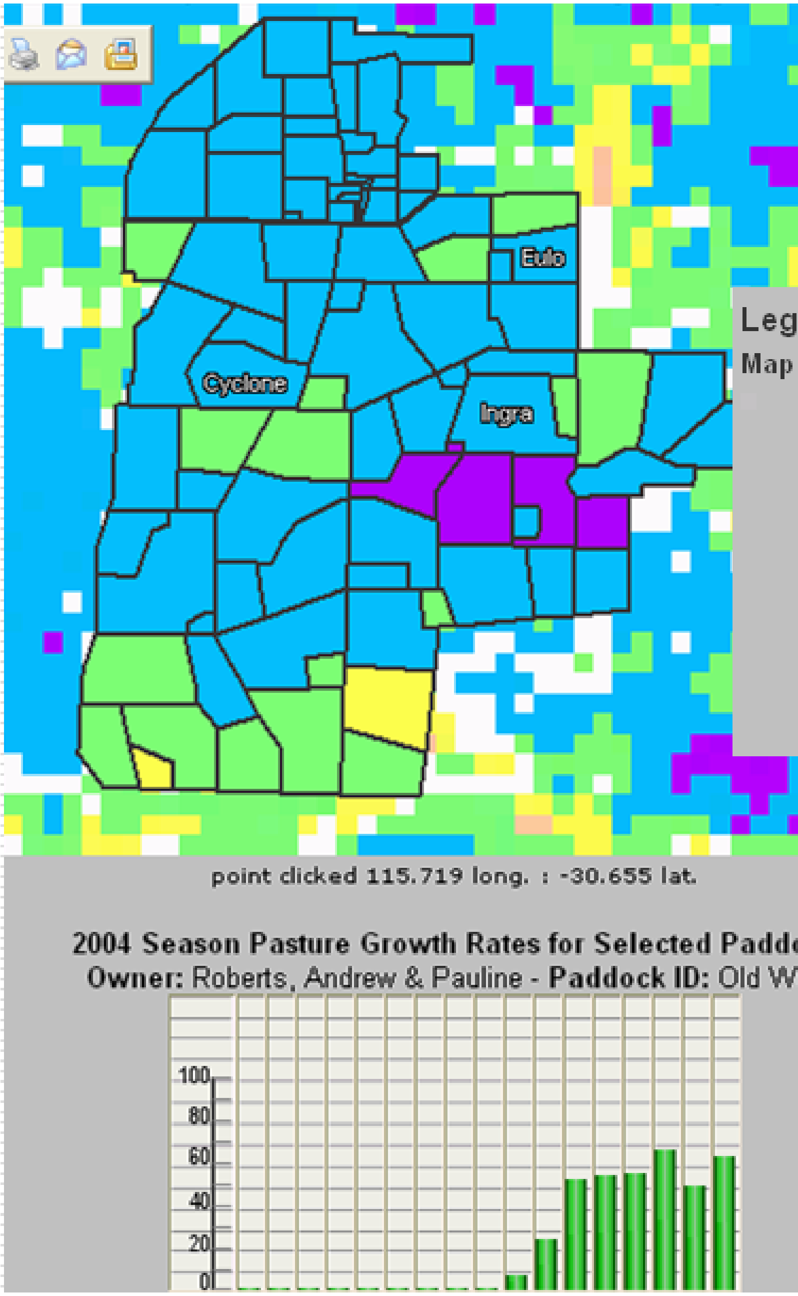
Management Tool to Improve Profitability for Livestock Producers

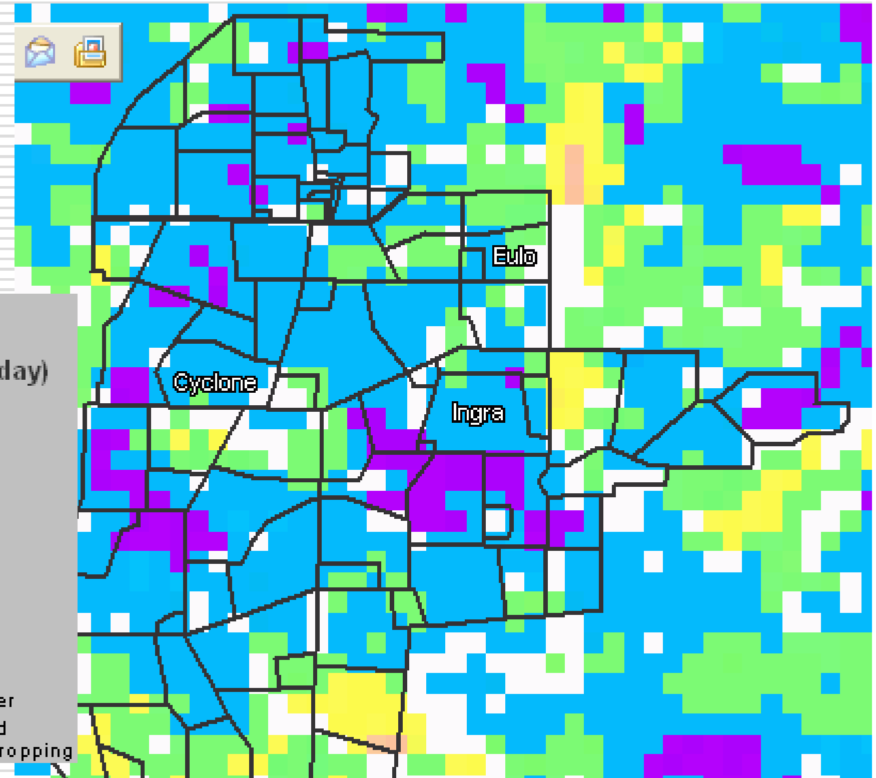
- Remote sensing of pasture growth rate (PGR) for a growing season by combining satellite data (MODIS) with climate and soil data.
- The PGR information can assist farmers with management decisions such as:
  - grazing rotations, feed budgeting, fertilizer application and other "precision agriculture" techniques



- Information is delivered to producers by email and website (http://spatial.agric.wa.gov.au):
  - FOO monthly (within 5 days of satellite pass),
  - PGR weekly,
  - PGR forecasted 7 days forward and historical PGR

Pasture from Space Program



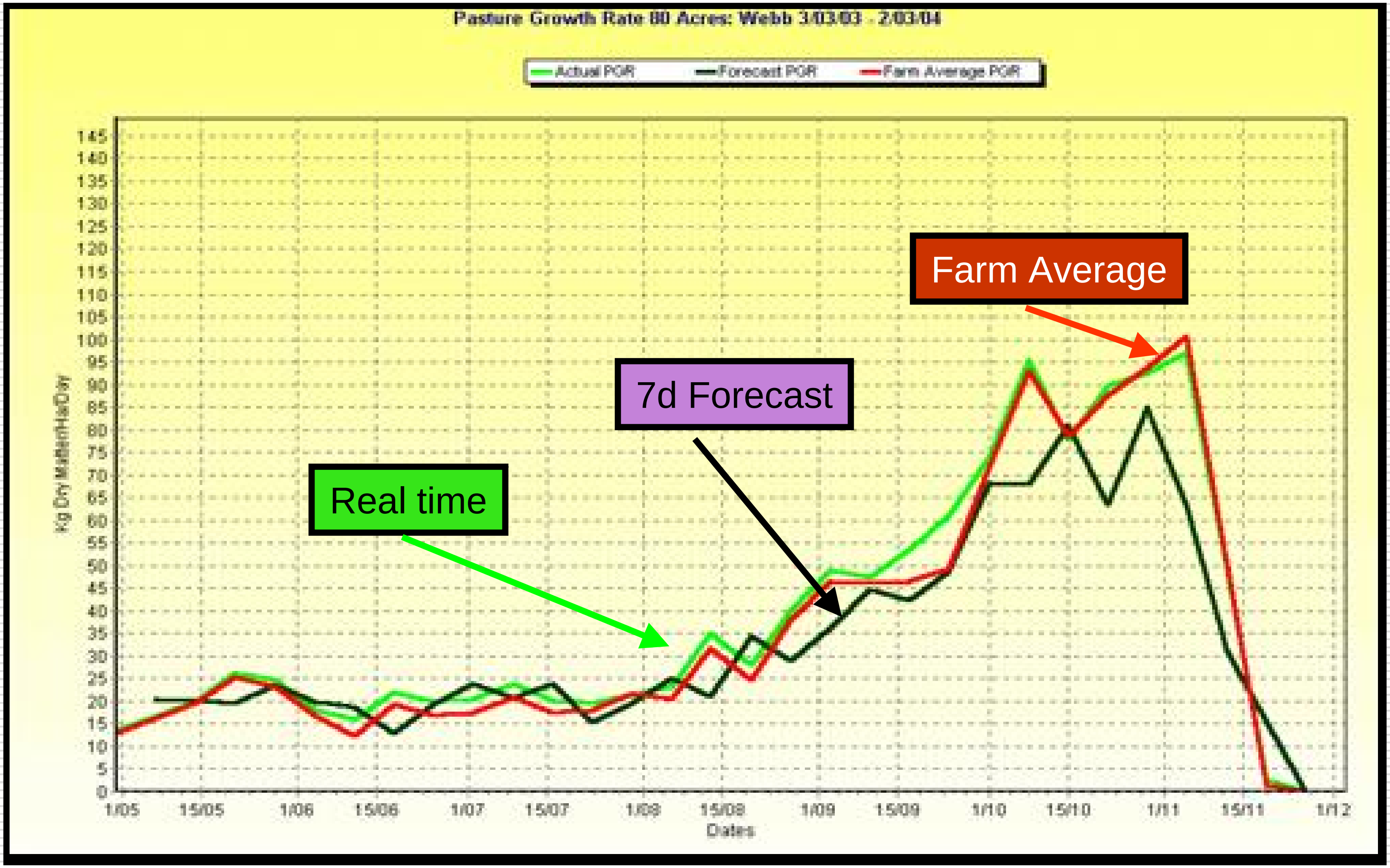


PGR spatial distribution

PGR paddock averages


Lists
Pasture Growth Rate
Total Dry Matter Production
Browse Dataset
Green Feed
Budget
Map
Default Values
PastureWatch™
About
Close
Help
Internet Settings
Check My Subscription Status
Upload my Maps to PFS - I'm Subscribing!
Download "Pastures from Space" Data
View my Farm PGR Image Online
Download Data
FAIRPORT
TECHNOLOGIE
developers of the
PAM
series of farm software

Pasture Watch ™



PGR (kgDM/ha.day)

Date (Day/Month)

Precision Agriculture and Satellite based Positioning Systems

Global Navigation Satellite Systems (GNSS)

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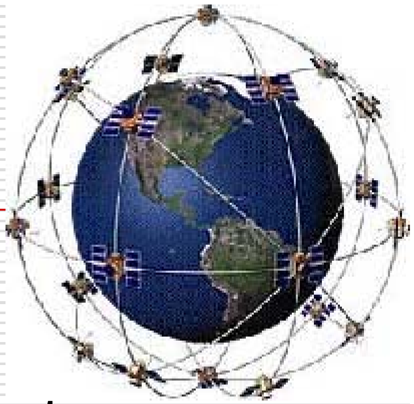
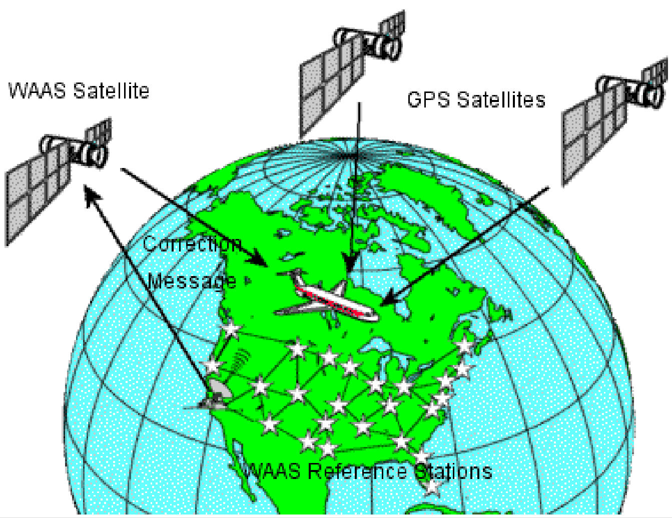
Global Navigation Satellite Systems:

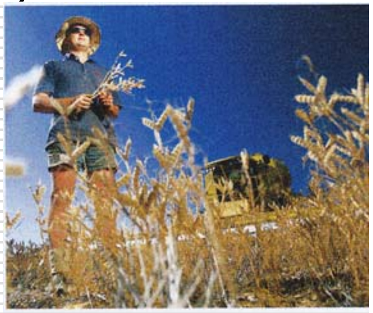


- GNSS: generic term covering a number of existing and planned constellations of satellites together with supporting infrastructure systems, used for determining positions across the globe.
- Current and proposed satellite navigation systems
  - GPS
  - GLONASS
  - Galileo
  - EGNOS
  - Beidou
  - DORIS and
- their associated augmentation systems.



Precision Agriculture and GNSS

- Agricultural Uses:
  - Coarse mapping functions, recording locations (e.g. weed infestation, insects, etc)
  - Greatest accuracy is required if a satellite based positioning systems is used for 'guidance' during planting and chemical applications (pesticides, fertilizers).
  - Reliability is a critical factor for high dynamic applications like air-spraying.
- Farming activities using GNSS:
  - Soil sampling
  - Tillage
  - Drilling
  - Variable Rate Applications: Fertilizing, Spraying
  - Harvesting




GNSS usage in agriculture

- Adoption of GNSS technology is concurrent with grid sampling, yield monitoring, VRA of fertilizers, seed or pesticide.
- Common adoptions (US and Australia):
  - Grid soil sampling
  - Fertilizer VRA
  - Seed VRA
  - Pesticide VRA
  - Yield monitor

Australia: perceived adoption barriers

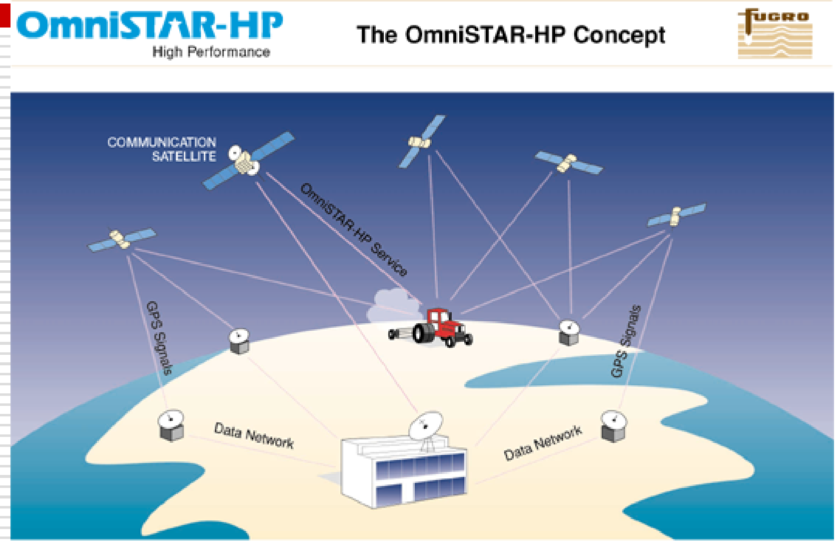
- High initial costs
- Difficulties in assessing the benefit/cost ratio
- Survey indicates GNSS-equipped tractors and other terrestrial agricultural vehicles are being introduced on Australian farms at a rate of 10% per annum.

Survey of Australian on-farm GNSS usage

Equipment category	Purpose	Use	Accuracy required
High End	Automated steering assist systems	Planting irrigated cotton	2 cm
Mid range	Visual guidance systems	Controlled traffic farming	10-20 cm or sub-metre
		Sprayer guidance & mapping	
Harvest monitors	Yield monitoring	Broadacre cropping	2.5 - 10 m
		Hand held receivers	

Australian on-farm GNSS usage: terrestrial (1)

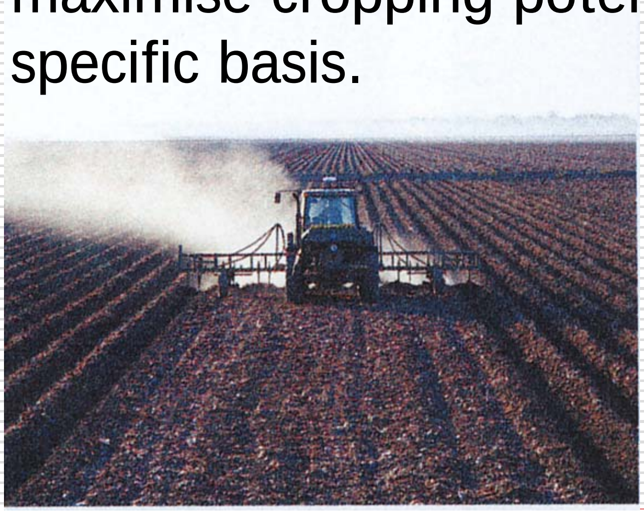
- **Automated steering assist or high-end equipment**:
  - the steering of the tractor is at least partly controlled by satellite signals
- **Visual guidance or mid-range equipment**:
  - the tractor or specialized spray/fertiliser rig is managed entirely by the driver but a light bar on the bonnet, and often a moving map display and audible tone assist the driver to maintain the correct track.
  - Equipment available offers various levels of accuracy
- **Yield monitoring and mapping or harvest monitors.**
  - Connected to GNSS equipment and provided with suitable farm office computer programs can create yield maps.
- **Low-end equipment**
  - Hand held GPS devices in combination with palm-sized computers for scouting, recording specific paddock conditions.



Australian on-farm GNSS usage: terrestrial (2)

□Drilling

Varying seed rate application based on soil characteristics or environmental factors allows farmer to optimise plant populations through regulating drilling rate and depth, helping maximise cropping potential on a specific basis.



□Soil tissue sampling

GNSS enables exact location of soil samples that are taken. Tests are used to produce profile maps which provide a clear analysis of varying soil types and nutrient status over the recorded area, aiding management and optimising yield potential.

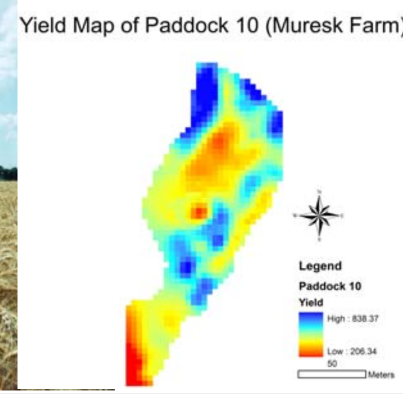
Australian on-farm GNSS usage: terrestrial (3)

Machine guidance

High accuracy facilitates the use of manual and automatic steering aids. Using satellite technology for machine guidance helps reduce skips and overlaps and maximises operator efficiency.

Harvesting

Sensors on the combine can record yield harvesting. Yield information allows the farmer to identify variations in his field. This information can be used to investigate reasons for yield fluctuations and to implement appropriate management plans.



Australian on-farm GNSS usage: terrestrial (4)

VRA

Variable rate fertilizer and lime applications and the use of nutrient status maps of a field reduce input costs & environmental impact. Through automatic control of sprayers and fertiliser applicators the amount of pesticide or nutrient applied can be varied on the move.

Tillage

Tillage depth can be varied according to soil profile or compaction status. Assisted guidance for cultivation work helps minimise the skips and overlaps and increases working widths. Autonomous steering systems allow more machine operating hours per day, reducing operator fatigue.

Australian on-farm GNSS usage: aerial & others (1)

- GNSS equipped aircrafts to:
  - Spray fertiliser and pesticide
  - Distribute seed onto agricultural properties.
  - Australian crops currently serviced aerially are cotton, sorghum, sugar and wheat.
- Other perceived uses in agriculture:
  - GNSS technology to track individual animals, especially cattle in remote parts of Australia where herds are measured in thousands.
  - Unique identification allows tracing back for disease; precise count of animals and their movement;
  - In case of disease break, fast mapping of disease spread based on animal movement.

Integrated GIS-Remote Sensing-GPS advantages:

- Ultimate goal of detecting and managing field variability is to save costs. In Australia, farmers spend up to 25% of their gross income in herbicides;
- Reduction of pollution risks by applying fertilisers or herbicides only where it is needed;
- Provide field maps of weeds, nutrient deficiencies that can guide farmers during the spray of their paddocks;
- Assist determining causes of field variability.

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- Projects: www.spatial.curtin.edu.au/~graciela