# RURAL INDUSTRIES RESEARCH AND DEVELOPMENT CORPORATION

# REPORT



***Project Title:*** Evaluation of high resolution SPOT satellite imagery for use in the preparation of Property Management Plan base maps for graziers and grain growers in Central Queensland.

***Project Number:*** DAQ-150A

***Research Organisation:*** Queensland Department of Primary Industries
Rockhampton, Queensland

Central Queensland University
Rockhampton, Queensland

***Principal Investigators:***

Mr Ken Adsett
Land Use & Fisheries Group
Qld Dept of Primary Industries
**ROCKHAMPTON QLD**

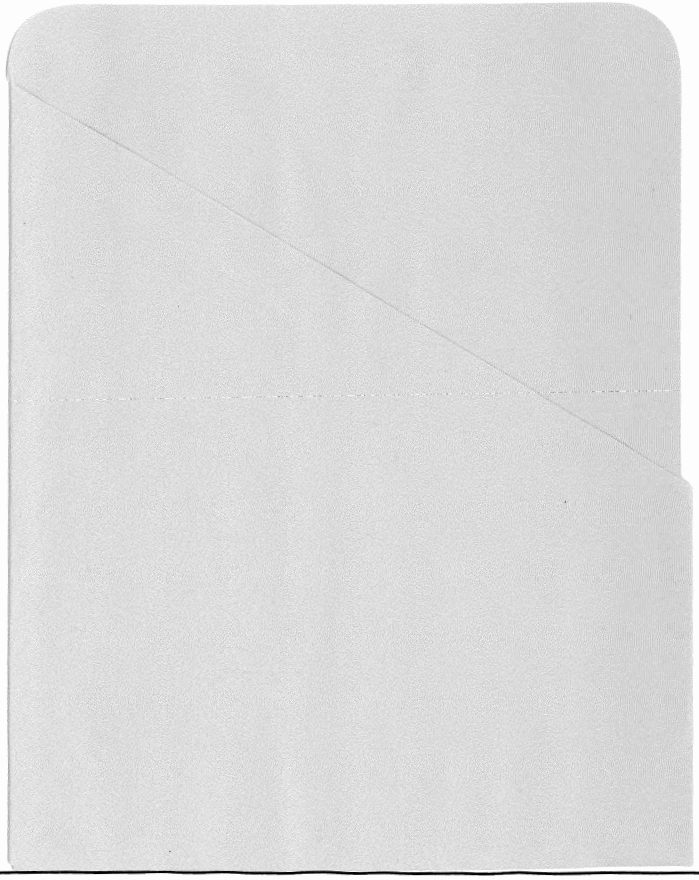
Mr Peter Rey
Faculty of Applied Science
Central Queensland University
**ROCKHAMPTON QLD**

**A FINAL REPORT PREPARED FOR THE RURAL INDUSTRIES RESEARCH & DEVELOPMENT CORPORATION**

# EVALUATION OF HIGH RESOLUTION SPOT SATELLITE IMAGERY FOR USE IN THE PREPARATION OF PROPERTY MANAGEMENT PLAN BASE MAPS FOR GRAZIERS AND GRAIN GROWERS IN CENTRAL QUEENSLAND.

MR KEN ADSETT
LAND USE & FISHERIES GROUP
QLD. DEPT. OF PRIMARY INDUSTRIES
ROCKHAMPTON

MR PETER REY
FACULTY OF APPLIED SCIENCE
CENTRAL QUEENSLAND UNIVERSITY
ROCKHAMPTON



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K.R. Adsett - Department of Primary Industries
P.M. Rey - Central Queensland University

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Department of Primary Industries
GPO Box 46
Brisbane QLD. 4001

Department of Primary Industries
PO Box 6014
Rockhampton Mail Centre QLD. 4720

# ABSTRACT

Since the early 1980's, DPI has produced individual Property Management Planning base maps using manual air photo mosaicing techniques. The aerial photographs used in the preparation of Property Management Planning base maps are often many years out of date. Preparation of base maps is currently very labour intensive and requires the careful assembly of numerous air photo prints to produce an overall view of a single property. The base map has inaccuracies due to the distortion in the original photographs.

DPI is now adopting computerised Geographic Information System (GIS) and Satellite Image Processing technology (Refer Appendix A) to assist with base mapping preparation that was done manually in the past.

This RIRDC Research Project has evaluated the suitability of SPOT panchromatic satellite imagery as a substitute for aerial photography in the preparation of Property Management Planning base maps.

SPOT Panchromatic (Pan) and Multispectral (XS) scenes covering two properties in the Central Queensland area were purchased. A series of base maps for each property were produced utilising different data, techniques and output devices. This base map production process required mapping work using both DPI's Arc/Info and image processing work using CQU's MIPS/TNTMIPS image processing system.

The products were evaluated on a group basis by people who had experience and knowledge in different aspects of base map utilisation.

It was concluded that use of SPOT panchromatic imagery was very practicable for preparing grazing property base maps, where property size is 4 000 hectares or larger and the maps are produced at scales of 1:20,000 or smaller. Using SPOT panchromatic data as an alternative to the current air photo mosaicing technique reduces the overall cost of producing grazing property PMP base maps.

Production of base maps utilising satellite imagery for properties less than 4 000 hectares at scales larger than about 1:20,000 produced images that were too 'blocky' for landholders to use effectively. Further investigation into more advanced spatial filtering techniques may in part provide a solution to this problem (Crowley, pers. com.).

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# 1. OBJECTIVE

The objective of this research project was to determine if high resolution SPOT digital satellite imagery could be used as an economic substitute for the currently produced, manually assembled, aerial photography property management plan base maps.

The grazing and cropping properties selected for this evaluation project were chosen in consultation with DPI field staff from Rockhampton and Emerald. "Namoi Hills" (located near the town of Dingo) was selected as the grazing property, and "Mount Lowe" (located near the town of Capella) was selected as the cropping property.

### *Satellite Imagery*

DPI is now adopting computerised Geographic Information System (GIS) and Satellite Image Processing technology (Refer Appendix A) to assist with base mapping preparation that was done manually in the past.

Property boundaries, obtained from Queensland's Digital Cadastral Data Base (DCDB), are entered into a GIS. If the DCDB linework is overlain onto a photo mosaic, there is a noticeable positional discrepancy between features identifiable in the photo and those shown by line work due to the distortion in the aerial photographs. Satellite imagery, being able to be digitally rectified, is therefore a more suitable product to be incorporated into a computer based mapping system.

There are many papers in the literature that describe potential uses of remote sensing and Geographic Information Systems (GIS) for land management. A review of recent Remote Sensing literature has shown that only a few of these papers, for example Nellis *et al* (1990), specifically describe actual applications related to rural land use.

The application of this technology for base map preparation in the Central Region was unknown. This RIRDC Research Project has evaluated the suitability of SPOT panchromatic satellite imagery as a substitute for aerial photography in the preparation of Property Management Planning base maps.

# 3. RESEARCH METHODOLOGY

## Production of Base Maps

SPOT Panchromatic (Pan) and Multispectral (XS) scenes covering the "Namoi Hills" and "Mount Lowe" properties were purchased through SPOT Imaging Services. A number of technical problems were encountered with the data due to ACRES processing procedures. These problems resulted in significant delays and workload pressures being placed on the project.

A series of base maps for each property were produced utilising different data, techniques and output devices.

The technical procedures of the base map production are detailed in Appendix C.

## Map Product Evaluation

### *Map Products Evaluated*

This base map production process required mapping work using both DPI's Arc/Info and image processing work using CQU's MIPS/TNTMIPS image processing system. A range of products were produced for evaluation under the project. The products generated for the project were produced at scales normally used for maps of this type by the cartographic unit at DPI's Rockhampton office. The scales used were 1:20,000 for the grazing property "Namoi Hills" and 1:10,000 for the cropping property "Mount Lowe". The products produced were:

1. Aerial Photograph Mosaic as currently produced
2. SPOT Panchromatic Photographic Print
3. SPOT Panchromatic Electrostatic Plot
4. SPOT Multispectral Photographic Print
5. SPOT Multispectral Electrostatic Plot
6. SPOT Panchromatic/Multispectral Composite Photographic Print
7. SPOT Panchromatic/Multispectral Composite Electrostatic Plot
8. SPOT Panchromatic/Landsat Thematic Mapper (TM) Composite Photographic Print
9. SPOT Panchromatic/Landsat Thematic Mapper (TM) Composite Electrostatic Plot
10. Landsat Thematic Mapper (TM) Photographic Print

### *Evaluation Teams*

It was decided that the evaluations should be performed separately by different groups who had experience specific to the test sites. The products were evaluated on a group basis by people who had experience and knowledge in different aspects of base map utilisation. The evaluation was carried out by four groups.

Group 1. Ken Adsett and Peter Rey who evaluated the maps as officers involved directly in map production.

Group 2. David Chapman and Kerrie White, two DPI extension officers, involved directly with landholders, organising Property Management Planning (PMP) workshops for the "Namoi Hills" property.
George Bourne and Bill Wilkinson, two DPI extension officers, involved directly with landholders, organising PMP workshops for the "Mount Lowe" property.

Group 3. Landholders involved directly in the property management planning process and property decision making. The landholders were Kerry and Betty Park and their son Scott and his wife Sally, for the grazing property ("Namoi Hills"), and Murray and Trish Brimblecombe for the cropping property ("Mount Lowe").

Group 4. Ken Day and Ian Heiner, two DPI Land Resources officers involved in providing support to the PMP workshops.

### *Criteria For Evaluation*

The criteria for evaluating the various map products were developed during January 1994. A set of draft evaluation criteria were prepared by Ken Adsett and Peter Rey. A workshop was then held at Rockhampton DPI involving other DPI officers, involved in Property Management Planning and Land Information Management, to discuss the merits of the criteria. From this workshop a final set of eight criteria was derived. Each criteria were scored from 1 (poor) to 5 (good).

The evaluation teams evaluated the usefulness of the base maps for the following eight criteria:

- Location of features, eg. fences, access track, runoff control structures, powerlines.
- Location of drainage lines.
- Location of upland areas.
- Location of watering points, yards, sheds, homesteads etc.
- Location of land types, heavily timbered areas, open forest and grassland.
- Identification of current land use and intensity of land use.
- Identification of problem areas, eg. denuded areas, salinity or woody weeds.
- How suitable is this map overall as a base map of your property.

A copy of the evaluation form used is shown in Appendix B.

It was decided that only the five most appropriate base maps for each property would be evaluated.

### *Statistical Analysis*

Ratings are *ordinal data* in the sense that observations can be ranked from best to worst, but are not *interval data*, since the difference between a rating of 4 and one of 5 may bear little relationship with the difference between a rating of 1 and one of 2.

The teams graded each product on a 1 to 5 rating scale according to how well it matched each of the evaluation criteria. These ratings were then converted into *ranks* or *preferences* for each group and analysed using a Friedman nonparametric analysis of variance (Conover, 1971). Data were processed using the *Statistix* version 4.0 software package. This procedure tests whether or not some maps are preferred over others when taken across all groups. It also allows differences between evaluation teams to be tested.

### *Evaluation Results - "Namoi Hills"*

The following base maps were evaluated for "Namoi Hills".

| Base Map | Abbreviation |
|---|---|
| Air Photo Mosaic | APM |
| SPOT Panchromatic Photographic Print | PPP |
| SPOT Panchromatic Electrostatic Plot | PEP |
| TM Photographic Print | TMPP |
| SPOT Pan/TM Composite Photographic Print | COMP |

Table 2 shows the average ranks (1 = most preferred, 5 = least preferred) of each of the products for each criteria. Also given is the statistical significance level, which measures the probability that the observed result was due to chance.

**Table 2.**

| Criteria | APM | PPP | PEP | TMPP | COMP | Significance |
|---|---|---|---|---|---|---|
| 1 | 1.6 | 2.0 | 4.4 | 4.5 | 2.5 | 0.014 |
| 2 | 1.8 | 1.6 | 4.5 | 4.5 | 2.6 | 0.008 |
| 3 | 3.0 | 1.6 | 4.5 | 4.3 | 1.6 | 0.009 |
| 4 | 2.9 | 1.8 | 4.1 | 4.3 | 2.0 | 0.050 |
| 5 | 3.0 | 1.0 | 4.9 | 3.5 | 2.6 | 0.005 |
| 6 | 3.5 | 1.0 | 4.8 | 3.4 | 2.4 | 0.008 |
| 7 | 3.6 | 1.0 | 4.1 | 4.0 | 2.3 | 0.014 |
| 8 | 2.8 | 1.3 | 4.8 | 4.3 | 2.0 | 0.006 |
| Average | 2.8 | 1.4 | 4.5 | 4.1 | 2.2 | |

Statistically significant differences between products were found in all criteria. In general, SPOT Panchromatic Photographic Prints (PPP) are preferred over SPOT Panchromatic/TM Photographic Prints (COMP) and Air Photo Mosaics (APM), with SPOT Panchromatic Electrostatic Plots (PEP) and TM Photographic Prints (TMPP) being least preferred.

### *Evaluation Results - "Mount Lowe"*

The following base maps were evaluated for "Mount Lowe".

| Base Map | Abbreviation |
|---|---|
| Air Photo Mosaic | APM |
| SPOT Panchromatic Photographic Print (1:10,000) | PPP(10) |
| SPOT Multispectral (XS) Photographic Print | MPP |
| SPOT Pan/Multispectral (XS) Composite Photographic Print | P/X |
| SPOT Panchromatic Photographic Print (1:15,000) | PPP(15) |

Table 3 shows the average ranks (1 = most preferred, 5 = least preferred) of each of the products for each criteria. The statistical significance level is again given, with the abbreviation "ns" indicating no significant differences.

**Table 3.**

| Criteria | APM | PPP(10) | MPP | P/X | PPP(15) | Significance |
|---|---|---|---|---|---|---|
| 1 | 1.0 | 3.1 | 5.0 | 2.9 | 3.0 | 0.006 |
| 2 | 1.5 | 3.3 | 4.9 | 1.9 | 3.5 | 0.011 |
| 3 | 3.0 | 3.0 | 4.3 | 2.3 | 2.5 | ns |
| 4 | 1.8 | 2.9 | 5.0 | 2.4 | 3.0 | 0.022 |
| 5 | 1.1 | 3.6 | 4.3 | 2.3 | 3.8 | 0.025 |
| 6 | 1.5 | 3.5 | 4.4 | 1.9 | 3.8 | 0.026 |
| 7 | 2.6 | 3.3 | 3.9 | 1.8 | 3.5 | ns |
| 8 | 1.6 | 3.8 | 4.6 | 1.6 | 3.4 | 0.012 |
| Average | 1.8 | 3.3 | 4.5 | 2.1 | 3.3 | |

Statistically significant differences between products were found in all except two criteria. In general, Air Photo Mosaics (APM) and SPOT Panchromatic/Multispectral Composite Prints (P/X) are preferred over the two SPOT Panchromatic Photographic Print (PPP(10) and PPP(15)), with SPOT Multispectral Photographic Prints (MPP) being least preferred.

## Costs of Map Production

Manual production of aerial photograph mosaic maps is a very labour intensive process and hence, with properties involving a number of aerial photographs, the process can become expensive by virtue of the labour component. A typical map involving 8 to 10 aerial photographs would cost :

| | |
|---|---|
| Labour | $275 |
| Materials | $ 50 |
| Total Cost | $325 |

Utilising Satellite imagery in an in-house situation, a map would typically cost :

| | |
|---|---|
| Labour | $ 60 |
| Negative creation | $ 90 |
| Photographic Print | $150 |
| Freight | $ 20 |
| Total Cost | $320. |

With experience, and continuing changes in hardware and software technology it is believed that the costs of negative creation and photographic prints may be able to be reduced by as much as 30%. This could result in the cost of a satellite image map being reduced to approximately $225 to $250. It is extremely unlikely that costs will fall for the production of aerial photograph mosaics.

Purchase costs for aerial photography are rising steadily and are costing DPI approximately $3300 for Black & White photography and $6000 for colour photography for each 1:100,000 map sheet area flown and purchased. Costs for satellite imagery on the other hand are steadily decreasing. Utilising in-house facilities for the rectification, the cost could fall as low as $2000 to $2500 per 1:100,000 map sheet area.

## Other Issues Raised During the Evaluation Process

The analysis of the rating data showed a high degree of consistency across evaluation teams. Of the 16 sets of rankings, only criteria 5, 6, and 8 for "*Namoi Hills*", and criterion 1 for "*Mount Lowe*" showed any difference between teams. In general, groups 3 and 4 tended to judge all products more harshly than did groups 1 and 2. The relative rankings of the products however, remained consistent.

George Bourne and Bill Wilkinson, extension officers, of Emerald Department of Primary Industries, raised the issue of utilising the satellite images in DPI's Computerised Property Planning workshops. Digital images such as satellite data are much more suitable as bases for Computerised Property Planning workshops than the currently utilised line and point vector bases, as they can be imported into the Autosketch program used for the workshops. This process as well as scanning aerial photographs is being currently investigated.

Mr. Kerry Park of "Namoi Hills" indicated that costs of base maps at $300 to $400 is not really a major issue when looking at the lifespan of a map of three to five years.

All landholders stated that time frames are important when looking at data capture in that the capture must coincide with the event that the landholder requires information on, while still being as up to date as possible.

Satellite base maps raise many more management issues than do black and white photo bases as they contain additional information from various parts the electromagnetic spectrum.

## Discussion of Results

### *"Namoi Hills"*

The results indicate SPOT Panchromatic satellite imagery, in photographic print form at a scale of 1:20,000 and smaller, provides a better property planning base map than mosaics of aerial photographs. When the SPOT Panchromatic image was combined with Landsat TM imagery, the base while having the addition of colour from the TM imagery is not as good a base as is the SPOT panchromatic image. It was found during discussions with the landholders that the addition of colour from the Landsat TM image had a negative effect upon the base map as the colours were "false" colours, not the true colours of the landscape. During discussions the landholders indicated that while the map had great potential, they were put off by the false colours as they found them distracting.

The most significant question asked in the evaluation was:

"How suitable is this map overall as a base for your property?"

The landholders responses to this question reflect the scores of the previous evaluation tables in that the SPOT Panchromatic Photographic Print is the most suitable base, while the aerial photo mosaic and the SPOT Pan/TM composite photographic print were useful, and the other products were seen as unusable. The scores for this question are shown in Table 4 and are ranked from 1 (most preferred) to 5 (least Preferred).

**Table 4. Grazing Landholder's Assessment of Product Suitability**

| Base Map | Score |
|---|---|
| Air Photo Mosaic | 3 |
| SPOT Panchromatic Photographic Print | 2 |
| SPOT Panchromatic Electrostatic Plot | 4 |
| TM Photographic Print | 5 |
| SPOT Pan/TM Composite Photographic Print | 3 |

### *Mount Lowe*

The results indicate that air photo mosaics provide better property planning bases than do SPOT Panchromatic satellite imagery at a scale of 1:10,000 and larger. When combined with SPOT

XS imagery however, the satellite image base scored well. It was found during discussions with the landholders that the colours were useful to the landholder as the false colours indicate changes in the landscape that are were unable to be seen on the air photo mosaics or on the SPOT Panchromatic prints or on the ground. This phenomenon was unable to be explained in the course of this research and requires further research to ascertain the exact cause. An example of colour that was able to be explained was the distribution of buffel grass at the time of the data capture. The landholders indicated that while the map has great potential they were put off in part by the lack of resolution in the imagery at this scale.

Again the most significant question asked in the evaluation was:

"How suitable is this map overall as a base map for your property?"

The landholders responses to this question reflect the scores of Table 2 in that the aerial photo mosaic and the SPOT Pan/TM composite photographic print were equally useful as the most suitable bases while the SPOT Panchromatic photographic print at a scale of 1:10,000 and the SPOT XS Photographic Print were seen as less useful. The SPOT Panchromatic Photographic Print at a scale of 1:15,000 was seen as being too small a plan to be useable. The landholders comments were that the 1:10,000 scale was preferred, even if the image resolution was slightly more grainy. The scores for this question are shown in Table 5 and are ranked from 1 (most preferred) to 5 (least preferred).

**Table 5. Cropping Landholders Assessment of Product Suitability**

| Base Map | Score |
|---|---|
| Air Photo Mosaic | 2 |
| SPOT Panchromatic Photographic Print (1:10,000) | 3 |
| SPOT Multispectral(XS) Photographic Print | 3 |
| SPOT Pan/XS Photographic Print | 2 |
| SPOT Panchromatic Photographic Print (1:15,000) | 4 |

## Conclusion

It was concluded that use of SPOT panchromatic imagery was very practicable for preparing grazing property base maps, where property size is 4 000 hectares or larger and the maps are produced at scales of 1:20,000 or smaller. Using SPOT panchromatic data as an alternative to the current air photo mosaicing technique reduces the overall cost of producing grazing property PMP base maps.

Production of base maps utilising satellite imagery for properties less than 4 000 hectares at scales larger than about 1:20,000 produced images that were too 'blocky' for landholders to use effectively. Further investigation into more advanced spatial filtering techniques may in part provide a solution to this problem (Crowley, pers. com.).

It was concluded that routine use of SPOT imagery for preparing typical cropping property base maps was not practicable due to the small property size and the need for large scale (>1:20,000)

mapping. However, where cropping properties were large (>4 000 ha), SPOT panchromatic imagery could be used as an alternative to aerial photography as the mapping scale would be 1:20,000 or smaller. SPOT multispectral imagery also provided useful information about vegetation and soil conditions due to the colour imagery.

It was concluded that the cost of production of maps using SPOT Panchromatic imagery was very similar to the costs of producing aerial photograph mosaics. There is however a substantial saving that can be made in the data purchase prices of SPOT imagery. This saving is even greater if the properties requiring maps are large enough to utilise Landsat TM imagery instead of SPOT imagery. Comparing the resolutions of the two data sets however these maps would have to be of properties of 35 000 hectares or greater and produced at scales of approximately 1:50,000 and smaller.

One part of the research project involved obtaining accurate position coordinate data to assist with rectifying the SPOT imagery to a standard map projection. Field work using a global positioning system (GPS) was conducted at the grazing property near Dingo on 18 November, 1993. It was found that use of a topographic map was almost as accurate and was far more practicable than the GPS, and hence GPS work was not done for the cropping property near Emerald.

## Recommendations

It is recommended that DPI in the Central Region :-

- Develop a policy for the use of satellite imagery for use in the production of PMP base maps.
- Purchase SPOT satellite imagery in areas identified as a high priority for the use of satellite imagery in the production of PMP base maps.
- Seek further funding to continue to investigate the integration of GIS and Remote Sensing technologies for use in the production of PMP base maps.
- Investigate unexplained texture patterns such as found in multispectral images of the "Mount Lowe" cropping property.

# 4. PROJECT SUMMARY

**"Evaluation of high resolution SPOT satellite imagery for use in the preparation of Property Management Planning base maps for graziers and grain growers in Central Queensland".**


OBJECTIVE

The objective of this research project was to determine if high resolution SPOT digital satellite imagery could be used as an economic substitute for the currently produced, manually assembled, aerial photography property management plan base maps.

BACKGROUND

Queensland Department of Primary Industries (DPI) currently encourages land holders to prepare their own land management plans. Preparation of these plans ensures that both land conservation factors and agronomic factors are considered when deciding how to manage agricultural land. Land holders are assisted with the preparation of Property Management Plans by attending PMP Workshops run by DPI. A PMP Kit is supplied at a nominal charge to land holders attending these workshops, and a base map of the land holder's property is included in the kit.

This RIRDC Research Project evaluated the suitability of SPOT panchromatic satellite imagery for use as a property management planning mapping base for Central Queensland grazing and cropping properties at scales of between 1:10,000 and 1:40,000. In addition, panchromatic and multispectral SPOT imagery were compared and evaluated for use in cropping property management.

The grazing and cropping properties selected for this evaluation project were chosen in consultation with DPI field staff from Rockhampton and Emerald. "Namoi Hills" (located near the town of Dingo) was selected as the grazing property, and "Mount Lowe" (located near the town of Capella) was selected as the cropping property.

CONCLUSION

It was concluded that use of SPOT panchromatic imagery was very practicable for preparing grazing property base maps, where property size is 4 000 hectares or larger and the maps are produced at scales of 1:20 000 or smaller. Using SPOT panchromatic data as an alternative to the current air photo mosaicing technique reduces the overall cost of producing grazing property PMP base maps.

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It was concluded that routine use of SPOT imagery for preparing typical cropping property base maps was not practicable due to the small property size and the need for large scale (>20 000) mapping. However, where cropping properties were large (>4 000 ha) SPOT panchromatic imagery could be used as an alternative to aerial photography as the mapping scale would be 1:20 000 or smaller. SPOT multispectral imagery also provided useful information about vegetation and soil conditions due to the colour imagery.

It was concluded that the cost of production of maps using SPOT Panchromatic imagery was very similar to the costs of producing aerial photograph mosaics. There is however a substantial saving that can be made in the data purchase prices of SPOT imagery. This saving is even greater if the properties requiring maps are large enough to utilise Landsat TM imagery instead of SPOT imagery. Comparing the resolutions of the two data sets however these maps would have to be of properties of 35 000 hectares or greater and produced at scales of approximately 1:50 000 and smaller.

One part of the research project involved obtaining accurate position coordinate data to assist with rectifying the SPOT imagery to a standard map projection. Field work using a global positioning system (GPS) was conducted at the grazing property near Dingo on 18 November, 1993. It was found that use of a topographic map was almost as accurate and was far more practicable than the GPS, and hence GPS work was not done for the cropping property near Emerald.

# 5. BIBLIOGRAPHY

Commonwealth Department of Primary Industries and Energy, (date unknown). *The National Property Management Planning Campaign.* Commonwealth Department of Primary Industries and Energy pamphlet.

Conover, W. J. (1971). *Practical Nonparametric Statistics.* John Wiley & Sons Inc. New York

Environmental Systems Research Institute Inc, (1992), *Understanding GIS, The Arc/Info Method.* Environmental Systems Research Institute Inc., Redlands. California

Grasso, D. N. (1993). *Applications of the IHS colour transformation for 1:24,000-scale geologic mapping : A low cost SPOT alternative.* Photogrammetric Engineering and Remote Sensing, Vol. 59, No. 1, pp 73 - 80.

Nellis, M. D., Lulla, K. and Jensen, J. (1990). *Interfacing Geographic Information Systems and remote sensing for rural land-use analysis.* Photogrammetric Engineering and Remote Sensing, Vol 56, No 3, pp 329-331.

Queensland Department of Primary Industries (date unknown). *Planning Your Property.* Queensland Department of Primary Industries pamphlet.

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Mr. Allan Lisle, Senior Biometrician, Agricultural Production Group, DPI, Central Region for assistance with data analysis and statistical interpretation of the evaluation questionnaire.

Miss Katrina Gibson, Administrative Officer, Corporate Services Group, Central Region for word processing.

## 7. PERSONAL COMMUNICATIONS

Jim Mollison, Account Manager, ACRES.

Laurie Oliver, Technical Manager, ACRES.

Bruce Walker, Manager, Slide Works.

Keiko Crowley, Customer Services Manager, SPOT Imaging Systems.

## 8. COMPUTER PROGRAMS

Analytical Software, 1992), Statistix 4.0, Statistical Analysis Package.

Autodesk Inc., 1992, Autosketch, Computer Aided Drawing Package.

ESRI, (1993), Arc/Info, Geographic Information System.

MicroImages Corp., 1993, MIPS and TNTMIPS, Image Processing System

Yoshizaki, H (1991), LHA, data compression program (shareware).

## 9. INTELLECTUAL PROPERTY

This research project did not involve the development of any intellectual property.

# 10. APPENDIX A

# Geographic Information Systems

## Geographic Information Systems (GIS) - What Are They?

A GIS is a system for capturing, storing, checking, integrating, manipulating, analysing and storing data that are spatially referenced.

Essentially the technique is an integration of computerised mapping technology and relational database management systems. Any information that is spatially referenced can be stored and manipulated in a GIS. GIS's are used to manage and analyse data sets from different data sources.

A GIS system is fundamentally different from a Computer Aided Drafting (CAD) system in that a GIS has and creates "Topology". That is, in a true GIS, a polygon has non-static attributes, ie.: area, multiple arc boundaries and adjacent polygon relationships (ESRI, Understanding GIS, 1992).

Computerised Geographic Information Systems (GIS) are a relatively new technology. "While hardware and software for geographic information systems have improved exponentially in the United States, implementation of technology for management purposes has grown linearly" (Nellis, *et al* 1990).

GIS requires accurate placement of line work in a consistent coordinate system. Property boundaries are now obtained from Queensland's Digital Cadastral Data Base (DCDB) and incorporated into a GIS. The precision of this mapping is such, that when the digital linework is overlain onto a photo mosaic, there are often large positional discrepancies between features identifiable in the photo and those shown by linework.

## Advantages of GIS

GIS assists Land Resource Managers to organise information and to recognise and understand their spatial relationships thus providing a basis for making better and more informed decisions. A major advantage of utilising a GIS over a relational database is that it allows the identification of spatial relationships between spatially related data sets. A significant feature of using a GIS is that information can be viewed, edited and queried through a graphical environment.

DPI uses GIS technology to assist with Land Resource Mapping that was in the past done manually. This RIRDC Research Project assisted DPI to learn more about the capabilities and limitations of the Arc/Info GIS, when incorporating satellite imagery. The project also demonstrated how GIS and remote sensing can be used to assist with Property Management Planning.

### ARC/INFO - What is it?

Arc/Info is a GIS developed and marketed by Environmental Systems Research Institute (ESRI) of Redlands, California. Arc/Info is one of the most powerful and up to date GIS's available. In Arc/Info, Arc handles the location of features while Info handles the feature attributes and how the features are interrelated.

## Image Processing Systems

### Image Processing Systems - What are they?

Image processing systems are computer software packages for the collection, examination, analysis, synthesis and presentation of remotely sensed imagery.

### MIPS/TNTMIPS - What is it?

MIPS is a DOS based image processing system developed and marketed by Microimages Inc. of Nebraska, USA. MIPS has now been superseded by TNTMIPS, which runs under Windows 3.1. TNTMIPS is one of the leading low cost image processing systems available today.

### Satellite Data

High resolution digital satellite data are ideal for use as a mapping base at regional scales (1:100,000 through to 1:1,000,000). However, the potential for using these data at scales of 1:25,000 or greater has not been fully validated. This is primarily due to the relatively poor spatial resolution of satellite imagery in comparison to images acquired by aerial photography.

The French SPOT satellite provides panchromatic (black and white) imagery with a ground resolution of 10m. These are the highest resolution digital image data currently available from commercial satellite systems. This RIRDC Research Project evaluated the suitability of SPOT panchromatic imagery for use as a mapping base for cropping and grazing properties at scales of between 1:10,000 to 1:40,000. In addition, panchromatic and multispectral SPOT imagery were compared, and evaluated for use. The SPOT satellite also provides multispectral (false colour infrared) imagery with a ground resolution of 20m.

A major advantage of using digital satellite data is that a whole scene (3,600 $km^2$ for a full SPOT image) can be geometrically corrected in one operation. Individual properties can then be subset from the full scene as needed, thereby ensuring a consistent geometric accuracy. This greatly assists with the overlay of GIS data.

# 11. APPENDIX B

## Property Plan Base Map Evaluation Form

# PROPERTY PLAN BASE MAP EVALUATIONS:

| | Criteria | | Rating | | | | |
|---|---|---|---|---|---|---|---|
| | | | Poor | | Average | | Good |
| (a) | Location of features, eg. fences, access track, runoff control structures, powerlines. | Map1 | 1 | 2 | 3 | 4 | 5 |
| | | Map2 | 1 | 2 | 3 | 4 | 5 |
| | | Map3 | 1 | 2 | 3 | 4 | 5 |
| | | Map4 | 1 | 2 | 3 | 4 | 5 |
| | | Map5 | 1 | 2 | 3 | 4 | 5 |
| (b) | Location of drainage lines. | Map1 | 1 | 2 | 3 | 4 | 5 |
| | | Map2 | 1 | 2 | 3 | 4 | 5 |
| | | Map3 | 1 | 2 | 3 | 4 | 5 |
| | | Map4 | 1 | 2 | 3 | 4 | 5 |
| | | Map5 | 1 | 2 | 3 | 4 | 5 |
| (c) | Location of upland areas. | Map1 | 1 | 2 | 3 | 4 | 5 |
| | | Map2 | 1 | 2 | 3 | 4 | 5 |
| | | Map3 | 1 | 2 | 3 | 4 | 5 |
| | | Map4 | 1 | 2 | 3 | 4 | 5 |
| | | Map5 | 1 | 2 | 3 | 4 | 5 |
| (d) | Location of watering points, yards, sheds, homesteads etc. | Map1 | 1 | 2 | 3 | 4 | 5 |
| | | Map2 | 1 | 2 | 3 | 4 | 5 |
| | | Map3 | 1 | 2 | 3 | 4 | 5 |
| | | Map4 | 1 | 2 | 3 | 4 | 5 |
| | | Map5 | 1 | 2 | 3 | 4 | 5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (e) | Location of land types, heavily timbered areas, open forest and grassland. | Map1 | 1 | 2 | 3 | 4 | 5 |
| | | Map2 | 1 | 2 | 3 | 4 | 5 |
| | | Map3 | 1 | 2 | 3 | 4 | 5 |
| | | Map4 | 1 | 2 | 3 | 4 | 5 |
| | | Map5 | 1 | 2 | 3 | 4 | 5 |
| (f) | Identification of current land use and intensity of land use. | Map1 | 1 | 2 | 3 | 4 | 5 |
| | | Map2 | 1 | 2 | 3 | 4 | 5 |
| | | Map3 | 1 | 2 | 3 | 4 | 5 |
| | | Map4 | 1 | 2 | 3 | 4 | 5 |
| | | Map5 | 1 | 2 | 3 | 4 | 5 |
| (g) | Identification of problem areas, eg. denuded areas, salinity or woody weeds. | Map1 | 1 | 2 | 3 | 4 | 5 |
| | | Map2 | 1 | 2 | 3 | 4 | 5 |
| | | Map3 | 1 | 2 | 3 | 4 | 5 |
| | | Map4 | 1 | 2 | 3 | 4 | 5 |
| | | Map5 | 1 | 2 | 3 | 4 | 5 |
| (h) | How suitable is this plan overall as a base map of your property. | Map1 | 1 | 2 | 3 | 4 | 5 |
| | | Map2 | 1 | 2 | 3 | 4 | 5 |
| | | Map3 | 1 | 2 | 3 | 4 | 5 |
| | | Map4 | 1 | 2 | 3 | 4 | 5 |
| | | Map5 | 1 | 2 | 3 | 4 | 5 |

# 12. APPENDIX C

# Production of Property Management Planning Base Maps

## *Grazing Property : "Namoi Hills"*

### (a) SPOT Image Acquisition

A scene search conducted by SPOT Imaging Services in Sydney showed that a SPOT Panchromatic (Pan) image acquired on 23 June 1993 had been recorded for the Dingo 1:100,000 map sheet area. The image covered most of the map sheet, and fully covered the grazing property "Namoi Hills" selected for use in the evaluation project. This SPOT image was ordered as an ACRES Level 6 product. ACRES Level 6 data are rectified to the Australian Map Grid (AMG), but the rows and columns (lines and pixels) remain oriented to the satellite path. The Level 6 data also retain their original 10 m pixel size (Mollison, pers. com.).

### (b) Rectification

Although the Level 6 data were pre-rectified, it is understood that the coordinate data supplied for the image corner pixels were incorrectly written in the image header file. This was caused by the production software being used by ACRES at that time (Oliver, pers. com.). Hence, it was necessary to manually add ground control points (GCP's) to georeference the data. A total of 20 GCP's were identified in both the image and 1:100,000 topographic maps. An additional 2 GCP's were added from differentially corrected global positioning system (GPS) data collected in the field. All GCP's having a residual error greater than 2 pixels (20 m) were removed, leaving 13 GCP's.

Rectification rotates the data to align the image lines and pixels with the Australian Map Grid (AMG). It was decided to rectify only the area covered by the "Namoi Hills" property, to optimise computer disk space. This generated a rectified image that was approximately 2,000 pixels (20 km) wide and 2,500 lines (25 km) long. About 5 Mb of computer disk space was required to store this image.

### (c) Use of Global Positioning System (GPS)

Use of a global positioning system (GPS) in the field is appropriate for 'one off' intensive fieldwork studies which may require DPI officers to collect other data on a specific property. However, use of GPS solely to gather control point data for preparation of Property Management Planning base maps is not practicable, due to the need to visit each property. It is much more efficient to use published 1:100,000 topographic maps as the georeference base.

Use of GPS with satellite imagery requires that a specific pixel can be identified in the field. A number of potential pixels were selected in the image prior to field work being undertaken. However, only 2 of these points could be confirmed on the ground. One

reason for this is that land conditions change over time, so that a pixel identifiable in an image may not appear the same when field work is undertaken at a later time.

### (d) Cadastral Boundaries

Queensland's Digital Cadastral Data Base (DCDB) comprises position coordinates for cadastral boundary lines, and tabular data describing the legal identity of each land parcel. Cadastral boundaries of all land parcels comprising the Namoi Hills property were extracted from the DCDB as digital files, and converted to the PC Arc/Info GIS format. A buffer zone extending 1 km outside the actual property boundary was generated.

### (e) Property Masking

The buffer zone (vector) created above was converted into a binary raster conforming to the previously rectified Namoi Hills image subset. All pixels inside the buffer were assigned a value of 1, and all external pixels assigned a value of 0.

Masking of areas outside the Namoi Hills property was achieved by multiplying the rectified Namoi Hills image subset raster (A) by the binary mask raster (B). This resulted in all pixels within the buffer being unchanged (A x 1 = A) and all external pixels being set to zero (A x 0 = 0). The external pixels were subsequently converted to a value of 255 to create a white background.

Later experimentation with the MIPS image analysis software used for the image processing work showed that the masking and conversion of the background to white could have been achieved in a single step by using an equation that included logical operators :-

$$((B = 0) * 255) + A.$$

### (f) Contrast Enhancement

Overall brightness of the Namoi Hills image subset was adjusted using a logarithmic contrast stretch to give the best appearance possible to the image. Contrast enhancement is required to bring out image detail and minimise the saturation of dark and light areas. This enhancement is similar in effect to paper grade selection and exposure adjustment when printing photographs.

The selected contrast stretch was saved as a look-up table (LUT), and the image subsequently processed through the LUT to make the contrast enhancement permanent.

### (g) Cartographic Enhancement

The output raster image produced above was transferred to the Arc/Info GIS. Cadastral boundaries were added from the DCDB. A title, scale bar and other cartographic information were also added as an overlay on top of the raster. This provided ancillary information to assist the land holder interpret the image. Finally, the digital Property

Management Planning base map that had been created was converted to an Encapsulated Postscript (EPS) file.

### (h) Image Writing

The EPS file comprising the Property Management Planning base map was compressed using the LHA 'shareware' program (Yoshizaki, 1991), and transferred to floppy disk. The disk was sent to Slideworks in Sydney, a bureau service specialising in the generation of photographic products from digital data. Slide Works generated a 120 mm x 100 mm (5"x4") format negative from the EPS file. The image was written to the negative at 1,600 dots per inch. Later work was also transferred using the Unix TAR command and 8 mm Exabyte tapes.

### (i) Hard Copy Production

The 120 mm x 100 mm negative generated by Slideworks was sent to the Prolab photographic laboratory in Brisbane, and prints produced at scales from 1:15,000 through to 1:40,000. It was found that black & white (B&W) photos printed on colour paper (from a B&W negative) had a superior definition when compared to prints done on B&W paper.

In addition, electrostatic plots were prepared directly from the digital file created above. The electrostatic plots were about 1/10th the cost of the photographic prints. However, electrostatic plots are of a far lower quality. The electrostatic plot was prepared for comparison with the photographic image.

## *Cropping Property : "Mount Lowe"*

### (a) SPOT Image Acquisition

A scene search conducted by SPOT Imaging Services in Sydney showed that no SPOT Panchromatic (Pan) imagery was available for the Cotherstone 1:100,000 map sheet area, which includes the "Mount Lowe" property. In addition, only one Multispectral (XS) image had been recorded for the area, and this image contained some clouds. It was therefore necessary to submit a Programming Request (PR) so that SPOT Pan and XS imagery could be acquired simultaneously.

SPOT Pan and XS images of the required area were successfully recorded on 19 September 1993. ACRES Level 9 digital data were ordered for the 1:50,000 map sheet area covering the south west quadrant of the 1:100,000 Cotherstone map sheet (8552-3). ACRES Level 9 data are rectified to the Australian Map Grid (AMG), and the rows and columns (lines and pixels) are oriented to the AMG grid. The Level 9 data have a resampled pixel size of 6.25 m (Mollison, pers. com.). Theoretically, the geometric accuracy of an ACRES Level 9 product is such that no further geometric corrections should be needed.

A number of problems were experienced with the Level 9 data produced by ACRES. Some problems were due to ACRES production system, which resulted in the data being written to tape at the wrong density. However, more severe problems were encountered with the quality of data supplied. Data quality was degraded by a repetitive 'texture' pattern being present in the image. When the image was enlarged, the texture pattern became very obvious, so the data were rejected.

Subsequent investigations by ACRES and Central Queensland University traced the problem to ACRES' production system software. It was later determined that ACRES could produce a degraded, but acceptable, Level 9 product if they used a non-standard KD-16 resampling kernel. However, to ensure that no degradation occurred, it was resolved that ACRES would exchange the Level 9 XS and Pan data for Level 4 products. This necessitated rectification of the Level 4 data, which was not originally planned for.

## (b) Rectification

### (i) Panchromatic Data

A total of 44 ground control points (GCP's) were identified on both the panchromatic image and 1:100,000 topographic maps. GPS data were not collected in the field, as work on the "Namoi Hills" property demonstrated that use of GPS would not be practicable in a 'production' base map generation system. All GCP's having a residual error greater than 2 pixels (20 m) were removed, leaving 17 GCP's.

In contrast to the work done for "Namoi Hills", where only the area covered by the property was rectified, the full area corresponding to the 8552-3 1:50,000 map sheet was rectified. This generated a rectified image that was approximately 2,600 pixels (26 km) wide and 2,800 lines (28 km) long. About 7.3 Mb of computer disk space was required to store this image.

### (ii) Multispectral Data

As it was planned to merge the Pan and XS SPOT data, the XS data were registered to the already georeferenced Pan image. This ensured a good match between the images.
The task of rectifying the XS image was quite straightforward, as GCP's could be selected for any point shared by the XS and Pan image. This contrasted with the original Pan image rectification, where a GCP had to correspond with a feature marked on a 1:100,000 topographic map. A total of 30 GCP's were identified in both the Pan and XS image. Because the XS data were registered directly to the Pan data, no GCP's needed to be deleted even though the XS data had a 20 m pixel size and the Pan data had a 10 m pixel size.

Again, as done for the Pan data, the full XS area corresponding to the 8552-3 1:50,000 map sheet was rectified. This generated a rectified image that was

approximately 1300 pixels (26 km) wide and 1400 lines (28 km) long (approximately 1.8 Mb per band). The XS image comprised 3 bands ('green', 'red', and 'infrared'), so about 5.5 Mb of computer disk space was required to store this image.

### (c) Cadastral Boundaries

Cadastral boundaries of the "Mount Lowe" property were extracted from the DCDB as digital files, and converted to the PC Arc/Info geographic information system (GIS) format.

A subset of the Pan image was created for the "Mount Lowe" property. This subset was 801 pixels (8 km) wide and 851 lines long (8.5 km). Similarly, an XS image subset was created, comprising 401 pixels and 426 lines.

The SPOT images of the "Mount Lowe" property were not masked. Hence, the complete image subsets were retained. The main reason for not masking the image subsets was that an ancient volcanic cone occurred just north of Mount Lowe, which added interest to the images.

### (d) Contrast Enhancement

Overall image brightness was adjusted in the Pan image and in each of the 3 bands in the XS image. A normalised contrast stretch was used for the Pan and XS images.

The selected contrast stretches were saved as look-up tables (LUTs), and the images subsequently processed through the LUTs to make the contrast enhancement permanent.

### (e) Data Merging

As stated above, the SPOT Pan data have a 10 m pixel size, while the XS data have a 20 m pixel size. The Pan image provides a high level of spatial resolution, while the XS image provides the advantage of spectral information (colour).
It is possible to merge the Pan and XS data sets, so that the resulting hybrid image has the high spatial resolution of the Pan image and the spectral information from the XS image. A relatively simple procedure described by Grasso (1993) was used for merging the data sets. The technique involves transforming the XS colour information from the standard red-green-blue (RGB) colour space to the intensity-hue-saturation (IHS) colour space, substituting the Pan data for the intensity (I) band of the IHS data, then back-converting the IHS data to the RGB colour space.

Work for data merging was done using TNTMIPS 4.5, which is the Windows version of the MIPS software used for all other image processing. TNTMIPS was used for the merging, as this software had a superior RGB-IHS-RGB conversion algorithm to the DOS version (MIPS 3.3). The XS 20 m pixels were replicated, so that each original pixel was converted to 4 x 10 m pixels. The resulting XS image was approximately 2600 pixels (26

km) wide and 2800 lines (28 km) long. The last column and last row of pixels was deleted so that the XS image size conformed exactly to the Pan image. The XS data were then converted to the IHS colour space, the Pan data substituted for the intensity (I) band, and the data back-converted to the RGB colour space, as described by Grasso (1993). This resulted in a false colour infrared image having a 10 m spatial resolution. In general, the colours achieved closely matched those observed in the original XS image.

**(f) Cartographic Enhancement**

Initially, no cartographic enhancements were added to the Mount Lowe images. The objective of omitting these enhancements was to determine if production costs could be reduced without degrading the usefulness of the final product.

The raster images produced above were later enhanced by the addition of cadastral boundaries from the DCDB. A title, scale bar and other cartographic information were also added as an overlay on top of the raster. Finally, the digital Property Management Planning base map that had been created was converted to a Post Script EPS file, and sent to DPI's electrostatic plotter in Brisbane.

**(g) Image Writing**

TIFF files comprising the SPOT Pan, XS and merged Pan/XS "Mount Lowe" Property Management Planning base map were compressed using the LHA shareware program (Yoshizaki, 1991), and transferred to floppy disk. The disk was sent to Slide Works in Sydney, who generated 120 mm x 100 mm (5"x4") format negatives from the TIFF files.

**(h) Hard Copy Production**

The 120 mm x 100 mm negative generated by Slideworks was sent to the Prolab photographic laboratory in Brisbane, and prints produced at scales from 1:10,000 through to 1:20,000. As noted above, the photographic prints of the image files did not contain cartographic enhancements. However, cartographic enhancements were added to output printed using DPI's electrostatic plotter.

## Issues Raised During Map Production

### *ACRES Product Selection*

It was found that rectified images produced by ACRES (level six and 9) did not result in suitable products being generated for use in the preparation of Property Management Planning base maps. The Level 6 data were not supplied with correct corner point coordinates, and also required rotation to conform to the Australian Map Grid. The Level 9 data were degraded by the

processing technique used at ACRES in October 1993, and additionally the synthesised brightness value of 6.25 m pixels reduced the clarity of the image.

It was resolved that data purchased from ACRES should be Level 4 or Level 5, and that georeferencing and rectification should be done 'in house' to ensure consistency and to maintain desired accuracy.

### *Image File Formats*

A number of tests were undertaken to determine the optimum format for sending image data to Slideworks, for subsequent conversion to a photographic negative.

Initially, test files were sent in TARGA format. However, the level of detail resolvable in prints produced from the negatives was less than desired. Discussions with Slideworks (Walker, Pers. com.) resolved that their software automatically replicated pixels so that the image occupied the full negative. This replication caused the loss of detail.

It was resolved that raster images should be sent to Slideworks in TIFF format, as their software did not alter the pixels of TIFF files.

Where the image data contained line work and other cartographic enhancements, it was resolved that the data should be sent in Encapsulated Postscript (EPS) format. This allows DPI to use the Arc/Info GIS to its full capability to produce high quality output.

### *Data Storage*

In projects dealing with satellite imagery, the data files are inevitably large, hence making data storage requirements a significant factor. The original satellite data files for this project totalled more than 100 Mb. With rectification, contrast stretching, production of image files, Arc/Info graphics files and EPS files, the requirements for data storage increased to almost 400 Mb. In full map production mode, the storage of satellite and manipulation of digital data would require significant disk storage facilities. It is estimated that the minimum data storage requirements for this would be 2 Gb with desirable storage of 5 to 10 Gb. Storage of original satellite data and rectified data on CD ROM would alleviate some of this problem but the requirement for disk space would still be very high. Transfer of data to and from backup tapes was found to be time consuming and inefficient.