finalreport

RESOURCE MANAGEMENT - MONITORING

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VegMachine – Extending Integrated Rangeland Monitoring Information to Industry

Northern Territory Government
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Abstract

The VegMachine project has successfully delivered and evaluated the benefits of satellite based monitoring information for use by pastoral producers. Critical elements of the project are; human extension expertise; carefully prepared monitoring data products, and a purpose-built software system. Active participation of pastoralists has also been essential to the project. Its centrepiece is the VegMachine© software, which is used together with satellite data, and human experience, to allow pastoralists to monitor long term changes in ground cover across large extents of their properties. The software has the unique capability to allow users to easily access satellite images and cover change products and extract temporal cover information for any given area, and compare this against a regional average. This is all possible through a standard windows computer in the pastoralist's home, and so represents the conception of producer-led land monitoring. The project has met with strong support on the 32 northern Australian pastoral properties where it was trialled. We document the development of the software, promotion and producer recruitment, validation of ground cover indices and producer feedback on the software and data products. We conclude that the VegMachine approach has significant potential to improve the power of pastoralists to monitor, communicate and respond to changes in their land condition. The Project has attracted widespread interest. We recommend that MLA support continuation and expansion of the VegMachine model regionally through agencies or regional NRM bodies which are prepared to co-invest in human expertise and dedicated data for their region.

Executive Summary

The VegMachine project pioneered a new approach to rangeland monitoring in a system that brought together human extension expertise, carefully prepared monitoring data products, and the purpose-built VegMachine© software. In doing so the project has demonstrated the benefits that satellite technology can provide the grazing industry in monitoring and managing country in a sustainable approach. It has successfully delivered new satellite monitoring information in a simple, yet effective format that has engaged and satisfied the needs of a range of pastoralists.

The project achieved its objectives and was successful in delivering outcomes on many levels including; the development of a world first software application, pastoralist interaction and uptake of satellite data, and assisting pastoralists to implement change in management at the paddock level and monitor the results. These outcomes were accomplished through the following key achievements.

- The VegMachine© software was developed by CSIRO with significant input from pastoralists and project officers at workshops and on-property trials.
- Softwares unique capability for users to easily extract and graph a temporal sequence of cover indices for any given area of interest and compare against regional cover indices.
- Collation of large time series of satellite data spanning 13 to 21 years, data management and preparation for analysis.
- Starting with limited experience, Queensland project officers demonstrated the transferability of the technology to new regions/agencies by collating various digital datasets, establishing and surveying on ground monitoring sites, developing regionally relevant data products, and engaging 8 pastoralists managing 6 properties (3600km^2) in the trial.
- The Northern Territory / Western Australia project officer built upon achievements of previous research and extension, to expand regional use of satellite monitoring from a few properties, to 19 pastoralists managing 27 properties (78000km^2).
- Numerous workshops, public presentations and publications aimed at various audiences.
- Extensive pastoralist feedback gathered through workshops, personal training and surveys.
- Two participant surveys which indicated high interest in the satellite data and associated products, a variety of practical uses for the monitoring system, and pastoralists' perspectives on future uses for VegMachine.
- Generation of high levels of interest in VegMachine© among pastoralists, pastoralist advocates, software developers, science and extension agencies, and regional NRM bodies.

The project has produced immediate improvements in producer monitoring capacity. VegMachine© allows pastoralists to graph (time trace) historical cover levels in areas of interest (paddock, monitoring site) at whichever landscape scale they require. Time trace analysis can provide pastoralists with relevant information such as, cover level change over time, and the ability to compare the area of interest against the regional average, or benchmark, for that land type. Such information can help to demonstrate appropriate management practices that justify meeting rangeland friendly market requirements, to obtain funding through bank loans or government grants, and to provide spatial and temporal context to identify when and where landscape change has occurred.

The software has many practical spatial data management capabilities that pastoralists can employ such as measuring distances, obtaining GPS locations for infrastructure planning, drawing polygons that denote areas such as paddocks, calculating the perimeter and area of these polygons, and linking ground site photos to mapped locations for easy viewing. The software is also capable of handling any raster or vector data (correctly formatted), and a number of data products were developed and provided to pastoralists for use via the VegMachine© software including the following.

- A single year image signifying cover level, cover type and structure (eg Downs or Mulga country) and indicating to pastoralists the levels of utilisation and extent of area grazed or unaffected (patch grazing). This provides an easy way for pastoralists to keep a record of grazing activity, woody thickening, scalding etc.
- A colour coded two-date cover change image indicating the change in cover from one year to the next. Pastoralists can use this information to identify or verify grazing habits, monitor the pasture response to a management decision such as spelling, assess response to fire, and identify areas that may require further monitoring.
- A colour coded multi-date cover trend image for three or more years that indicates both level (high, low, average) and trend (positive, steady negative) in cover over the time period analysed. This assists pastoralists to identify long term cover trends such as the extent of areas with consistently low cover, and distance from water that cattle consistently graze to.

The beneficiaries of the project were pastoralists, government agencies, non government support groups and industry representative bodies. The project was designed to benefit pastoralists primarily and this was achieved through training, provision of relevant satellite data products, and provision of an easy to use software platform by which to access and utilise the information.

Government agencies benefit from the increased ability to efficiently and effectively monitor large areas of productive pastoral country. A further benefit is the software and data available allow both government officers and pastoralists to discuss property matters using a common data source and frame of reference.

Non government and industry representative bodies benefit from the greater gains towards encouraging economically and ecologically sustainable production. VegMachine© and the information available through it will support extension officers to assist pastoralists with, for example, best management practice, funding applications, or addressing environmental or production issues.

To ensure the continuation of VegMachine it will be necessary to find a long-term advocate for the software and ensure the development of an extension model, either through NRM bodies or a larger agency that supports the development of data products and provides a support framework for users.

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1 Background

To understand and communicate both the impacts of grazing and opportunities for improved management, information on where and when vegetation has changed is critical. In recent years, time series Landsat imagery has been processed to provide spatially detailed rangeland monitoring information for institutional programs (Karfs 2000). In combination with pastoralists own knowledge of seasons and management decisions, this technology can provide a powerful tool to inform management and sustainability questions. A growing number of pastoralists in Australian rangelands are requesting objective information on vegetation change and condition to assist in property management. It is now accepted that this information cannot be supplied from ground-based rangeland monitoring systems alone and that the integration of satellite-based systems is required (e.g. Holm 2000). Remote sensing is the only tool that can view an entire paddock or property and which can compare conditions from one time to another. This research proposal sought MLA funding to develop a practical software toolbox i.e. 'VegMachine' for interrogating time-series satellite data and to provide support in the use of this monitoring information at enterprise and regional levels.

The VegMachine project was built upon R&D conducted in north Australian rangelands (Wallace & Thomas 1999; Karfs *et al.* 2000). Its initial focus was in the Victoria River District where collaboration with management trials by a major pastoral company, produced a unique opportunity for incorporating satellite-based monitoring information into enterprise level decision-making. VegMachine also implemented extension in other regions including Queensland (Qld) and Western Australia (WA), demonstrating ability for widespread adoption by the pastoral industry and facilitating the use of comparable satellite-monitoring methods, where land managers have expressed a keen interest in obtaining land condition information.

Development of the VegMachine software toolbox for the first time allowed non-technical users the ability to display, interrogate and summarise satellite-monitoring data for tailored applications. Support of VegMachine to landholders and State agencies was resourced through a dedicated extension/research officer in each region. MLA funding ensured that satellite-based information products were both timely and relevant to land managers for increasing efficiencies of sustainable pastoral enterprises.

2 Project Objectives

1. Provide pastoralists with the VegMachine software package so that remote sensing pasture condition information can be used in grazing management representing various biophysical environments and beef operations.

2. Ensure that pastoral properties in the VRD and southwest Qld can use VegMachine to benefit from the application of satellite-based monitoring products for pastoral land management.

3. Develop a land condition monitoring program in southwest Qld, based on time-series Landsat data and ground data related to landscape function.

3 Methodology

3.1 Software Development

CSIRO had developed a prototype version of the VegMachine software using seed funding from the Ord Bonaparte Project. Satellite images and monitoring products, delivered as 'image-maps' or time traces, are visual and have high communication values. The aims were to produce a package which would allow pastoralists to view and interrogate this new specially-prepared monitoring data on-property. It was essential that the software be easy to use. Software development was concentrated in the first year of the project, and was carried out in several iterations with testing and feedback from producers and agency staff. Producers' trialled earlier versions of the software on their properties and provided feedback to the development team for incorporation in either the final version of the software or in customised data products that accompany the software. A formal review of progress, including local pastoralists, was held at Quilpie in April 2004, where the design and functionality of the software was approved as suitable to support the full extension program. The final version of the VegMachine software was completed in December 2004.

3.2 Project Promotion, Recruitment, and Producer Training

The project has included a substantial promotion component with the primary aim of attracting pastoralist recruits within the respective study areas (Figure 1). This type of promotion was achieved, particularly in the early stages of the project through articles and presentations in a number of professional, industry and community forums and publications. Later in the project some recruitment was generated through word of mouth from pastoralists already involved with VegMachine. As the project progressed our promotions focussed more on raising the awareness of the scientific and broader community about the project, again through a range of publications and presentations (Appendix 1).

The bulk of the extension work in VegMachine was one-on-one interaction with pastoralists on their properties, with each receiving an average of five visits from extension staff, plus phone support. The primary training for all pastoralists occurred in the first property visit by a VegMachine extension officer. This involved showing pastoralists how the VegMachine software operates as well as introducing pastoralists to the products and associated data developed for their property. A training manual was also produced to aid pastoralists when using VegMachine alone. The following visits to properties were used as further opportunities for training regarding the software, its application to management, delivery of an expanded range of products customised to individual enterprises, and feedback regarding software and products. The size and extent of this extension process provided a valuable opportunity to document the outcomes of producer training, and suggest optimal approaches for future extension programs.

VegMachine project officers were responsible for training pastoralists, both in use of the software, and in the interpretation of the monitoring products. They were also responsible for preparation of satellite imagery and monitoring products for participating properties. At the start of the project, the NT personnel (Karfs, Peel), as partners with CSIRO in the preceding R&D, were experienced in all aspects of the image processing, while the Qld team required training in this area. This provided a valuable opportunity for the Project to test and demonstrate the 'transferability' of expertise to a new

region and agency. The Qld team (Beutel, Bull) quickly developed the required expertise and experience in the background processing, and in use of the VegMachine software.

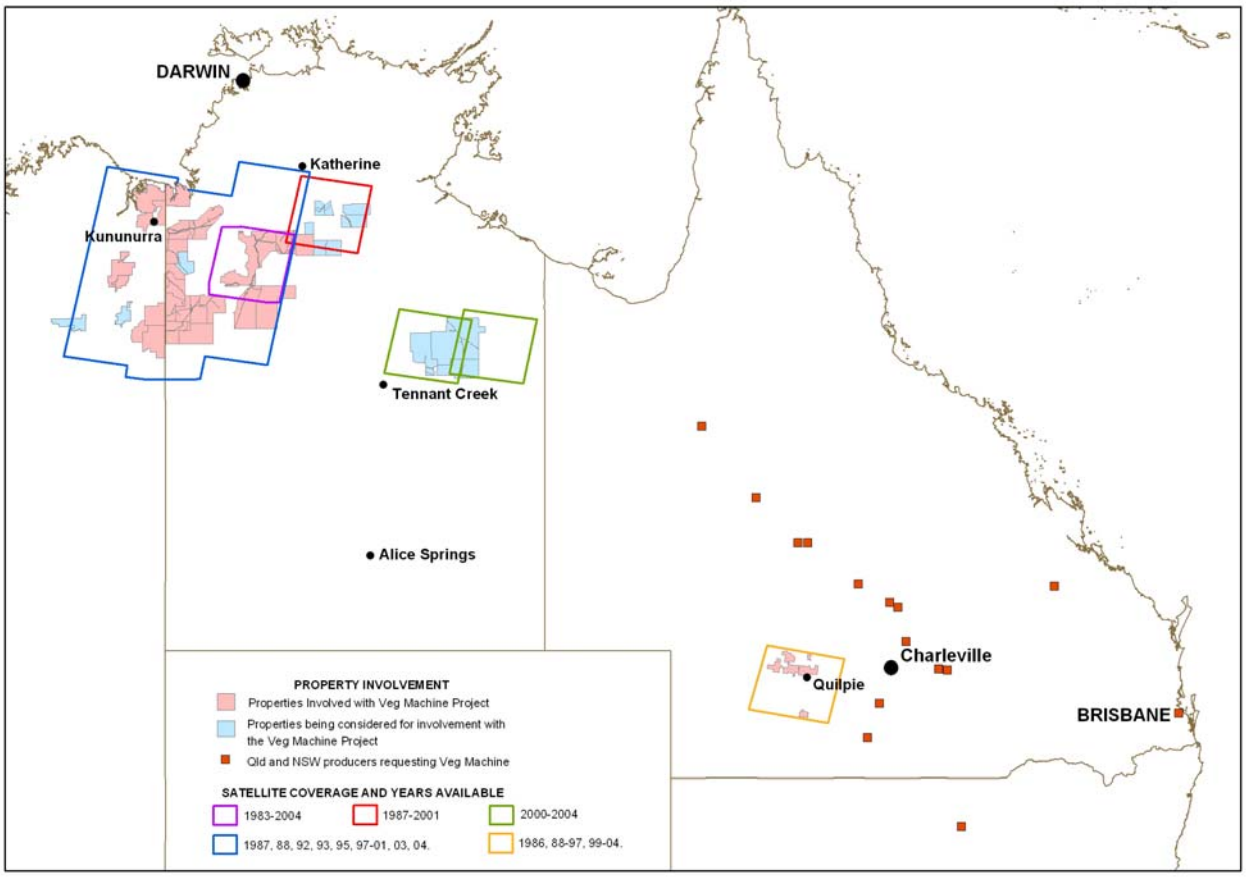

Figure 1: Map of Northern Australia depicting satellite data coverage and properties engaged.

3.3 Product Validation and Development

3.3.1 Cover indices

One of the key components of the VegMachine monitoring system is the set of digital products provided for use within the software. The primary data product is the cover index data, which allows estimation of ground cover at any point of the property and at any time in the time series. At the start of the project, the Northern Territory (NT) team had already established and validated cover indices for their region through previous work (Karfs *et al.* 2000; Karfs 2002). Cover indices for much of the NT/WA area of the project had already been developed and tested for a range of pastorally significant land types. Further testing and validation continued using established monitoring sites as part of the NRETA's pastoral monitoring (Tier 1 and 2) programs (Pastoral Branch 1993, Lynch & Karfs 2001).

By contrast, the Qld operation was required to establish a monitoring system including both ground monitoring sites that would allow the testing and validation of several cover indices. The methods employed in the development and validation of the Qld indices is discussed below.

Cover index development began with the acquisition of a long-term series of 16 Landsat TM images (1986-2004) of the Quilpie scene from the Climate Impacts and Natural Resource Systems (CINRS) group with Queensland's Department of Natural Resources Mines and Water. These images cover approximately 32 000km^2, and span two wet/drought cycles.

Soon after commencement of the project the CINRS group agreed to provide the VegMachine team with CINRS woody and ground cover indices, beginning with the 2004 data rollout. This agreement allowed pastoralists access to CINRS cover indices at limited cost to the VegMachine project. Though still experimental, the indices had been tested extensively across large parts of Qld (Armston *et al.* 2004). These indices became the base product for the remainder of the project. We assessed the accuracy of these indices plus Landsat TM band 3 that we extracted directly from the TM imagery, by comparing index values with on ground measurements at monitoring sites.

A network of forty monitoring sites were established and measured on five of the Qld properties in August/September 2004. Those forty sites were remeasured in August/September 2005 along with seven additional sites on the two most recently recruited properties. The placement of sites was based on several criteria.

Ground measurements on these sites included 250 point intercept records to assess vegetation and ground cover, two 50 metre LFA transects to assess ecosystem function and four photographs for visual records. A full account of the Qld monitoring system and the results it has produced is provided in Appendix 2.

3.3.2 Other data products

A range of satellite data products were developed on the basis of previous research, using appropriate cover indices. VegMachine officers also developed additional data products based on specific requests from pastoralists. Other non-satellite digital data products were also incorporated to the product list, such as the pastoral infrastructure map, topographic map with a plan to also add ground water capability, fire and weed mapping in the near future. A full list of the data products provided to participants is provided in Table 1.

3.4 Pastoralist Feedback

Significant project resources were invested to obtain pastoralist feedback on and involvement in the VegMachine project. Pastoralist feedback was sought through a number of forums including formal meetings, surveys via either phone or personal interview, and through one-on-one discussions during property visits.

Initial meetings between the project team and key pastoralists were held at Moolooloo in the Victoria River District in July 2003, and at Quilpie in April 2004. These meetings addressed a number of objectives, but included opportunities for pastoralists and project team members to discuss;

- general project directions;
- promotion and recruitment;

- software development; and
- data product development.

Table 1: Data products provided in the VegMachine project.

Product	**Purpose**
.bil file	Raster cover index data for extraction of long term cover.
Averages file	Text file showing average cover index value in each year and each land system across district. Can incorporate any annual data (rainfall, stocking rate)
Paddock file	.svg file for display of internal and external property boundaries.
Land systems file	.svg file for display of land system / land type boundaries.
Field sites file	.svg file for display of location and boundary of monitoring sites
Water points file	.svg file for display of water point locations.
Property grid file	.svg file for display of 100km^2 grid.
True colour image	.ecw Landsat TM raster image presented in approximately true colour for display and navigation purposes.
Panchromatic image	.ecw high resolution (12.5m) black and white raster image for display and navigation purposes.
Elevation image	.ecw raster topography image from Shuttle Radar Topography Mission (SRTM).
Multi date cover change image	.ecw raster image in six colours depicting amount and trend in cover. Can be developed for varying periods of at least two dates, and for any cover index.
Annual difference images	.ecw raster image in three colours depicting change in cover. Can be developed for any two dates, and for any cover index.
Pastoral infrastructure image	.ecw raster image of the pastoral infrastructure map product with infrastructure, tenure boundaries, drainage, monitoring sites etc
Digital topographic image	.ecw raster image of the Auslig Topographic map series at the best available scale
Mesquite file (one property only)	.svg file for display of Mesquite (*Prosopsis velutina*) extent on one participating VegMachine property.
Bore drains file (one property only)	.svg file for display of bore drains on one participating VegMachine property.

Feedback from NT/WA, and Qld participants were collected in a survey (Appendix 3) during April and May 2005. The survey aimed to provide an insight into what pastoralists expected VegMachine to offer, how they have communicated about VegMachine, how VegMachine was used on property, if VegMachine software and data products have been working and the future plans pastoralists have for VegMachine. The NT/WA survey was completed during property visits and the Qld survey by telephone.

A second survey (Appendix 4) was conducted in April and May of 2006 to collect final feedback from participating pastoralists. This survey revisited many of the issues targeted in the first survey, but also focussed on future directions for this type of monitoring system, the latter issue being particularly relevant given the impending close of the project and the experience developed by the pastoralists over the life of the project. This survey was conducted by phone in the NT/WA region

and at a pastoralist meeting in Quilpie for the Qld participants. A total of thirteen and six properties were represented from the NT/WA, and Qld respectively in this survey.

Data from both surveys were compiled and analysed for any strong themes in the feedback. This feedback was summarised in internal reports. Reports were also provided to pastoralists, to ensure that they had an opportunity to comment on interpretation of their feedback.

Finally a great deal of informal feedback was provided by pastoralists during property visits. These visits generally included time spent by VegMachine staff and pastoralists using the software and data products together and often prompted pastoralists to offer opinions and experiences that helped the team to develop the software and data products. Feedback recorded during these discussions was noted and formed part of the final body of feedback on the project.

4 Results and Discussion

4.1 Software Development

Core functions of the final version of the software are the display of maps and satellite derived land cover change products (see 3.3.2) with the capacity to zoom, roam and to overlay vector files. In addition, images can be queried to produce graphs of vegetation cover trends over time for selected points or areas of interest. These graphs identify the timing and magnitude of vegetation changes in terms of the cover index. Comparisons of paddock or site trends with regional or reference-site trends can be displayed on the graph, and can be automatically transferred to a Microsoft Excel spreadsheet.

A split-screen ‘geolinked’ format was chosen to enable comparison of two images simultaneously or a map and graph simultaneously. Monitoring site locations can be overlaid on maps, and associated photographs linked to these locations and viewed in ‘pop-up’ windows. Other interactive tools assist with measurement (linear and area), GPS location on image display, drawing or planning infrastructure, and saving VegMachine projects to allow pastoralists to return to a project in progress with ease. Local users or other data providers can easily add photos, vectors and images (in supported formats) to the existing data and products.

The software development goals set for this project have been met. Pastoralist feedback (see 4.4) about the functionality of the software has been positive, and the software has performed relatively robustly on a range of personal computers. It should be noted though that if the software is to be used beyond this project, especially if it is to be used widely, further resources will be needed to bring it to, and maintain it at, a commercial standard. Feedback from project participants revealed a range of both necessary and desirable improvements that should be made to the software, and a full account of these is given in section 4.4. However, the most common feedback themes regarding software improvement suggest that as a minimum, such changes would include the following.

- Fix a number of known bugs which have intermittently affected VegMachine’s use in the current project, such as vector display and compatibility with other software.
- Ensure compatibility with future developments in hardware and other software, such as newer versions of the windows operating system.
- Develop the software in directions specified by clients, such as; capacity to print maps, and increased functionality and integration.

4.2 Project Promotion, Recruitment and Producer Training

Perhaps the most interesting outcome of the promotional work was the number of scientific and extension agencies interested in either providing, informing or facilitating the rollout of the software in other areas. These organisations have a vested interest in engaging pastoralists in natural resource management, and through their enquiries demonstrated a level of belief that the VegMachine software had relevance to relatively large numbers of land managers. Most notable among these agencies have been the following.

- Agforward, a joint initiative of Agforce and the Queensland Government.
- The Walgett Sustainable Agriculture Group, a non profit company group representing 25 grazing and cropping enterprises in New South Wales.
- The Australian Institute of Agricultural Science and Technology through its journal Agricultural Science.
- The Centre for Environmental Management (Central Queensland University).
- The Kondinin Group.
- CALM WA to use in the Gascoigne-Murchison region for rangeland monitoring.
- AgWA and CALM initiative to expand use into three other regions in WA.
- NT GLM officer evaluating use and integration of VegMachine to compliment the current training course.
- GHD Perth enquiry to the possibilities of use for Natural Resource Management (NRM) purposes in the SW of WA.

Promotional work also generated substantial pastoralist interest in VegMachine, as evidenced by numerous enquiries about the software's availability. Promotional efforts including presentations and published articles (Appendix 1) helped recruit 33 properties (27 in NT/WA and six in Qld) to the project. These properties cover approximately 78 000 and 3 500 km^2 in the NT/WA and Qld study areas respectively, and have all received the VegMachine software, customised data products and training from VegMachine extension staff. A substantial number of pastoralists also requested access to the project from outside the study areas. In these cases, they were added to the project mailing list, and received updates on the progress of the project.

VegMachine encourages pastoralist recruitment through a number of channels. The visual and interactive nature of VegMachine, lends it to a recruiting environment where potential clients can personally view and operate the software, hence field days, workshops, industry support groups and training courses are excellent avenues to recruit pastoralists. At the local scale, newsletters and industry media can also facilitate recruitment. At broader scales, future recruitment would be enhanced by integration with other programs, such as pastoral reporting or monitoring and Grazing Land Management courses.

Training pastoralists to use the software proved relatively easy for extension staff. Generally speaking, we have found that a pastoralist can be trained in one to two hours to operate the software with reasonable proficiency, although more time was generally provided to allow pastoralists to practice with real life examples of what VegMachine can provide. Extension staff gained a number of important insights into the training experience from their activities. These reinforce and/or improve the quality of the training. These include;

- allowing pastoralists to perform all operations rather than being shown;

- having more than one member of the family (or management group) present. This increases ownership and discussion, and support on property;
- asking pastoralists to select areas of interest to target first as case examples of how VegMachine can be applied to assist their management; and
- reminding pastoralists the tutorial provides examples and useful hints as to how VegMachine can be applied.

While training was largely completed on initial property visits, repeat visits were excellent opportunities for refresher training. The provision of new data on these occasions provided an opportunity to put the participating pastoralist back in the driver's seat to access more recent satellite data, and the extension officer could refresh any rusty knowledge about using VegMachine.

4.3 Product Validation and Development

4.3.1 Cover indices

The basis of satellite data product development and validation for VegMachine was accomplished through research and development conducted in north Australian rangelands (see Wallace & Thomas 1999; Karfs *et al.* 2000). Results indicated Landsat TM band 3 (MSS band 2) to be suitable for providing cover indices relevant to the management of pastorally important land types in the wet/dry tropics.

Appendix 2 summarises the methods and results of the Qld monitoring work. While these data are based on only two years of sampling to date, and there is clearly a need for further monitoring, they allow a number of conclusions to be drawn, including the following.

- Our work demonstrated that Landsat TM band 3 is an effective ground cover index across large areas of the region, in particular the red and grey soil land types, which account for approximately 80% of the Quilpie Landsat scene area. Similarly, the CINRS tree cover index was a useful index of woody plant cover across the same areas.
- Landsat TM band 3 also has reasonably good capacity to index woody cover. Future use of this band to index ground cover should therefore be concentrated in areas with minimal woody cover, so that ground cover measurement is not confounded by woody presence.
- Neither Landsat TM band 3, nor the CINRS bare ground index, was well correlated with traditional indices of landscape health, such as grass basal area or landscape function, with the exception that on grey soil land types both indices performed reasonably. Future work will focus on improving these correlations, given the importance of being able to index landscape health with the imagery. One of the insights of the previous research was that changes over time in cover indices can be much more strongly linked with land condition than their values at a particular date. Pastoralists using VegMachine are in a unique position to test and develop these links.

The monitoring work has been an important aspect of this project, and DPI&F will continue the monitoring in this area for at least another two years through the NHT funded *Sustainable Management and Conservation of Grazing Land in Queensland's Rangelands* project. There is a clear need for cover indices that are known to be reliable, and at this point in time the monitoring data is the best option for testing cover indices. However, as long term cover change methods such as those used here are rolled out in new regions, monitoring requirements in those areas may be scaled back compared to that seen here and even more so in NT work. This is because our

understanding of the validity of different indices will accrue with time and progressive use. Ultimately, it may be possible to start a project such as this by using cover indices such as those CINRS produce straight off-the-shelf with substantial confidence that they will behave as planned.

4.3.2 Other data products

A variety of products derived from satellite data and other sources (infrastructure, land resources, topographic etc) were developed to provide pastoralists with a range of management relevant products. This project was able to document the use of such products over time, primarily through feedback from pastoralists, and this is discussed in section 4.4. These monitoring products have been shown to be widely useful, and it is important to note that the scope of other products for VegMachine is limited only by the availability of imagery, or scanned map data. Several broad themes emerged from pastoralists requests.

- Pastoralists regularly requested more frequent imagery updates (e.g. twice per year), particularly for images around the end of the growing season. This would be possible with further Landsat imagery, although the value of such imagery for assessing condition may be questionable, given the capacity for varying ground cover classes to confound ground cover measurement at this time. Research with producers would be needed to establish added value of this imagery.
- Pastoralists were also very interested in capacity to measure biomass. This might be achieved with MODIS imagery which may have some capacity to index within season changes in growth flushes, haying off, utilisation or patch grazing, cover change and possibly biomass. Data are currently available as a free download across the internet or archived data are available for a small cost.
- Pastoralists also regularly requested higher resolution satellite data for finer scale monitoring and mapping needs. For monitoring, time series are required and cost and availability can be prohibitive for use, for example Quickbird data (1m resolution) costs approximately $8000 for a 100km^2 area. Given that in most cases such data are used primarily to document infrastructure locations, and this can be done with a GPS, such costs may be difficult to monitor in many cases, particularly on a regular basis.

In its current form, with an annual timetable for data updates, VegMachine is not software that is likely to be used more than a few times per year, and at this rate of use, skills can be lost. One way to avoid this problem may be to incorporate other NRM and production data derived from or relating to other extension programs, into the catalogue of VegMachine data products. Digital products associated with other NRM activities that might be incorporated into VegMachine upon request, could include some or all of the following;

- fire maps;
- tree/shrub monitoring site maps;
- weeds and feral animal maps;
- water availability maps;
- hydro-geological maps;
- conservation areas maps;
- cultural heritage site maps; and
- threatened species maps.

This model makes VegMachine the viewing platform for a wide range of digital data, and has the triple benefit of making VegMachine more relevant to pastoralists, maintaining pastoralist ability to

use VegMachine, and improving the delivery of other extension programs. The benefits will materialise however only if data are relevant to pastoral operations, so it is important that pastoralists are consulted regarding what they need rather than simply presenting them will all possible data.

4.4 Pastoralist Feedback

Rangeland monitoring has traditionally presented a number of problems for pastoralists, and these have greatly impeded the assessment of resource condition and trend, particularly at the property scale. VegMachine is a unique and efficient attempt to overcome many of these difficulties by providing pastoralists with the resources to assess changes on their land using satellite data in a user friendly format. Pastoralist response from the NT/WA, and Qld have varied, both in the type and amount of feedback provided. The majority of comments have been positive. Pastoralists used the package to address a range of issues on their properties and contributed valuable information for the development of VegMachine, while providing feedback on the effectiveness of the project outputs.

Feedback from pastoralists has been gathered on a range of topics including the performance of VegMachine software, data products, training and what they thought the future directions for VegMachine should be. The results from all three forms of feedback from pastoralists are presented under the following broad sections, pastoralist expectations (4.4.1), VegMachine data products (4.4.2), using the VegMachine software (4.4.3) and future directions (4.4.4).

4.4.1 Pastoralist Expectations

It was important to the VegMachine project that pastoralists' expectations were met. Pastoralists were asked a number of questions to gain an understanding of their expectations to find out if and how these expectations were or were not met.

The majority of pastoralists in the NT/WA had no actual expectations of VegMachine, except the possibility of looking at satellite images on their property and in Qld only 50 per cent of pastoralists had a preconceived idea of what VegMachine should offer. Overall pastoralists felt that VegMachine delivered on their expectations and many agreed that VegMachine offered them a number of real benefits such as; identifying patch grazing, areas consistently grazed, fire affected areas and the resulting vegetation response, identifying land types, infrastructure placement or modifications, and confirming past management decisions and the condition of certain areas based on personal knowledge.

The majority of pastoralists claim that VegMachine has not directly changed the way in which they manage their property, however they all agree that VegMachine is a tool to be used in conjunction with current decision making practices, with one pastoralist commenting that 'there is no substitute to getting out on ground and monitoring'. Before receiving VegMachine on their property the majority of pastoralists made decisions using experience and visual assessment of animal and pasture quality and quantity. Most have said that VegMachine is a great tool adding valuable information to their knowledge and experience (previously relied upon) to formulate management decisions. One of the greatest values pastoralists felt VegMachine offered was a holistic approach to management and access to difficult to reach areas. Pastoralists also remarked that VegMachine allowed them to take the guess work out of management decisions. Mark Tully from Ray Station near Quilpie, Qld was one such pastoralist (pers. comm. 06/05) saying, "…the best thing about VegMachine is that it's

measuring what is happening to the land and I think that that's critical for management … it takes the guess work out of it…".

In terms of support features pastoralists listed one on one interaction, training support and the mapping of their property as the best features provided by VegMachine. Support features that pastoralists felt needed some work included problems with running the software, this involved VegMachine's incompatibility with software such as Microsoft internet and Norton anti-virus. Pastoralists would also like VegMachine to be able to interact with other mapping software to import shape files that they have developed, to be able to download and upload GPS points and they would like to receive more frequent data updates throughout the year, especially during major management decision times (eg March).

Communication by pastoralists to people outside of the business/family group was limited in both NT/WA, and Qld. However the majority of pastoralists have discussed VegMachine within their business/family group and indicated that the discussions were positive and focused on the advantages of using VegMachine.

4.4.2 VegMachine Data Products

To gauge how well VegMachine data products performed for pastoralists and how data products could be improved, pastoralists were asked how often they used VegMachine, how often they would like to use it and which data products they found most useful and why.

Pastoralists' use of VegMachine has varied. Some indicated that they were using VegMachine on a monthly basis and others less frequently such as when new data were available. One pastoralist that had used VegMachine on a more regular basis (every few months) said that they did so out of interest for the software and to see what it could do. When pastoralists were asked how often they would like to use VegMachine the majority indicated that they would like to use it regularly, but particularly at specific management decision times (3 to 4 times/yr) and this would depend on how often new data would be made available. A number of pastoralists said that if they used it on a more regular basis they would remain more familiar with its use and it would make using VegMachine easier.

Throughout the project pastoralists indicated that they identified a number of uses for VegMachine and VegMachine data products and over 50% have used VegMachine for a number of purposes. These uses included;

- to aid in property planning and management decisions or confirm past management practices;
- to plan new or move existing infrastructure (waters and fence lines);
- looking at rainfall trends over time;
- compare cover between different paddocks or long term cover trends;
- for stock management/placement;
- checking distances and areas over their property;
- to identify patch grazing extents and fire affected areas;
- to assist with funding applications;
- to assist with fodder applications; and
- to show the integrity of their property management decisions to outside groups.

Pastoralists felt that VegMachine would be a useful tool when applying for leasehold land renewal and thought that it may also be useful for supplying hard evidence to justify their management practices to outside parties, this is the main reason why the majority of pastoralists joined the project.

Pastoralists also emphasised the features that they liked most about the VegMachine data. These included;

- single year satellite pictures of the property;
- access to data for monitoring to give a better understanding of their property;
- graphs showing seasonal change;
- accurate recording of ground cover, this highlighted that their memories can be hazy;
- access to historical data which produced the long-term cover trends;
- the variety of data that was provided to them, especially the three coloured image comparing each year to the next;
- ability to compare vegetation coverage from year to year;
- the panchromatic image (black and white map) supplied to Qld pastoralists of their property for easier navigation; and
- elevation mapping (Qld).

Further to this, pastoralists listed a number of features that they felt would increase the relevance of the VegMachine data to their management and increase the benefits that they would derive from its use. The main findings included, an increase in the number of images received per year, simplification of the six coloured image, further development of the index value to reflect real on-ground values, improved mapping data (Qld and WA), further testing of pasture and woody cover in Qld and integration of other relevant data sources (a more detailed list can be viewed in Appendix 5).

4.4.3 Using the VegMachine Software

Overall pastoralists' opinion of VegMachine was positive suggesting that the software and data products provided them with relevant information in a format that was easy to understand and use, with minimal training. Further to this pastoralists continued to show competency in using VegMachine during property visits and identified a number of practical uses for VegMachine as outlined in the VegMachine data products section of this report.

Pastoralists have also recommended a number of areas in which improvements could be made to the software package (see Appendix 6) to increase ease of use and maximise user satisfaction. These mainly focused on the function and addition of tools and the running of VegMachine and also a request for training in complementary property management tools.

On average pastoralists received four visits from project staff (some receiving more) and usage of VegMachine unassisted varies from three to 20 hours. The amount of time that pastoralists have used VegMachine is presented in detail in Tables 1 and 2 in Appendix 7. Results also indicated that pastoralists are likely to use VegMachine once a month, but particularly after receiving satellite updates. Pastoralists indicated that there were a number of factors that limited them from using VegMachine as much as they would have liked, these mainly included lack of time, computer problems, motivation and stress due to the current environmental situation (drought) in Qld, lack of confidence in using a computer and inaccurate fencing or land system mapping. Most pastoralists

commented that the training and tutorial were good, and as their confidence grew in using the software, they tended to use VegMachine more often.

4.4.4 Future Directions

Of particular importance to VegMachine is the future directions in which it may develop. To ensure that VegMachine is expanded in a way most useful to pastoralists, participants were asked to comment on their ideas for future use, how they would like to see the Program administered and funded and what changes in their circumstances or to VegMachine would encourage greater use of the software and the generated data products.

All participants in the VegMachine pilot project have expressed their enthusiasm for VegMachine to progress and grow into a tool that will strongly aid their property management decisions. Future uses of VegMachine for NT/WA, and Qld differed to an extent. This was primarily because of the different issues (climatic, political and spatial) that pastoralists face in these regions.

In the NT/WA over 70 per cent of pastoralists propose to use VegMachine to design new infrastructure in relation to land types, cover levels, pasture condition, topography and fitting it all together with the overall property management plan. This is due to some properties having paddocks greater than 200km^2 and in need of new or better placement of waters or fencing to maximise the use of more of their country rather than cattle degrading the more preferred patches of land. Allan Andrews (pers comm. 2005 Auvergne, NT) could see how he could use VegMachine to cover the above points especially after completing a GLM course. To a lesser degree pastoralists will also use VegMachine to monitor pasture condition of areas of concern, monitor grazing habits and effects of management decisions.

In Qld pastoralists plan to use VegMachine to compliment existing property decision making methods. A large number felt that VegMachine would be useful to monitor and justify their management practices to outside parties (including legislative compliance), to track cover change and monitor their property and to apply for grant applications. Pastoralists also felt that VegMachine would be useful for property planning including infrastructure changes and for improved use of land and water resources. A smaller portion of pastoralists planed to use VegMachine for reporting and securing finances. All Pastoralists agreed that they would like VegMachine to operate as a feed budgeting tool, to help them to determine stocking rates and stock placement on their property.

In the final project feedback questionnaire pastoralists commented that they thought VegMachine should be administered by a combination of government, industry, NRM groups and through existing projects, however they do not want to see VegMachine run by a commercial enterprise. Further to this, pastoralists felt that VegMachine should be mostly government financed, with industry or support groups also chipping in. Most pastoralists are prepared to pay a small price (with the majority selecting $1-$150) for the use of VegMachine. They felt that the price they would be willing to pay would depend on what they would be ‘getting back from it’. Some pastoralists felt that it needed more work before they would pay to use it and if payment is required pastoralists felt that some form of technical support would be needed, free of charge.

Following on from this pastoralists felt that to be a viable tool the price of satellite imagery would need to be kept to a minimum, with the majority of pastoralists selecting the $1-$150 category for the price of image updates. Pastoralists are also happy to receive updates via the web or email, as long as the size of files are not too large (restricted to 2MB), to minimise download time. Pastoralists also

felt that it would be good to have a choice of images (small and large file format) so that if they felt that they had more room on their computer or could afford the download time, they would have the opportunity to download the larger and more detailed file.

To make VegMachine more relevant to them, pastoralists felt that climatic and legislative changes such as changes to government reporting processes and also market incentives would make VegMachine more relevant to them. However some felt that market incentives were unlikely to develop an increased need.

Pastoralists also listed a range of features that they would like to be able to use VegMachine for and a number of ideas that they felt would improve the function of VegMachine. These ideas are listed in Appendix 8 under the categories of data products and software. The main improvements suggested included more frequent image updates (especially around March), software updates and operation of VegMachine as a general mapping program, further testing of pasture and woody cover data, use of VegMachine as a feed budgeting tool, improved mapping, access to and integration of ancillary data sets and training in complimentary property management packages.

Feedback from the mid-term and final project survey, property visits and the final pastoralists meeting in Quilpie all indicate that pastoralists are very interested in and value VegMachine as a property management tool. Further to this pastoralists have provided numerous ideas that will increase the capacity of VegMachine and the data products to meet pastoralist's needs. The suggestions listed by participants indicate that for VegMachine to be a successful pastoral management tool it will need to be developed into a multi-functional tool or receive a number of data updates per year to maximise use and maintain interest.

5 Expected benefits and current challenges

5.1 Benefits

The project has produced three major benefits for pastoralists. The primary benefit of this approach to monitoring is that it improves the capacity of individuals to record, monitor and communicate changes in land condition across their properties. As a consequence, pastoralists also benefit through an improved capacity to promote, defend, understand, and where necessary change their management activities on the basis of scientific data. Finally, pastoralists also have an improved capacity to access and interpret spatial data products developed specifically for their properties. These are substantial benefits, especially given the historical disinterest of most pastoralists in resource condition monitoring. Table 2 lists some of the purposes pastoralists have applied VegMachine to in this project, and demonstrates the high level of engagement it has allowed pastoralists with the data products.

Table 2: Recorded examples of how pastoralists are using VegMachine on property in Qld, NT and WA, and the outcomes of their work so far.

Property	Pastoralist's interest	Outcome
1	Understand the historical impacts of stock placement decisions and the validity of recent changes in stock placement.	VegMachine confirmed manager's suspicion that flood-out country has been steadily declining and so supported recent decisions to adjust stock numbers there.
2	Monitor tree and ground cover changes as part of the property's Environmental Management System.	VegMachine has been written into the property EMS to be used annually to monitor changes in tree and ground cover and subsequently guide stocking levels.
3	Place new fences and waters to maximise the potential of each land type and prevent overgrazing of sweeter country.	Single large paddock (150km^2) was split on the basis of land types using VegMachine to determine fence positioning.
4	Test the sustainability of cell grazing on highly productive grassland country after conversion from a single paddock / single water design.	VegMachine analysis of each cell showed that cover levels were maintained despite a productivity increase of 200%.
5	Quickly learn about property layout, and changes in cover after recently acquiring a property.	Manager was able to view property in VegMachine, and quickly appraise healthy and poor areas, distribution of different land types and placement of fence, road and water infrastructure.

5.2 Challenges

Three primary challenges have been identified for the future use of VegMachine. Firstly, the software needs support to maintain its compatibility with ever changing operating systems and other software. Without this support the software will be outmoded in a few short years. A second challenge is the timely and cost effective supply of useful cover data. This issue has presented some challenges to the Qld group, although data provided by the CINRS group helped considerably in meeting this challenge. It remains however a key issue for any future monitoring work beginning in other regions. Finally, there may be some challenges in maintaining pastoralist interest in the software. There is no doubt that some of the popularity of VegMachine among its users stems from its novelty, and given this, interest may wane as novelty declines. We believe that interests can however be maintained by evolving the software and data products to meet the demands of users, and by aligning the software's use with other extension programs and tools.

There has been uncertainty about continuing availability of Landsat-style data in the future. Australia's operational national monitoring programs (AGO NCAS, SLATS) depend on this type of data and have been active with Geoscience Australia in sourcing and evaluating alternatives so that these programs can continue. At this point in time the issue of Landsat data availability does not appear to be a significant threat for VegMachine. Alternative data sources such as the Chinese

CBERS satellites are coming on line. In addition, a recent announcement by the US government has confirmed that the US Landsat program will continue with a new satellite vehicle (Anon 2006).

6 Success in Achieving Objectives

Objective 1: *Provide producers with the VegMachine software package so that remote sensing pasture condition information can be used in grazing management representing various biophysical environments and beef operations.*

Software development was concentrated in the first year, and was carried out in several iterations with testing and feedback from field users. Pastoralists' trialled early versions of the software on their properties and provided feedback to the project officers for incorporation in both the final version of the software and customised data products that accompanied the software. The final version of the VegMachine software was completed in December 2004. At present a total of 33 properties in two different regions (27 in NT/WA and six in Qld) have received the VegMachine software and associated data products customised to their properties and personal training from VegMachine extension staff.

The software and data products give pastoralists the capacity to monitor short and long term cover change, and to relate this to property management and climate. Pastoralists can then make more informed decisions about their management with respect to the current and historical conditions, and assess the results of management change at a scientific and ground level.

Objective 2: *Ensure that pastoral properties in the VRD and southwest Qld can use VegMachine to benefit from the application of satellite-based monitoring products for pastoral land management.*

The project included substantial extension and feedback components aimed at pastoralists. Extension activities allowed us to ensure that pastoralists were adequately trained in the use of the software and data products, while pastoralist feedback was assessed to determine if and how pastoralists were benefiting from their access to VegMachine.

Training occurred mostly through one-on-one work with pastoralists in their homes. On average, VegMachine pastoralists received four visits from extension staff. We found that proficiency could be attained by most pastoralists in less than two hours of training, and refreshed on subsequent visits from extension staff. This ease of training was reflected in pastoralists' feedback about their experiences of the software which suggested most found the software relatively easy to operate.

Pastoralist feedback collected during property visits and surveys has identified a willingness among pastoralists to put the software to a range of uses, demonstrating that pastoralists have recognised the benefits of the system. Requests from pastoralists for a range of additional data products, such as historical aerial photos, to enhance their use of and benefits gained from VegMachine also speaks to the fact that pastoralists have seen the potential of the system.

Objective 3: *Develop a land condition monitoring program in southwest Qld, based on time-series Landsat data and ground data related to landscape function.*

Forty monitoring sites were established and measured across the three major landscape strata of the Quilpie area in August/September 2004. Those sites were remeasured in August 2005 along with an additional seven on the two most recent properties to join the project. Ground measurements were made at each site to record vegetation cover and landscape function on each site. Ground measurements were then correlated with a variety of satellite derived cover indices, to determine the best ground cover index for each landscape stratum, and so ensure the quality of cover data provided to pastoralists. Appendix 2 gives a full account of the results of these monitoring activities to date.

7 Impact on industry now and in five years time

7.1 Current impact on Meat and Livestock Industry

The first of these is that participating pastoralists have clearly taken up the software and the imagery. This was an industry first with pastoralists using the software and products for a variety of purposes on their properties. The ability to target individual parts of the property over a variety of dates has provided capacity beyond standard map products that have been trialled previously.

The second impact is that the project has generated clear industry interest among both the pastoralist and science/extension community. This suggests that there is substantial need and enthusiasm in these communities for access to VegMachine-like technology. It is worth note that this use of and interest in VegMachine has occurred in a political climate where there are still few formal incentives for land mangers to monitor their resource base. Presumably demand for VegMachine would increase if more formal incentives or pressures existed.

7.2 Expected impact on Meat and Livestock Industry

There are a group of converging factors that point to the likely importance of satellite based monitoring in the future.

- Increasing pressures and incentives for pastoralists to account for their impacts and demonstrate their stewardship.
- Historical failure of ground based monitoring to be adopted by land managers.
- Increasing availability and ubiquity of satellite imagery and other resource and property management data.
- Demonstrated capacity for pastoralists to use software like VegMachine.

While all four factors will influence the likely impact of VegMachine in the future, the first – increasing pressures and incentives - will ultimately determine the long term demand for, and impact of, VegMachine. Recent decades have seen significant moves toward regulation in the rangelands, including the area of natural resource management. Similarly, some markets are developing for rangeland products that can demonstrate sustainable production. In all these trends suggest that given sufficient resources, VegMachine has considerable potential to impact positively on industry in the future.

The other and single biggest, determinant VegMachine's impact on industry will be the decision about its continuation. It seems likely that regulatory and market forces will combine with other factors to make this system highly relevant to the NRM practices of pastoralists in the future. Further, the project has shown that pastoralists are willing to grasp this technology even now, and use it for a variety of purposes. However, failure to find a future for this system will ensure it has limited impact on industry in five years. Development plans for VegMachine will need to address a range of issues. These are discussed in the next section.

8 Conclusions and Recommendations

8.1 Conclusions

We have drawn four major conclusions from the work of the VegMachine project, and these conclusions are discussed below (8.1.1). The conclusions broadly indicate the success of the project and as such leave open the question of future options for VegMachine software and monitoring process. These options are addressed in section 8.1.2.

8.1.1 Key Conclusions

The most obvious conclusion that can be drawn from the project is that we have demonstrated the effectiveness of the VegMachine software. The software has been trailed now on 33 properties, and has received strong positive feedback from users. VegMachine's ease of use, capacity to incorporate a wide array of data products, and unique ability to display and interrogate satellite cover indices provides users with a wide variety of benefits regarding natural resource monitoring and management. Users have also identified some limitations in the software, such as compatibility with virus protection software that can be fixed with further resources, but not withstanding these issues , the software has met its goals and demonstrated its value.

A second conclusion is that the monitoring *process* used in the VegMachine project has also demonstrated its merit. This process combines the VegMachine software, data products and people (pastoralists and agency staff) to give pastoralists unprecedented capacity to manage their own monitoring requirements, and in doing so has provided valuable insight on *how* pastoralists apply their new monitoring capacity. VegMachine pastoralists are now more able to demonstrate their stewardship, detect long-term land condition trends, identify opportunities to increase profitability and assess management options for marginal/degraded landscapes. It is important to note though that this is the result of a larger process, not just the availability of software.

This project also demonstrated that the VegMachine extension process could be set up and running in a new region within a year. This was shown through the development of the Qld component of the project, which started with limited history in the area of satellite based monitoring. Clearly, the speed with which a monitoring system can be set up in a new region will depend on numerous factors including data availability, financial resources and personnel. In particular the Qld effort was greatly enhanced by support from its NT partner. However, the transferability of the technology demonstrated in this project suggests that other agencies, such as those which expressed interest in the VegMachine software, could also have or develop the capacity to roll out VegMachine relatively quickly. The technology transfer also suggests that the VegMachine system has substantial potential to establish across large areas if appropriately resourced in the future, producing commensurate benefits for local pastoralists.

Finally, while VegMachine received strong support from pastoralists, it also generated a great deal of interest from pastoralist representative groups, private companies and government agencies throughout Qld, NT, WA and NSW. These parties all showed interest in facilitating on some level the extension of the software to the rangeland management community. We believe that the level of interest seen is a clear indicator of the both the need for this type of monitoring system as well as the confidence that such a process can deliver results, as judged by professionals in the field. To date the VegMachine team has focussed largely on their study areas, with the exception of some demonstrations to professional groups such as AgForward, and extension of the software to a new region of WA (Gascoigne/Murchison). Clearly however, plans need to be put in place if VegMachine is extended widely beyond this project. To not do this is likely to ensure the long term failure of the software and process, and as such, we discuss future options in the next section.

8.1.2 Future Options

A clear theme that has emerged from this project is that the research team, participating pastoralists, and a wide range of other parties have seen considerable potential for VegMachine to deliver NRM outcomes across the industry. Assuming VegMachine is to continue, and is to do so in a more formal program, two critical issues need to be addressed. Firstly, the software needs an advocate. The role of the advocate will be to maintain and update the software, and ensure its long term viability. Secondly the software needs to be embedded in an extension model that allows it to meet its potential. We suggest this model reflect the extension process used successfully in this project. Below we discuss both issues.

To continue successfully, the software needs a committed long-term advocate, such as a industry representative commercial enterprise or government agency, to take ownership and responsibility for developing and maintaining the software. Development and maintenance will be necessary to ensure ongoing compatibility with future operating systems and other peripheral software updates. In the first instance modifications to the current software will also be necessary to bring the software up to commercial standards. These have been discussed in section 4.4. Further data are needed to fully determine the costs, but current estimates are between $200K and $250K for commercial upgrade (viable for approximately 5 years), and ongoing costs (approx $10K/yr) for yearly maintenance and update of the software.

Selection of an advocate for the software will be an important task. Clearly the advocate body would need either capacity to develop and maintain the software, or capacity to fund such work. Ideally though, the advocate should also have capacity to consult with and respond to the needs of industry groups, both pastoralist and extension, to ensure industry needs are met by the evolving software. We suggest that a workshop be conducted to examine alternatives for the selection of an advocate agency or partnership, and more closely outline their role. The workshop should involve a broad cross section of potential advocates and clients, and include the current stakeholders, as well as interested agencies, companies or groups who have indicated interest at various levels such as ER Mapper, Spatial Sciences CRC, Tropical Savannahs CRC, WA Ag, industry and community interest groups and others.

The second important issue for the future of VegMachine is the selection of an extension model for the software, and accompanying monitoring system. There are a variety of potential models – too many to discuss in detail here, however a number of points are worth note.

Broadly we see the extension of VegMachine as being regionally facilitated, either through regional entities like NRM bodies, or larger agencies that can provide regional support such as government departments. NRM issues and conditions will vary regionally, as will the availability of satellite data, appropriate cover indices and their validation, appropriate data products, and opportunities to combine with other extension programs. We think that regional support will be best placed to meet the needs of VegMachine clients in such circumstances, and that a one-size-fits-all global extension model faces greater risk of missing important regional needs in its delivery

Access to satellite imagery will be a key issue if VegMachine is extended to new regions. Image costs can be greatly reduced by accessing the substantial archives of the AGO, CINRS and similar bodies. Costs can also be reduced through shared acquisition of imagery across a number of projects that include VegMachine extension. In the latter case VegMachine could be used as a platform to display and integrate data from the cooperating project(s), providing a win-win outcome for stakeholders. Coordination across projects and/or agencies to share the cost of new acquisitions will best be formulated at a regional or district levels on a needs and resources basis.

The transfer of the technology to a new region, including the partial validation of cover indices was demonstrated in this project by the work of the Qld team. If cover indices, such as those produced by CINRS are available, technology transfer is accelerated, and we would recommend the adoption of validated indices (with at least some local testing) where available. However, from a zero start, the validation process can take a minimum of three years monitoring and analysis, and is clearly one of the significant challenges facing extension of VegMachine in new regions. In this period however, VegMachine could still be rolled out with a “best bet” index such as Landsat TM band 3. Best bet indices can be quickly identified - they should correlate reasonably well with historical rainfall data, and with grazing pressure across established fence lines and along grazing gradients. If best bet indices are used though, longer term validation should still be undertaken. In all cases, end users need to be made aware of the level of validation behind the cover indices they use, and their feedback on the accuracy of such indices can be a valuable part of the ongoing validation process, since they can often point to locations where an index works poorly or particularly well. To validate indices requires appropriate high level hardware and software costing $15-20K, plus staff for field monitoring and image analysis intermittently for at least three years.

Data products will vary according to regional needs and pastoralist interests. Listed below are the key data required to provide a base range of data products.

- a time series of recent historical satellite data (preferably > 10 years), with standard pre-processing and calibration applied (Karfs *et al.* 2000)
- all available infrastructure data in digital format eg tenure, fences, roads, waters, sites of significance; and
- appropriate digital land resource data (land types, regional ecosystems etc).

Other data that may enhance the value of the monitoring system include;

- monitoring site data, and other sites of relevance – location, photos, data;
- other relevant spatial data specific to region or property – rainfall, fire, weeds, topography;
- management specific information – infrastructure changes, stocking rates or movements, burning regime, supplements; and
- historical aerial photography preceding the satellite time series.

From these datasets a wide range of products can be developed, including all those produced in this study. The products produced should ultimately be determined by regional and property level needs.

Recruitment, delivery and training of pastoralists could be accomplished through a number of models, depending on the needs and resources applicable to the respective regions. However, significant longer term efficiencies can be achieved through two processes - linking VegMachine regionally into existing extension networks, and providing aspects of the data and software online.

Formally linking VegMachine with other regional extension networks such as GLM would significantly reduce costs for providers and increase support to participants. VegMachine would benefit from such a synergy by "piggy-backing" extension resources from cooperating projects, which would impact positively on all aspects of VegMachine from recruitment through delivery and ongoing support. Cooperating programs such as GLM would benefit from access to VegMachine's image and data handling capabilities as well as its demonstrated ability to attract pastoralists', so would also benefit from this synergy.

In 2005 the VegMachine team applied for NHT funding for the VegMachine National proposal that encompasses the broad model we propose for VegMachine's future. Under this model an advocate would develop and maintain the software, providing access to the software, data and updates via either download or CD mailout. Recruitment and training would occur regionally through the GLM program's existing extension network, greatly enhancing VegMachine's accessibility. VegMachine would provide GLM participants with capacity to;

- access property and paddock scale cover history and trend data;
- objectively assess past management (e.g. effect of stocking rate or fire); and
- track land condition changes resulting from GLM applications.

Similarly, GLM providers could use VegMachine to;

- strategically identify area for GLM extension in a region;
- track the impact of GLM training on land condition regionally; and
- engage pastoralists to consider GLM options for improving land condition, by interrogating historical remotely sensed data of their property. Whist the bid was ultimately unsuccessful we think it serves as a useful outline of what VegMachine's future directions could look like.

8.2 Recommendations

VegMachine has demonstrated its value. The software works. The monitoring process that includes the software, data and human elements has generated strong support from users, and high interest among potential clients and providers. Finally, the potential for technology transfer to new regions and agencies has been demonstrated. On the strength of these outcomes we make this single recommendation.

> ***MLA should support continuation and expansion of the VegMachine model.*** *This support should be targeted at regional implementation, so that access for pastoralists occurs via agencies or regional NRM bodies which are prepared to co-invest in human expertise and dedicated data for their region*.

Meeting this recommendation will require;

(a) Investment in software via an advocate body which provides a home for software including update and maintenance for a five year timeframe. This is a critical step in realising VegMachine's wider potential benefits, since confidence in the ongoing functionality of the software is a key to wider adoption. Funding partnerships are possible, but the cost is not great (~$200-250K). Web-capable versions should be considered along with some improved functionality.
(b) Maintenance and support of human expertise in targeted regions, again on the basis of industry needs and the capacity of support agencies. MLA support could range from lobbying and publicity, to full employment of dedicated personnel. In many receptive 'lead regions', NRM or agencies are likely to provide at least matching support, as has been seen in the current project.

Under this recommendation, data acquisition would be the responsibility of regional providers. Nationally, Landsat data availability has increased, and cost reduced, through national and regional datasets such as those in AGO, NCAS and CINRS. From this point forward, interested regions, agencies and pastoralist groups could be expected to cover their data costs, which would be significantly reduced through access to the above data.

By ensuring the continuity of the software and expertise in lead regions, MLA can provide a lead based on the experiences of this project, and the needs of its constituents. We believe that this single action can ensure the broad uptake of the VegMachine technology by pastoralists, and generate a wide range of benefits for industry and the wider community.

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See appendix 1 below for publications and communications arising from the project.

Appendices

Appendix 1 Publications and Communications Arising from Project

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Appendix 2 VegMachine Monitoring Report 2004 – 2005

VegMachine monitoring report 2004-2005

TS Beutel and AL Bull

This document outlines field monitoring undertaken for the VegMachine project in south west Queensland during August/September of 2004 and 2005. The work examined the relationship between satellite derived indices of land cover, and coincident ground measurements of landscape cover and health. The aim of the work was to identify indices that best indexed land cover and/or landscape health, so that VegMachine participants could be provided with optimal cover data.

Field measurements

The monitoring system was developed progressively over the two years of sampling. In 2004, sites were distributed across the four properties participating in VegMachine at the time of the field work, so that about 10 sites were placed on each property. Approximately 100 sites were inspected prior to commencement of field work, and final selections were made on the basis of the following criteria;

- that two land types, grey and red soils[1] were sampled approximately equally;
- that sampling in each land type captured as wide a range of land condition as possible;
- that sites of particular interest to landholders were surveyed; and
- that sites were relatively homogeneous in terms of soil and vegetation, and no closer than 100m to a fence to avoid the impacts of stock aggregation.

In 2005, the above 40 sites plus an additional seven sites were measured. Four of these were selected to provide better coverage of the gidgee land system group, which up to that point was represented by only six sites, while another three were measured in areas of particular interest to landholders on the newest properties to join the project.

We selected the period of mid August to late September as the optimal period for coincident field measurement and satellite image acquisition. In the Quilpie area this period has very low average rainfall, limited cloud cover, and generally the lowest levels of ground cover, making bare ground more visible in the satellite image (Beutel 2004). Field measurements for 2004 were made at the 40 sites between the 23rd of August 2004 and the 12th of September 2004. The repeat measurements of these sites as well as the initial measurements of the seven new sites for 2005, were made between the 27th of August and the 9th of September 2005.

2004 and 2005 field measurements were compared with cover indices derived from Landsat 5 TM images acquired on the 19th of August 2004 and the 23rd of September 2005 respectively.

Once sites were selected, three major activities occurred on each site to acquire the field data; site establishment, estimation of ground and vegetation cover and Landscape Function Analysis (LFA). These are all outlined below.

[1] Regional Ecosystems 6.3 and 6.9 were assigned to the grey soil stratum and Regional Ecosystems 6.5, 6.6 and 6.7 to the red soil stratum.

Site establishment

An approximate centre point was selected for the site, and a dumpy level placed on this point. The surrounding area out to a radius of 70m was then surveyed to establish the direction of the local slope.

During this survey, which took approximately 15 minutes, a GPS was placed nearby to establish an averaged Easting and Northing for that point. From this averaged point, the centre of the site was identified as the nearest point at the corner of four image pixels (GDA94 MGA55 Eastings and Northing values ending in 12.5, 37.5, 62.5 or 87.5m). This ensured, as far as possible, that ground measurements and a set of 4x4 25m pixels in the Landsat TM data shared a common centre for the analysis.

From the centre of the site four steel pickets were placed in an 80m square as per Attachment 1. Photos were taken from each corner facing toward the centre of the site, focussing the camera at the ground 10m from the corner post.

Cover estimation

Cover estimates for a variety of biotic and abiotic features were recorded at each site. We used the point intercept method, collecting from 250 points at each site. One observer moved around the site (Attachment 1) with a tripod mounted, down pointing laser. Ground cover, under-storey, and mid-storey intercepted by the laser were recorded as strikes in each of these strata, as were any mid-storey or over-storey intercepts assessed using a densiometer (Johansson 1985).

Landscape function analysis

Landscape function transects (50m) were established on the two edges of the site aligned to local slope (Attachment 1). We recorded a transect log for each transect to identify patch and interpatch zones, and soil surface analysis. Data were collected, and LFA indices calculated as per Tongway and Hindley (1995).

Analyses

The analyses in this work are simple bivariate correlations, each between a satellite index and a ground measurement. This simple approach stems from the simple aim of the survey, namely to understand the capacity of different satellite indices, to index aspects of landscape cover/health. In all cases we assessed both the linear and two term polynomial correlation of the satellite index with the ground measurement, although in no case did the two term polynomial significantly improve on the linear predictor. Satellite indices were compared in terms of the significance of their correlation with ground measurements.

Landscape strata

Because soil and vegetation colour impacts on reflectance values, we stratified analyses by land type. Up to the point of the 2004 survey, we had recognised only two land types, namely grey soils and red soils. These strata were based on regional ecosystem mapping (EPA 2005) with zones 6.5, 6.6 and 6.7 (sand plains, dunefields and ironstone jump-ups respectively) classed as red soil sites and generally sharing mulga as a major component of their vegetation. The grey soil land type is an amalgamation of land zones 6.3 (alluvia) and 6.9 (undulating country on sedimentary rocks), the latter of which are dominated by gidgee (*Acacia cambagei*) on various coloured soils.

During preliminary analyses of the 2004 data it became clear that land zones 6.3 and 6.9 have very different reflectance characteristics, and our that plan to lump these two groups was flawed. We thus adopted a three level stratification in the analyses, red soils (6.5, 6.6, 6.7), grey soils (6.3) and gidgee soils (6.9). A consequence of this decision was that gidgee sites were poorly represented in the 2004 sampling, with only six sites sampled. This was partially rectified during the 2005 sampling, when an additional four sites were added to the suite of gidgee sites.

The satellite indices

Three cover indices were tested in this work, and all were derived from Landsat TM imagery. All preparatory processing, including registration and rectification were performed by Department of Natural Resources Mines and Water (NRMW) staff in the Climate Impacts and Natural Resource Systems (CINRS) group. The indices used and the rationale for their inclusion is as follows.

- *TM3* is the red band (band 3) in the Landsat TM imagery, and indicates quantity of red light reflected back into space from the land surface. Following preliminary testing and discussions with project stakeholders we initially used this index as the foundation cover index in VegMachine data products in the Quilpie area. TM3 is an inverse index of cover, and for the purposes of VegMachine we inverted the index (255-TM3) so it had a direct relationship with cover.
- *GC* refers to the inverted bare ground cover index (100-index value) developed by the CINRS group. It was derived from multiple regression analysis of Landsat TM imagery, to model the combined percent cover of bare ground and rocks. CINRS currently view this product as under development, though it has been tested across a wide range of conditions and performed relatively well. CINRS prouce a number of different versions of the index (M Byrne, pers. comm. 2005), and the version used in this work is denoted by the file identifier bi0m5.
- *WC* refers to the tree and shrub (woody) cover index developed by NRMW's State Land and Tree Study (SLATS) group (Armston *et al.* 2004). It was derived by multiple regression analysis of Landsat TM imagery to model the percent projected cover of trees and shrubs. Like the *GC* index, this index has been tested across a large proportion of the state and performed well. The version used in our work is denoted by the file identifier bc2m5. CINRS provide a mask for their WC index that allows better identification of pixels with 0 true woody cover, by masking some of the seasonal fluctuations in non woody ground cover. Our mask was did not however cover sites near the edge of the scene. Consequently we made a decision to analyse all data using unmasked woody cover data. This decision is discussed later.

The ground measurements

Field measurements documented numerous potential covariates of the above cover indices. The focus of this report however is on variables relating directly to landscape cover and/or landscape health. As such a reduced suite of ground measurements were correlated with satellite cover indices. These variables, and a rationale for their inclusion are provided below.

- *Bare ground (Bare)* is the combined proportion of point intercepts on bare ground, fine gravel and rocks. Bare ground is the primary target of the *TM3* and *GC* indices, and in theory is negatively correlated with rangeland health.
- *Woody foliage projected cover (WFPC)* is the combined proportion of point intercepts on living woody plant leaves and branches in the mid and over storey. Woody cover is the primary target of the *WC* index. Woody cover is inversely correlated with productivity in this region, though its relationship with landscape health is more ambiguous. It is however a

variable of great interest to VegMachine pastoralists, and is a potentially important covariant of other cover variables.

- *Patch per 10 metres (P10)* and *patch area (PA).* These indices are derived from LFA transect measurements, and are related to the size and abundance of resource holding patches on sites. *P10* denotes the number of patches intersected by LFA transects. *PA* denotes the total area along transects within such patches. Both indices should be directly correlated with landscape health.
- *Grass basal area (GBA*). This is an index of the basal cover of perennial grasses. It is measured by the proportion of laser intercepts on perennial grass bases, and is directly correlated with better land condition in this area (Christie 1978).

Results

Below are the results of our analyses. We addressed three specific questions,

1. what is the best index of bare ground;
2. what is the best index of landscape health; and
3. what is the best index of woody vegetation cover?

For questions one and two we compared the performance of two satellite indices, *TM3* and *GC*. For question three, we compared the performance of *TM3* and *WC.* Analyses were conducted in each of the three land types, namely;

- red soils;
- grey soils; and
- gidgee soils.

Analyses were also conducted separately for 2004 and 2005 monitoring.

What is the best index of bare ground?

Both GC and *TM3* were tested as predictors of *Bare* (Table 1). While both indices correlated significantly with *BG* in most cases. It is worth note however that TM3 was very significantly correlated with *BG* in five of the six analyses for that index and in those five cases correlated more closely with *Bare* than *BG*. The single case where *BG* outperformed *TM3* occurred in the 2004 analysis in the gidgee stratum, for which there were only six observations.

Stratum	Year	n	*TM3*	*GC*
Red	2004	17	.37**	.36**
	2005	17	.49**	.03
Grey	2004	17	.52**	.25*
	2005	20	.34**	.21*
Gidgee	2004	6	.05	.76**
	2005	10	.53**	.00

Table 1. Correlation of *TM3* and *GC* with *Bare* across red soil, grey soil and gidgee sites in the Quilpie area. Significance of the provided r^2 values is indicated (*p<.05, **p<.01).

What is the best index of landscape health?

Several conclusions can be drawn from these analyses (Table 2). Firstly, neither index showed capacity to index grass basal area in any land system group. Secondly, of the three land systems, it appears that it is only in the grey soil land type that there were significant correlations between either of the satellite derived indices and the patchiness indices. Thirdly, the performance of these two indices the grey soil land types is too similar to draw any firm conclusions as to which is the better index of landscape health.

Table 2. Correlation of *TM3* and *GC* with four ground measurements of landscape health across red soil, grey soil and gidgee sites in the Quilpie area. Significance of the provided r^2 values is indicated (*p<.05, **p<.01).

Ground measurement	Stratum	Year	n	*TM3*	*GC*
GBA	Red	2004	17	.02	.00
		2005	17	.00	.27
	Grey	2004	17	.05	.14
		2005	20	.11	.06
	Gidgee	2004	6	.00	.06
		2005	10	.00	.12
P10	Red	2004	17	.09	.00
		2005	17	.00	.04
	Grey	2004	17	.52**	.24*
		2005	20	.44**	.31**
	Gidgee	2004	6	.37	.17
		2005	10	.05	.07
PA	Red	2004	17	.03	.00
		2005	17	.04	.03
	Grey	2004	17	.32**	.40**
		2005	20	.40**	.22*
	Gidgee	2004	6	.04	.01
		2005	10	.27	.01

What is the best index of woody cover

Two satellite derived indices of *WFPC* were tested (*TM3* and *WC*). Both *TM3* and *WC* demonstrated reasonable correlation with WFPC in grey and red soil land types, though *WC* the better index, on the basis of its performance in the grey soil land type (Table 3).

Table 3. Correlation of *TM3* and *WC* with *WFPC* across across red soil, grey soil and gidgee sites in the Quilpie area. Significance of the provided r^2 values is indicated (*p<.05, **p<.01).

Stratum	Year	n	*TM3*	*WC*
Red	2004	17	.43**	.28*
	2005	17	.41**	.49**
Grey	2004	17	.08	.31**
	2005	20	.22*	.57**
Gidgee	2004	6	.58*	.12
	2005	10	.27	.19

Both of the satellite derived woody cover indices correlated significantly with WFPC in four of the six correlation analyses, with TM3 failing in both grey and gidgee land systems. By comparison WC failed only in Gidgee land types, suggesting that at least across the dominant land types of the region (red and grey) WC is the more consistently performing index of the two indices exam.

Discussion

This report examined the capacity of several satellite derived indices to index aspects of landscape cover and health in the Quilpie area of south west Queensland, with the goal of identifying preferred cover indices for the ongoing extension of the VegMachine project. While only two years of monitoring data are currently available, these data provide good preliminary indications of which indices work, and in some circumstances, tentative conclusions about which indices work best for a given purpose.

Ground cover indices

In terms of indexing bare ground, the *TM3* index performed relatively well. It performed better than *GC* on red and grey land types in both years, and given the predominance of these land types in the region, accounting for about 80% of the area, the results suggest *TM3* is the better index of ground cover in this area for the purposes of VegMachine. *TM3* should be used as the ground cover index for the VegMachine project over the next year. This said further evaluations are justified. *GC* has performed well in other validations across a wide range of land types, and it is entirely possible that longer term evaluation in Quilpie will prove GC to be the superior cover index.

Land condition indices

Neither *BG* nor *TM3* showed any correlation with grass basal area, and only limited capacity to index the three landscape function measures of patchiness (*P10* and *PA*). Capacity to predict patchiness indices was limited entirely to the grey soil land type, and it is impossible to state conclusively which cover index performed better in these cases.

This finding presents suggests that in at least some land types, the long-term cover change (LCC) is a useful indicator of land condition trend. However it also raises the very pertinent questions of whether the same is possible in all land types, and if so, why it didn't in these analyses? Potential reasons for this selective failure may include inadequacies in the field methods (eg patchiness indices were measured without sufficient precision or do not relate strongly to land condition) and/or

biological conditions in the red and gidgee land types that confound correlations between actual land condition and cover indices.

The connection between ground cover indices and land condition is an important one - the only real reason to monitor ground cover is to understand changes in landscape health. At this point in time we can give no objective explanation for why cover indices only correlated with land condition indices on grey soils. Subjectively we felt that sites on grey soils captured a wider range of land condition (from A to D) compared with perhaps C to D on the red soils, and this may have limited our ability to test the relationships across a sufficiently range of land condition. Whether this, or one or more other factors is the reason will only be answered by further investigation and data, and so this issue will be particularly important in future work.

Woody cover indices
In terms of an index of woody plant coverage, both *WC* and *TM3* demonstrated reasonable to good predictive skill on red and grey land types, though *WC* performed more consistently on grey land types than *TM3*. Neither performed consistently on gidgee land types, though given the more limited coverage of gidgee land types , this may not be a particularly significant shortcoming.

Another point of note is that the good performance of the *WC* index occurred using unmasked index values. CINRS provide a mask for their WC index that allows better identification of pixels with 0 true woody cover, by masking some of the seasonal fluctuations in non woody ground cover. Our mask data however did not cover some sites near the edge of the scene, and so we analysed all sites unmasked so that all sites were similarly processed. Despite this shortcoming in the analysis, *WC* performed marginally better than *TM3* anyway. As such we recommend *WC* as the woody cover index for ongoing VegMachine work in Quilpie.

The better performance of the *WC* index is not surprising given both the amount and quality of work behind the index. The comparison with the *TM3* index did however demonstrate another point of relevance to the future progress of the VegMachine work. *TM3* has substantial capacity to index both woody cover and ground cover. Woody cover therefore confounds the measurement of ground cover with *TM3*. Future data provision through VegMachine may be better served by applying ground cover measurements to areas of limited woody cover only. This is an issue that will receive further consideration in future planning for the project.

Future issues
Future options for the VegMachine project in the Quilpie area are not entirely clear at this point in time. Formally the project finishes on the 30th of June 2006. DPI&F does however have funding available through Desert Channels Queensland's *Sustainable management and conservation of grazing lands in Queensland's rangelands* project, to continue ground and remote monitoring in this and other regions to January 2008. With or without the use of the VegMachine software, this will allow us to continue to supply the Quilpie VegMachine participants with LCC data products, though obviously continued access to the software would greatly enhance this process.

The discussion above has highlighted two issues for the future extension of VegMachine data products. Firstly, more information is needed to determine if and how the ground cover indices can be used to provide useful information about land condition across a wider range of land types. Secondly, ground cover index data will probably perform better if areas of significant woody cover

are screened from the monitoring data. There are at least another two issues that also warrant discussion.

This work has shown that indices are available with quite good capacity to monitor change in ground and woody vegetation cover, and in at least some circumstances, land condition. It should be noted though that though significant, the proportion of variance in cover these indices can explain was often below 50%. This underscores an important point about satellite monitoring – that it is, and for the foreseeable future will probably remain, a reasonably blunt measuring tool. This does not however detract greatly from its value. At this point in time there is no alternative technology that offers both the coverage and economy that satellite derived indices do. Further, though r^2 values as low as 25% provide little value in managing sites of one hectare, they have substantially greater value in understanding change over larger areas and longer periods.

Finally, it must be noted that further evaluation of these indices will greatly enhance the certainty with which we conclude which works best for which purposes. Given the great temporal variance in cover across the Quiplie region, and the similarity in conditions during the two sampling periods, two sampling dates are clearly a very limited data base on which to draw final conclusions. At worst, further monitoring will support the conclusions we have drawn, though there is a substantial chance that further data could suggest better options. Maintenance of the monitoring program through the *Sustainable management and conservation of grazing lands in Queensland's rangelands* project will therefore add value to the monitoring system.

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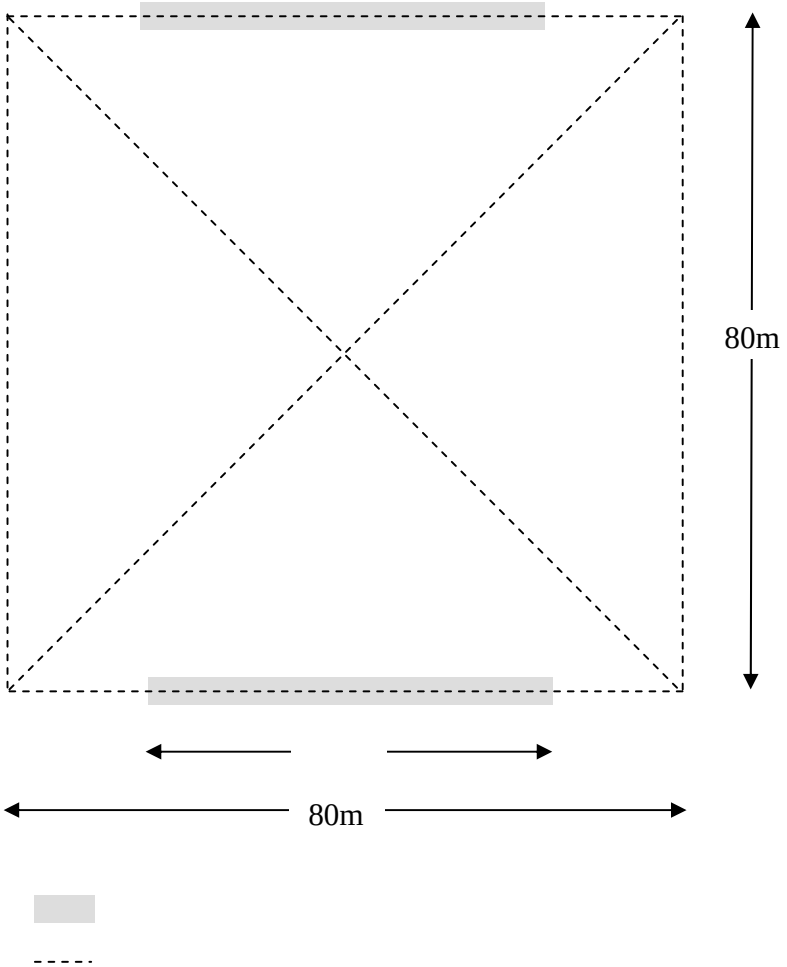
Attachment 1
Field sampling protocol

Sites were established around an 80m square site, with sides aligned along and across the slope. Sites were permanently marked with steel pickets at the corner and centre.

250 intercept points were collected along 546m of cover transect (see figure). Intercepts with a down facing, tripod mounted laser beam, and an upward facing densiometer were recorded in four strata strata; ground, understorey, mid storey and over storey. Intercepts recorded in each layer were as follows, and are not necessarily mutually exclusive.

Ground layer: bare ground, cryptogams, litter, rocks, plant
Understorey: green, dead
Mid storey: dead, green, branch, species, within crown
Over storey: dead, green, branch, species, within crown

Landscape function analysis was conducted on two 50m transects aligned with the slope on the outer edges of the site. We followed Tongway and Hindley's (1995) methods, with the single addition of also assessing perennial grass basal area (PGBA). Along each transect, the proportion of the LFA tape intercepted by perennial grass bases was recorded as well as the species intercepted. Total cover for the site was determined from the sum of totals from each transect.



Appendix 3 Rolling Out VegMachine: A Guide for New Regions

This appendix provides a guide to agencies and individuals interested in rolling out VegMachine in new regions. We have endeavoured to bring together the best available information regarding both tasks and costs based primarily on our experiences in the Quilpie region, where the system was trialled in the current project. Where appropriate we have also included data and information from the NT/WA trial.

Rollout costs will vary greatly between regions, and in many cases it is difficult to offer clear advice on likely costs. Where possible though, we have provided these data. We have also provided clear lists of the tasks necessary to roll VegMachine out in a new region. Interested parties can cost these lists according to the circumstances in their region.

Broadly there are two aspects to the rollout of VegMachine in any new area. Firstly and most obviously, the extension of the software and data products needs to occur, and secondly, assuming that there is no rigorously validated cover index available for the region, available indices will need to be tested to identify those most suitable for each land type. These are both discussed below.

Extending VegMachine
There are eight broad steps to extending VegMachine to a new region (Figure 1). After initial setup activities (steps 1-3), the extension process becomes cyclical, with the provision of updated cover data, generally on an annual basis. The major steps in this process are as follows.

1. *Recruit participants*

Our experience has been that recruitment of producers is not difficult, and that costs are minimal. Recruitment can be achieved largely through articles in producer newsletters, attendance of field days and in some cases, targeted approaches to selected producers.

2. *Acquire support software*

Provision of VegMachine involves a significant amount of spatial data management, in particular the preparation of imagery for on-property use. This processing requires specialised software capable of manipulating raster and vector data. In our work, we used ER Mapper, primarily because the ecw image compression format native to ER Mapper is a prerequisite format for any image imported to VegMachine. Note that standard GIS platforms such as Arcmap are not suitable for this level of data manipulation. Currently a single node locked license for ER Mapper costs $9900 with an annual $1400 maintenance charge after the first year.

3. *Acquire land type data*

Land type mapping data are necessary for the interpretation of cover indices, since ground cover index values can vary according not only to ground cover, but also soil, and vegetation characteristics. Stratification should improve the accuracy and interpretability of ground cover time traces because it better ensures like is compared with like.

We used the Queensland Environmental Protection Agency's regional ecosystem data as the basis for land type stratifications, though other data such as land system or soil mapping could act as a useful substitute. These data are often available free or at a nominal charge to government agencies

and regional NRM bodies, though their availability and cost should be checked early in project planning.

4. Acquire property infrastructure mapping

It is useful to acquire both paddock and waters mapping for participating properties, since these should be provided as part of the VegMachine data to help managers orient themselves in the imagery, and to interpret spatial and temporal patterns in cover. Roads and tracks are not as important but in some cases (eg larger paddocks) they can act as a grazing pathway allowing easier cattle access.

Mapping property infrastructure can be both time consuming and expensive. Essentially, all water and fence corner locations on the property must be recorded with a GPS, these points are then downloaded to a GIS, and vector data are then created for both waters and paddocks. If all tasks are handled by the extension agency this may represent several full time equivalent days of labour per property.

The costs of acquiring these data can be offset in a number of ways. Many properties have existing infrastructure mapping, and these could be given preference for entering the extension program. Alternatively, producers could be asked to provide all or some of the resources required to acquire these data, in particular the GPS work on the property. In our work we started with good infrastructure mapping for all properties, but experience in previous projects suggests that the office time necessary to map paddocks after coordinates are collected could be as much as one day. In some cases a high resolution image (eg SPOT-TM merged image) can be used to verify or map some paddock boundaries or update data sources. Note that production of these data also requires access to a GIS platform such as Arcmap.

5. Acquire imagery

This is an extremely important part of the process, and in particular two issues, the type of data used, and its subsequent cost will need to be incorporated in the planning for VegMachine in any new region.

The VegMachine software can interpret any correctly formatted type of raster data, so a wide range of satellite and aerial photo data are useable within the system. As a prerequisite through, image series of fewer than about four (generally annual) images are of little value, and this time frame excludes data from newer satellites with limited historical archives. The cover indices can be extracted from single bands of data (eg Landsat TM band 3), or multiple bands such as CINRS ground cover index.

Cost of imagery can vary enormously. For Landsat TM, the most likely data source, data are available free through the Australian Greenhouse Office for multiple dates, and state agencies in Queensland can access the CINRS Landsat archive for approximately $70 per scene. These data come calibrated and registered to industry best practice. The NT/WA project purchased annual updates for three triple TM scenes (triples are three TM scenes along the same path on the same date), at a total cost of $4500, plus $5000 for a private provider to mosaic the scenes and calibrate to the existing data set. Other commercial sources may be more expensive, with a single ortho-rectified scene for one date costing about $1200, though discounts are available for multiple scenes and multiple dates. Given the number of dates and or scenes in any time series, arrangements for

supply of imagery will be an important part of planning and budgeting for the rollout of VegMachine in a new region.

6. Prepare property data

Property specific data are prepared and supplied to each property. These data include, but are not limited the bil file which holds pixel-by-pixel, year-by-year cover index values. Colour and grey scale images of the property, cover change images and various vector data including property infrastructure and land type mapping.

The time taken to prepare these data varies considerably depending on the experience of the software operator (this is primarily where ER Mapper is used), the number of land type strata within the property, and the range of imagery products provided. It is therefore not possible to specify the amount of time this can take. As an example, the data for our Quilpie properties could be produced in about five working days by a single moderately experienced ER Mapper user, however, we recognised only three landscape strata, and provided to only 6 properties.

It should also be noted that this part of the process is repeated annually. While some data can simply be recycled each year (eg water point data), many of the more labour intensive products, such as trend imagery will need to be reprocessed as each data update arrives. Data preparation therefore represents a substantial and ongoing maintenance cost for any monitoring program.

7. Distribute data and software

Data delivery and software installation occurs through extension visits to properties, and the cost of visiting each property for these tasks needs to be built into project planning. As a general rule of thumb, one person can complete the initial data and software installation, and train the manager in about three hours, and subsequent annual updates can be installed and explained in about one hour. The primary cost here is likely however to be travel to and from properties, particularly where properties are widely spread or a long distance from base for extension staff.

Distribution costs could be greatly reduced if VegMachine were developed for user installation (not allowed under the current contract). Software and data could then be transmitted via mail, or possibly the web. Over a large number of properties this could save considerable extension effort.

8. Train users

Training is a relatively simple process. We have developed a number of training tools that are available for use as is, or in an adapted form, in new regions. Our training was conducted on the day of software installation, and rarely took more than three hours. Subsequent refresher training was provided on delivery of annual data updates, though this took only about an hour, except where managers had changed, in which case full retraining was necessary. As with data and software delivery, training's main cost will generally be in travel time, especially where properties are widely distributed.

9. Ongoing support

Our experience of VegMachine was that limited ongoing support was necessary. The primary expense was reinstallation of crashed software, which had to be performed by extension staff under existing contractual arrangements, and so necessitated property visits. This was generally performed during normal scheduled visits to the property to make the best use of existing resources.

Assuming VegMachine is updated and brought to full commercial standard, this problem will be significantly reduced.

A secondary ongoing support issue is that of maintaining interest in the monitoring system. In its current incarnation, using annual image updates, VegMachine is not a tool that is likely to be used with weekly or even monthly regularity. Consequently, users can lose skills and interest. Planning for use in new regions should include strategies to maintain interest in VegMachine after its delivery. One useful strategy might be to link it to other extension programs, so that VegMachine is better incorporated in other on-property activities.

Validating cover indices

The second aspect of implementing VegMachine is validation of cover indices. Cover indices are the estimates of ground cover derived for each pixel from the satellite image, and validation ensures that variation in a cover index is indicative of variation in ground cover, or where this is not the case, to identifies reasons and potential solutions. Validation is critical to ensure the accuracy of any subsequent monitoring.

Validation occurs through site based annual monitoring. Ground cover is measured on a number of sites and the correlation between ground cover values and extracted satellite cover index values is assessed. This approach requires several years of data, though some conclusions can be derived from only one year's data. It includes the five major steps (Figure 2) explained below.

1. *Stratify land types*

Different land types have different reflectance characteristics. This means that a cover index that works in one land type may fail, or have a different range of values in another land type. It is therefore necessary to stratify regions into a number of internally homogeneous land types.

Decisions about how to stratify are made primarily on the basis of soil and vegetation characteristics, since these are the major influences on cover indices. A preliminary stratification can often be established through good local knowledge, and can be quickly supplemented by comparing land type by land type the variation in cover index values within a region over a number of years.

Stratification is a two edged sword. Having more strata should reduce the probability of erroneously applying a cover index where it doesn't work, but also increases processing time, and complicates assessments for end users. As such, reviewing the stratification is an important part of ongoing validation work.

2. *Select sites*

Validation should occur in as many land types as possible, but the number of sites measured within any land type should be sufficient to adequately test the accuracy of the cover index in each assessed land type. It is difficult to advise on the minimum number sites needed to do this, but our experience in Quilpie has been that 10 sites is probably not enough, and we currently work on 14 or 15 as a minimum, and even this number provides limited statistical power.

Site selection should identify a set of sites that range widely in terms of ground cover within each assessed land type. These sites can be found through consultation with land holders and experienced field staff, inspection of cover index imagery, inspection of likely areas such as ends of

grazing gradients, and sometimes serendipity. Any project plan should include the time and resources needed to inspect a large number of potential sites, from which the validation sites are selected. Again, it is hard to specify how much time this will take, but in the Quilpie area we spent three to four weeks of full time equivalent work time inspecting and documenting potential sites before the first year of sampling.

3. Do field measurements

The key focus here is ground cover measurement, but it is also important that measurements capture other aspects of the site, such as cover in upper vegetation strata and landscape function. These latter data are critical in later determining why on a given site, actual and indexed cover and values do not concur.

In the Quilpie work, measurements took approximately two full time equivalent hours per site, an effort similar to that in the NT/WA work and in other studies currently under way in Queensland. This measurement time, and of course travel time to properties and between sites should be budgeted for in any project planning.

4. Assess index validity

Assessment in its most simple form involves the correlation of ground measurements with satellite cover index values. Analyses are run land type by land type and cover indices that work should correlate reasonably well with ground measurements. An important part of the assessment will include identification of outliers, so that potential reasons for their departure from the assumed relationship can be examined.

This stage of the validation is not particularly time consuming or expensive. We were able to decrease the time taken by recording most field measurements on PDAs in the field, eliminating the need for transcription later. Excluding transcription time, only two days per year were needed to get the data in order, extract cover data from imagery, and assess correlations.

5. Repeat measurements and assessments annually

Validation of any cover indices should proceed over a number of years, and a number of indices can be tested simultaneously in this time. Repeated allows validation across a wider range of seasonal conditions, and also has the advantage of assisting monitoring officers to see in detail the vegetation changes that occur on a site due to management and climate, increasing their capacity to interpret how satellite cover indices describe these changes. The length of the validation trials will depend on resources and time constraints, but the longer validation is possible, the better. Time and resources needed for monitoring should reduce slightly after the first year as staff gain more experience and sites are already selected, and should stabilise thereafter.

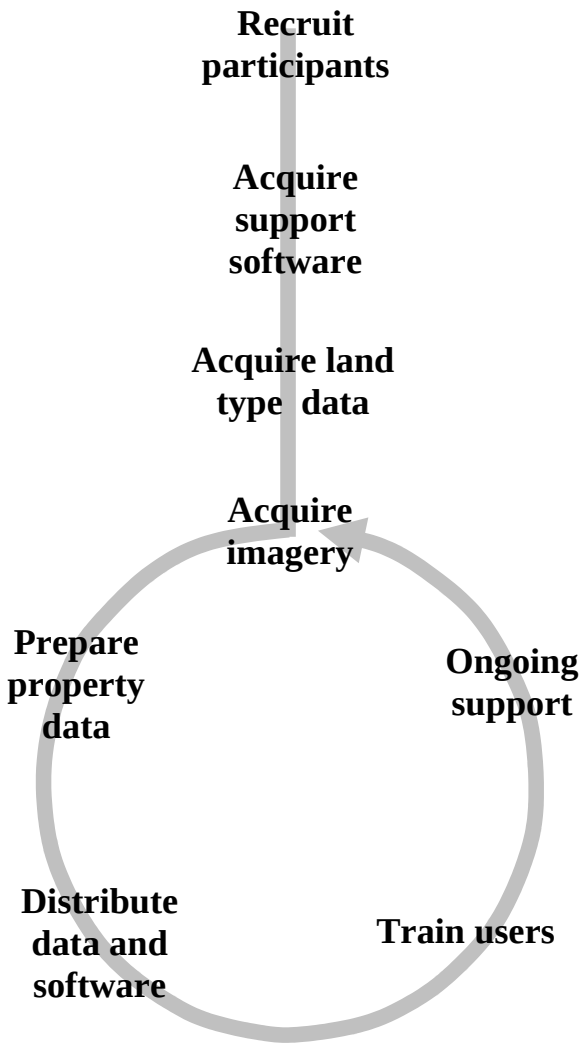


Figure 1. Flow chart for extension of VegMachine software and monitoring system in a new region.

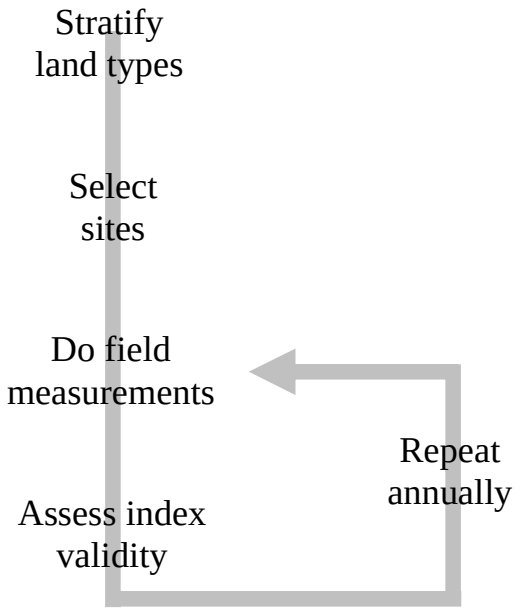


Figure 2. Flow chart for validation of ground cover indices in a new region.

Appendix 4 Pastoralist Survey 2005

VegMachine Pastoralist Survey (April – May 2005)

Date:
Property:
Interviewee:
Time taken:

- In June of 2005 we will report to MLA about the progress of the VegMachine project.
- We would like your thoughts on both the software and the project to give MLA the complete picture and improve aspects of the project that are lacking.
- To aid us with this task we're interviewing participants about their experiences.
- The questions are broken into 6 parts covering:
    - Your expectations;
    - Communication of VegMachine;
    - How you've used VegMachine so far;
    - Difficulties you've faced in using the software
    - Your intentions for using it in the future, and
    - Ideas you have to make it work better on your property.
- If you get stuck on a question I'll provide you with some examples, they will just be memory joggers though and may not be relevant to you. In any case, your honest opinion is the only correct answer.
- With your permission I will tape the interview, but this will just be for my benefit so that I don't have to write notes and have a conversation at the same time.
- If it is ok, I may quote what you say in this interview, but any quotes will need your approval and I'll run them by you first. You will also be able to withdraw your approval at any stage in the future.

Your expectations
- What did you expect VegMachine to offer?
- Is this different to what you feel VegMachine offers now?

Talking with others about VegMachine
- Do you discuss VegMachine with your neighbours, friends or people outside the business, and if so what are their responses.
- Do you speak about positive or negative things to do with VegMachine?
- (Companies only) Have you involved business partners such as family in your work on VegMachine? What has been their response and has it helped with communication or reporting?
- (Managers only) Have you involved the property owner in your work on VegMachine and if so how? What has been their response and has it helped with communication/reporting?

Using VegMachine in your management
- Can you give some examples of how you use VegMachine on your property (changed management)?
    - To help decide where/when to move or keep stock;
    - In decisions about where to place new infrastructure such as fences or waters;

  - To confirm the effects of management practices;
  - To back up any claims to financiers, government agencies or other parties outside your enterprise.
  - Any other ways (changed management?).
- How did you make decisions on your property before you started using VegMachine?

Using the software

- Have you been able to use VegMachine as much as you like? What has stopped you from using it? (offer prompts when they get stuck)
    - Lack of time;
    - Computer problems
    - Difficulty understanding some of the images;
    - Inaccurate data and/or images;
    - Lack of training on computer or VegMachine.
- Are there things that would make VegMachine easier to use? (offer prompts when need)
    - More options like measuring available feed;
    - More regular image updates;
    - General computer training;
    - Training/information about grazing land management;
    - Better training on the VegMachine software;
    - Better image or data products.

Using VegMachine in the future

- What do you think you will use VegMachine for in the future? (offer prompts when need)
    - Decision making;
    - Monitoring;
    - Incorporation into the properties management system;
    - Reporting;
    - For grant applications;
    - In an EMS;
    - Infrastructure (fencing) changes;
    - Tracking cover change;
    - Deciding stock movements;
    - Helping secure finance; or
    - Justifying your management to outside parties.
- How many times a year would you spend using VegMachine?
- How much time since the start of the project until now do you think you've used VegMachine for? (Have you ever used VegMachine when I'm not there)
- Have you put any photos into VegMachine?
- Have you saved workspaces?
- Have you referred back to these workspaces for more information or for further clarification or yearly changes?
- Is there too much data supplied? Can you keep up with the number of products or is it confusing or overloading?
- Are there any other comments that you would like to make about VegMachine?

Appendix 5 Pastoralist Survey 2006

Final VegMachine Pastoralist Survey (April – May 2006)

The VegMachine project is in its final stages. An integral part of this project is to collect feedback from our participants. Your final feedback is extremely important to us and will ensure that your views and ideas for the VegMachine Project are incorporated into the projects final report that will be delivered to Meat and Livestock Australia (MLA). Some questions require you to write your answer and some require that you circle your answer (these are indicated).

Your expectations

- What did you think was the best feature of VegMachine?
- What did you think was the worst feature of VegMachine?
- What did you think was the best support feature that was offered for using VegMachine?
- What did you think was the worst support feature that was offered for using VegMachine?
- How did/didn't VegMachine offer what you expected/required?

Using VegMachine in your management (data products)

- How often would you currently use VegMachine?
- How often would you like to use it?
- How do you currently use VegMachine on your property?
- What else would you like VegMachine to do?
- Which maps did you find most useful and why?

Using the software

- Did you have any difficulties using the VegMachine software? If so what were they?
- Have you used other monitoring and mapping software such as Pinpoint, Stocktake or others?
    a) Which software have you used?
    b) Did you find them useful?
    c) What was a key component of the program that you used?
- What would you have to add or change about VegMachine to make it more useful to you?

Using VegMachine in the future

- Ideas for future use? How do you plan to use VegMachine on your property in the future? (Please circle your answer)
    a) Management decisions: stocking rate/placement
    b) Monitoring effects of management changes: stock/infrastructure, rehabilitation areas, seasonal conditions, weeds & woody thickening
    c) Property Planning: infrastructure changes, improved use of land & water resources
    d) Property reporting processes, legislative requirements, financial assistance
    e) Not at all
    f) Other – please add comments

- How would you prefer to see the VegMachine project continued to be administered? (Please circle your answer) Through;

a) Government Department
b) Commercial enterprise
c) Industry representative or support groups ie MLA, Landcare, regional group
d) Joined with other similar projects; satellite fire mapping, GLM, AussieGrass
e) A combination of some/all of the above
f) Other – please add comments

- How would you prefer to see the VegMachine project to be financed in the future? (Please circle your answer)
    a) Government Dept/s
    b) Commercialised, private company
    c) Industry or Community support groups
    d) Individual or User pays
    e) Combination of some/all of the above
    f) Other – please add comments
- What would you be willing to pay for the use of the VegMachine software and for the provision of maintenance and updating with technology change on a yearly basis? (Please circle your answer)
    a) $1 - $150
    b) $150 - $300
    c) >$300
    d) No
- What would you be willing to pay for annual updates of satellite data products? (Please circle your answer)
    a) $1 - $150
    b) $150 - $300
    c) >$300
    d) No
- Would you access and use updates if they were supplied through a secure internet site or emailed to you?
- What changes in your circumstances or external influences would make VegMachine more relevant to you? (Please circle your answer)
    a) Climatic changes, such as extended period of dry or poor seasonal conditions
    b) Legislative changes/changes to reporting processes
    c) Market incentives to demonstrate your stewardship
    d) Other – please add comments
- What would have to change to make VegMachine something that you use monthly? (Please circle your answer)
    a) More regular satellite image updates
    b) Links with other data sources i.e. Fire, rainfall distribution
    c) Improved software capabilities i.e. GIS capabilities, export maps/infrastructure data
    d) Ability to estimate feed biomass
    e) Other – please add comments
- Are there any other issues that you would like to discuss?

Appendix 6 Pastoralist Suggestions to Improve Data Products

Features pastoralists felt would increase the relevance of VegMachine data to their management and increase the benefits that they would derive from its use;

- provision of more years of data further into the past to better reflect long term trends and cycles (aerial photos could be used to gain more data);
- an increase in the number of image updates per year, especially a March image in Qld to coincide with their major decision times for changing stock numbers on property;
- simplification of the six coloured image. Pastoralists found the six coloured image confusing, 'too many colours' and preferred using the panchromatic image;
- a selection of data products developed, Qld pastoralists especially liked a three coloured image that compared one year to the next;
- pastoralists would like to compare data between land types and were disappointed that they could not look at an entire paddock, but had to split their analysis between the different land systems within that area;
- a number of pastoralists would like the index value in VegMachine to be a reflection of on ground cover;
- pastoralists felt that some of the data products supplied struggled with accuracy, especially in areas of mixed country with a number of land types. In some cases pastoralists said that fence line cover differences were not being revealed by the data and areas that they had pushed or pulled for fodder were also not visible on the image. Another pastoralist found that the woody weeds on their property were showing up as high cover, were as the dense Mitchell grass patches on their property (in good condition) were not. They felt that this was not a true indication of their Mitchell grass area;
- one pastoralist felt that using red in the image was confronting and 'too negative'. They felt that this colour was likely to project negativity to landholders and put them off side, rather than encourage them to make improvements in their management and suggested that thought should be given to alternative colours;
- some pastoralists felt that more training in interpretation of the satellite imagery was required;
- improved and updated land system and fencing data where required (Qld and WA);
- greater image detail. The introduction of a panchromatic image in Qld produced a lot of interest as it made it easier to navigate around property;
- pastoralists would also like to be able to add their stocking numbers and rainfall averages into VegMachine (rather then exporting to excel) to compare with on-ground changes;
- greater data coverage. Two pastoralists in Qld were disappointed that the VegMachine data did not cover their entire property. The purchase of more data would rectify this issue; and
- in relation to the CINRS tree and ground cover data in Qld, pastoralists felt that it did not always give an accurate reflection of cover. They thought that these inaccuracies were related to woody weed species. Pastoralists said that woody weed cover may reduce or increase depending on the time of year, and thought this may be producing fluctuations in cover.

Appendix 7 Pastoralist Suggestions to Improve VegMachine Software

Improvements suggested by pastoralists to be made to the VegMachine software package;

- the operating features of VegMachine. Quiet a few pastoralists experienced difficulties when using the vector tool function. This involved the disappearance of vectors once they had been drawn. This issue was thought to be due to the updating of Microsoft internet files and could be corrected by rerunning the .netfx Microsoft file in the VegMachine set up process. Once this file was reinstalled VegMachine would operate as designed and the vectors would reappear. Most pastoralists found that VegMachine had trouble operating when Norton antivirus software was running on their computer and they had to disable the internet safeguard to allow VegMachine to operate;
- graphs in VegMachine to show a trend line or box and whisker plots to allow for easy interpretation of the VegMachine graphs and to show minimum and maximum figures respectively;
- workspace files. If older ecw. image files are removed from the data file, then the workspaces that these are associated with no longer function;
- the easting and northing point location tool. Some pastoralists had trouble with the easting and northing or point location tool in VegMachine, as a zone line intersected the middle of their property, they suggested that it would be better if this tool functioned on latitude and longitude;
- the draw line tool which would draw a line for a number of points and then create an error;
- the photo tool, one pastoralist could add only photo per camera icon and the camera icon also failed to resize as the pastoralist zoomed in an out on the screen. This was an isolated issue;
- the choice of colours displayed in the graph. pastoralists found the colours for preset data in some graphs, too faint to see (VegMachine choose light colours for display). Pastoralists would like to be able to choose the colour in which the pre-set data, such as the averages information in the graph is displayed;
- the legend button which did not provide any detail, pastoralists would like this tool to display information linked to the image that they can see on screen; and
- training in complementary property management tools such as Grazing Land Management (GLM) or Environmental Management Systems (EMS) to increase the relevance of VegMachine to their overall property management system and allow for easier incorporation into their property management planning.

Appendix 8 Time Pastoralists Spent Using VegMachine

The following tables list the amount of time that pastoralists have used VegMachine in the NT, WA and Qld.

Table 1: Property visit and amount of time using VegMachine in the NT and WA

Property	No. of Visits by NT DIPE	Time Pastoralist used VegMachine unassisted	Times/year Pastoralist has used VegMachine
Moolooloo	7	15 hours	6
Centre Camp	5	6 hours	6
Pigeon Hole	5	12 hours	4-5
Mt. Sanford	3	3 hours	2
Wave Hill	2	Very little	1
Auvergne	6	20 hours	Once a month or more
Newry	4	12 hours	Once a month or more
Carlton Hill	4	24 hours	Once a month or more
Mistake Creek	4	12 hours	6
Rosewood	4	12 hours	6
Flora Valley	3	6-8 hours	4
Birrindudu	3	12 hours	4-5
Bunda	2	6 hours	4
Riveren	3	12 hours	6
Inverway	3	8 hours	5
Killarney	3	4 hours	3

Table 2: Property visit and amount of time using VegMachine in Qld

Property	Number of Visits by DPI&F	Time Pastoralist used VegMachine unassisted	Times/year Pastoralist plans to use VegMachine
Ardoch	4	14 hours	Once every couple of months
Bunginderry Aggregation	5	7 hours	A couple of hours a month
Comongin	6	20 hours	Quarterly
Maybe Station	2	Very little so far	Depends on the number of updates
Ray Station	5	20 hours	Every few months
Wallyah	2	10 hours	Every few months

Appendix 9 Future Directions Suggested by Pastoralists

Future Directions

Future VegMachine directions suggested by pastoralists are presented under the headings of data products and software.

Data Products

Future directions concerning data products that were suggested by pastoralists included;

- ability of VegMachine data to estimate feed biomass (kilos per hectare) and operate as a feed budgeting tool;
- more frequent image updates: pastoralists were interested in real-time imagery to provide up to date cover information to gives pastoralists' information on grazing patterns and utilisation rates to help determine stocking rates and placement within a season. MODIS satellite imagery is easily accessible and could possibly provide this information, although at a coarser scale than Landsat imagery. Historical value of MODIS is limited and land monitoring products are yet to be developed. A courser scale may be of less value to smaller Qld properties. The benefit of this data is that it is freely accessible and if pastoralists had a reason to use VegMachine more regularly then they would become more familiar with the Program. Greater familiarity with the software and products will encourage pastoralists to use VegMachine more often, as with most people learning to use new software and data;
- further development and testing of Qld data products to ensure accuracy. The second round of on-ground data collection occurred in September 2005 in Qld. This data aided in the on-ground verification and further testing of Qld indices to ensure data accuracy. This information was reported to Pastoralists;
- further testing of data differentiating pasture and woody cover. Data sourced from Natural Resources Mines and Water, State wide Land and Tree Cover Study (SLATS) was delivered to Qld pastoralists. It was thought that this data would be able to more accurately measure long term cover change of pasture and woody cover, separately on their property. Pastoralists have reported that this was not always the case and felt that the data required further testing;
- finer scale images to allow pastoralists to see more detail. These images are available but at a higher cost and with reduced coverage per scene. High-resolution satellite data was considered to be beyond the project's budget, and this data would not have had the same historical context and data regularity as Landsat for cover change analysis. However if a specific need was identified to monitor, appropriate high-resolution data could be used. The need would have to justify the cost of the data and development of an analysis method and resultant products. For example Qld pastoralists were supplied with a 12 X 12 metre panchromatic image to allow for better navigation on property;
- access to ancillary datasets that pastoralists would find useful as part of their decision making process, such as; fire mapping and weed monitoring (Mesquite). Pastoralists suggested a fire map for the year, with burnt areas colour coded relating to the month that it was burnt. A map or vectors indicating outbreaks of weeds and other information such as if the infestation is being treated and monitoring conducted;
- Improved and updated land system and fencing data where required. In Qld this information was updated on participating properties during field work in 2004 and 2005. Land type mapping in WA is to be incorporated into the land cover change analysis and VegMachine as a product, when it is finalised. Infrastructure mapping is updated as information becomes available;

- a number of data updates per year, especially for March and September to coincide with time of major property management decisions;
- enlisting of more pastoralists in Qld so that discussions amongst participants could occur more readily. VegMachine was a pilot project and for this reason only a limited number of properties were enlisted. If VegMachine were to continue and be delivered to catchment groups across Qld, discussion groups could more easily form and information exchange amongst participants would be increased; and
- extra training in complementary property management tools. Some pastoralists combined VegMachine with other tools such as GLM and EMS.

Software

Future software directions included;

- Increase GIS/Mapping capabilities i.e. add & update infrastructure, export/import vectors;
- operation as a general farm operation Program to integrate all information into one package (stock rates, finances, supplement etc);
- an environmental check. VegMachine is a tool that aids the pastoralist in monitoring the sustainability of infrastructure and property management changes. VegMachine has been designed to verify to the pastoralist the effectiveness of their changes and if further changes are required. The ability of VegMachine to act as an environmental check lies within the value that the pastoralist places on their interpretation of the cover index displayed in VegMachine;
- a forwards and backwards function in the image viewing tool so that pastoralists can easily change from each yearly image to the next to view a slide show of their cover change over time;
- a trend line (line of best fit) or box and whisker plot function in the graphing window to allow for easy interpretation of which way the graph is travelling or where the maximum and minimum cover of the selected area sits;
- ability to download and upload GPS tracks and points;
- a print function for the printing of maps and graphs directly from VegMachine;
- relation of colours on screen to measurements on ground, not just an index value; and
- extra training in complementary property management tools. Some pastoralists from the NT and Qld combined VegMachine with other tools such as GLM and EMS. Pastoralists have been and will continue to be encouraged to combine VegMachine with other management tools.

Appendix 10 VegMachine Software Tutorial

Tutorial included with training and software to clients

This document has been prepared to assist users in getting started with VegMachine and how to operate the functions. There are some hints and tips on how to setup the software, access information and general tips on how to interpret the information viewed.

After loading the software (see Readme.htm file for instructions) there now should be an 'icon' or picture on your computer that looks like Figure 1.

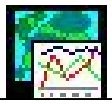


Figure 1. VegMachine icon

1. To start VegMachine, double-click on the VegMachine icon.

2. There will be a window open such as the one below (Figure 2), this is where all the background calculations and operations of the software occur. Generally this is not required to be viewed except if there is an error, as it can inform the user as to what the problem is, eg vector overlay error. **Do not close this window!**

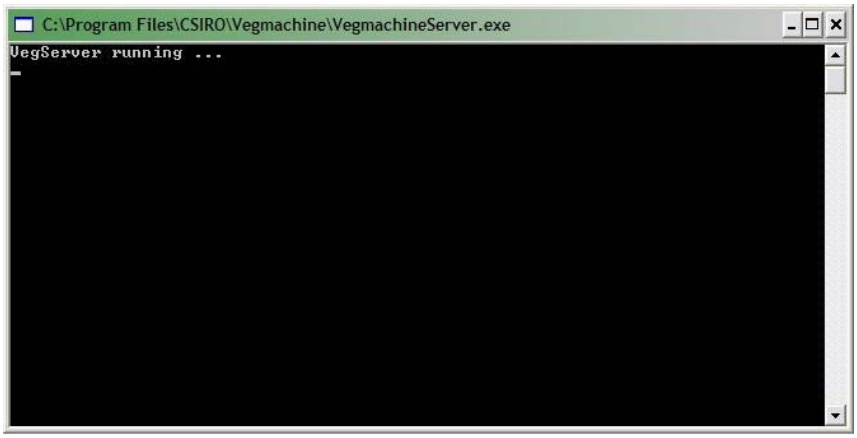


Figure 2. VegMachine server, background operating system

3. Another window will automatically open (Figure 3) where you can choose to load an image, a previous setup the user was working on (load existing workspace), or simply choose '**Ok**' on the window to open a pair of basic images.

For simplicity and when first getting started, just choose 'Ok', and continue with the next steps in this document.

If an error occurs opening images see Appendix A for hints and tips to rectify the situation.

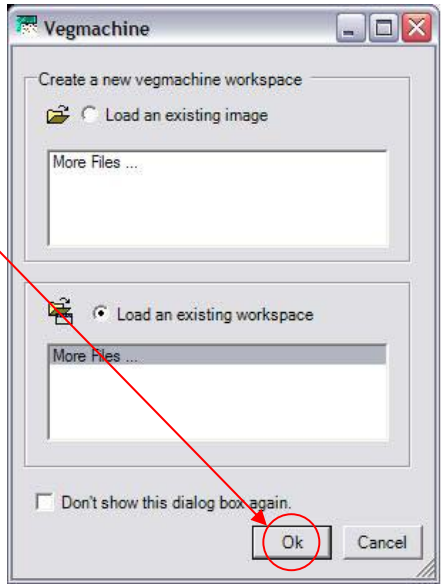


Figure 3. Automatic prompt - Open image or existing workspace

4. If the user selected 'Ok' without choosing an image or workspace, the following standard window and images will appear (Figure 4).

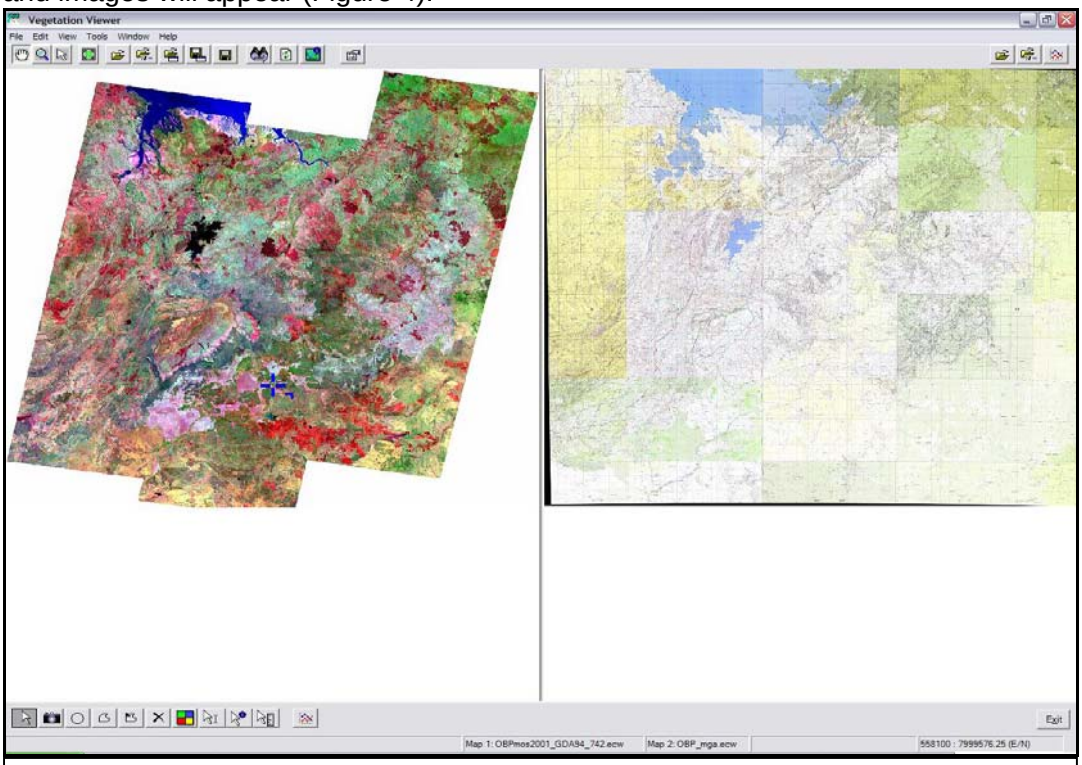


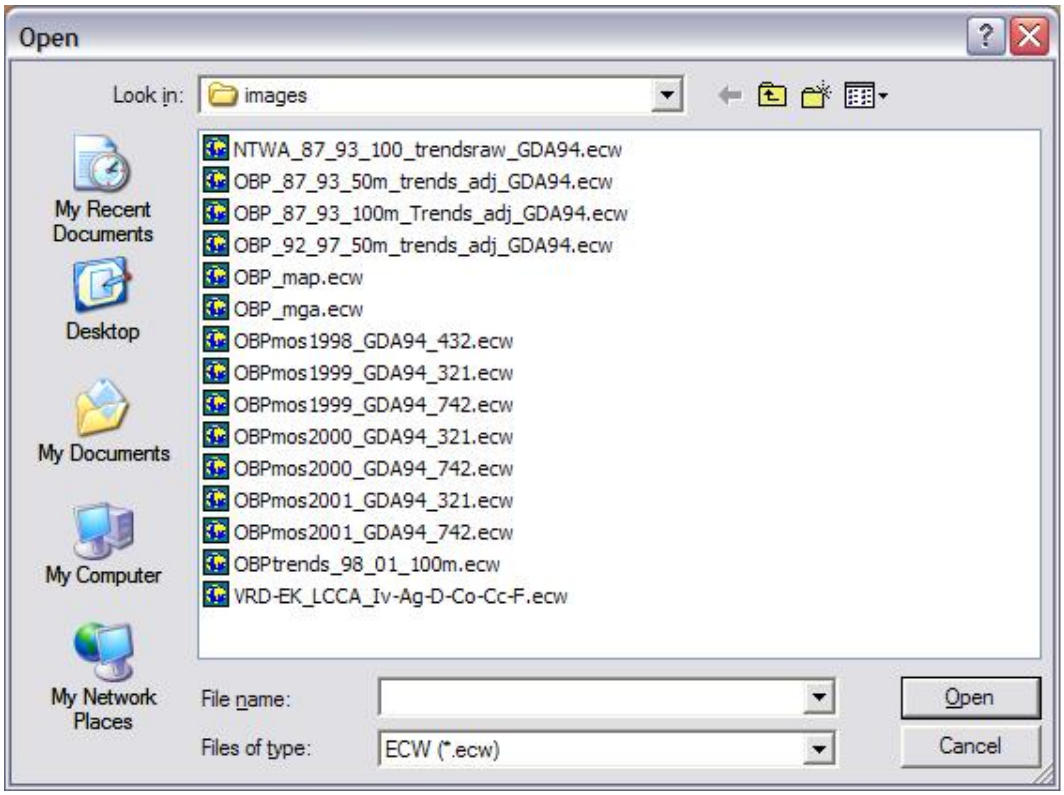
Figure 4. Initial VegMachine window with basic images

The image on the left-hand side is the 2001 satellite image over the Ord Victoria Rivers region. This is a basic image highlighting soil and vegetation types, but it is not directly used for vegetation cover and trend analysis. The areas of red or reddish colour indicate flourishing vegetation growth ie areas burnt recently (red) have generally a vigorous regrowth.

The image on the right-hand side is a single image of the topographic maps over the area. This will assist the user in locating their position on the image on the left-hand side. If you select an area to look more closely at, both images will move to display the same area in each window. Hence making it easy to locate your position and surrounds i.e. rivers, main roads, mountain ranges.

5. Open an image displaying cover level and trend.

A window will open advising of a number of files to choose from (see below). Files with the word 'trend' in the name are ones to choose, they will also have a filename describing the years used for the analysis (eg OBPtrends_98_01_100m.ecw). Select a file and then select open. The image will open in the left hand side of the viewer window.

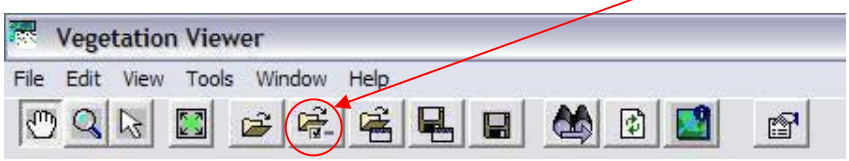


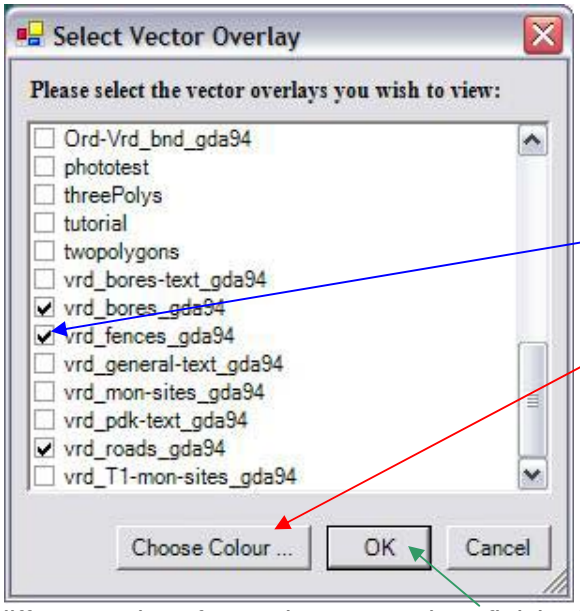
6. Select the 'zoom' tool.

Place the cursor over the area you want to view more closely, click and hold down the left-mouse button and push the mouse forward. The image will slightly distort (this is normal) but quickly reset itself providing a good image (unless you zoom right in and can see individual squares).

Check your location using the map on the right hand side of the screen. Zoom in or out (reversing the direction of the mouse) to the area of interest. If the area of interest is off the screen use the 'hand' tool to grab the image (left or right side image) click and hold the mouse button and move the mouse in the direction you want to move the image.

7. To assist in locating your position a number of 'vectors' (lines of information i.e. fences, bores) are available to select and display on the image, this also helps users recognise grazing pressure relative to distance from water or within a paddock. Open and select a vector.





A window will open allowing you to choose a vector to display.

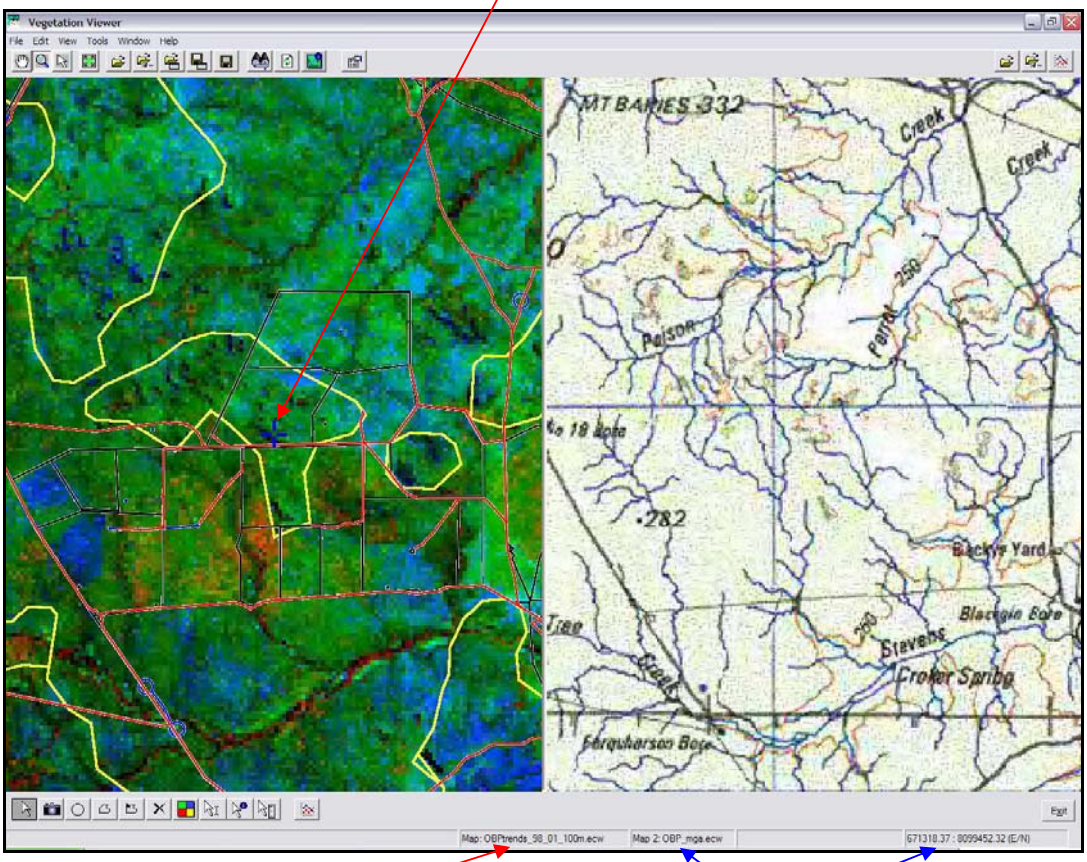
'Click' your left mouse button twice on the data file you would like to display, a 'tick' should appear in the box.

While it is selected, go to the box saying 'choose colour' and 'click' the left mouse button, another window will open allowing you to select a colour to display the data and choose 'OK'.

The choose colour window will disappear. If more vectors are required to be activated repeat the process above including choose a different colour for each vector, when finished select 'OK' to display the vector on the image. If no colour is chosen a default colour of red is allocated.

Important Note: An important vector to display is the land type information. Analysis is conducted on each land type separately, but the cover change image shows the analysis as a single image. So when comparing the colours within a paddock that relate to cover levels and trend over time be sure that it is all one land type you are looking at. This is also important when you are selecting areas to draw points and polygons (described below) to graph the actual cover levels, so that you are comparing cover levels over the same land type. That is comparing black soils plains with other similar areas and not comparing with red soil country.

8. Now you should have a window that looks something like the picture below on the area you are interested in. The image below is of the Mt. Sanford trial area. The yellow lines are the land systems, blue circles (a little hard to see) are the bores, troughs and pipelines, black lines are fences, and red lines are roads and tracks. There is a blue cross-hair in the middle of the left hand image window signalling the centre of the image.



The coordinates for this position are also listed at the bottom of the VegMachine window. The name of the left hand image is shown also on the bottom of the VegMachine window, which helps remind you what years have been used to produce the image. It is important to remember that the image is describing the cover and trend of cover over this time period. The name of the right hand image is also displayed at the bottom of the VegMachine window.

Legend for Long Term Cover Trend Image Products

Red: Vegetation cover is initially (for the series of years analysed i.e. 1998 to 2001) lower than the regional average (for that particular land system) and there has been a reduction in cover over time, as an average.

Blue: Vegetation cover is initially lower than the regional average and there has been an increase in cover over time, as an average over time.

Black: Vegetation cover is initially lower than the regional average but has remained at this level (neither decreasing or increasing) over time.

Yellow: Vegetation cover is initially higher than the regional average and there has been a reduction in cover over time averaged over the years.

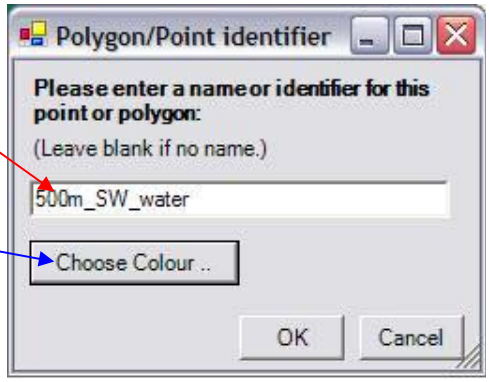
Light Blue: Vegetation cover is initially higher than the regional average and there has been an increase in cover over time.

Green: Vegetation cover is initially higher than the regional average but has remained at this level (neither decreasing or increasing) over time.

9. Viewing the images gives an indication of how vegetation cover and trend over time is behaving. To get more information as to by what amount is the cover increasing and compare it with other areas of the same land system, follow these next steps.
Select the 'pointer' tool at the top left of the VegMachine window.

Select either the 'draw point' or 'draw polygon' tool at the bottom left of the VegMachine window. The point will select a single 'pixel' (or square, when you zoom right in) and the polygon lets you draw an area as big or small as you like.

If you chose draw point, move the cursor to the spot on the map of interest and click the left mouse button, and a window will appear asking for you to enter a name for the point and type in a name. Don't select 'OK' yet, go to the 'choose colour' button to choose the colour of the point. It is a good idea to choose a different colour for each of the points or polygons you draw as it makes it easier to read the graph you may eventually make. Now select 'OK'. The point will appear, but disappears momentarily while the image and all the vectors are redrawn to take into account this new addition. Continue drawing more points on areas of interest if you so wish following the same procedure.

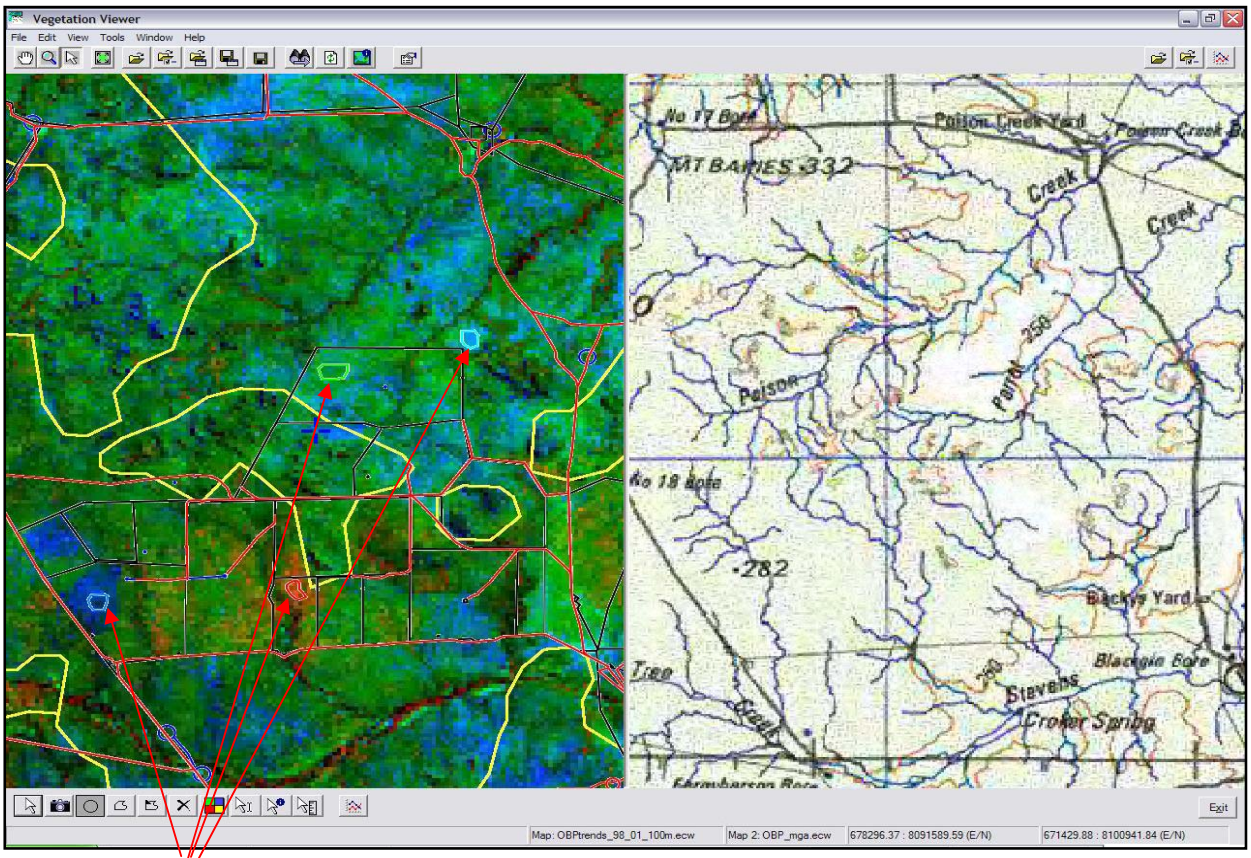


If you chose 'draw polygon', move the cursor to a point where you wish to start drawing the boundary for the polygon, and click the left mouse button. Move the cursor to the next spot where you wish the boundary to proceed and click again, you will see a line appear. Continue drawing the

boundary line until you have surrounded the area of interest and nearly back at the start point, but stop before you reach the original start point. Move the cursor to the bottom left hand tool box and select 'close the current polygon vector' and select this tool. Another window will automatically open similar to 'draw point' asking for a name and to choose a colour. As with draw point, type in a name for the area, and select 'choose colour' for the polygon. Once this is done, select 'OK' and the

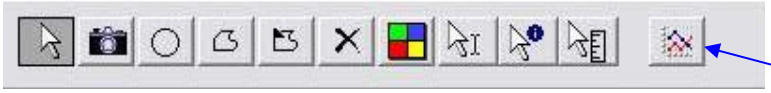
polygon you have drawn will be in view, it will disappear for a moment until the image window re-freshes itself to take into account this new polygon. Continue with this procedure for more areas that you wish to investigate.

You may now have a VegMachine window that looks something like this.



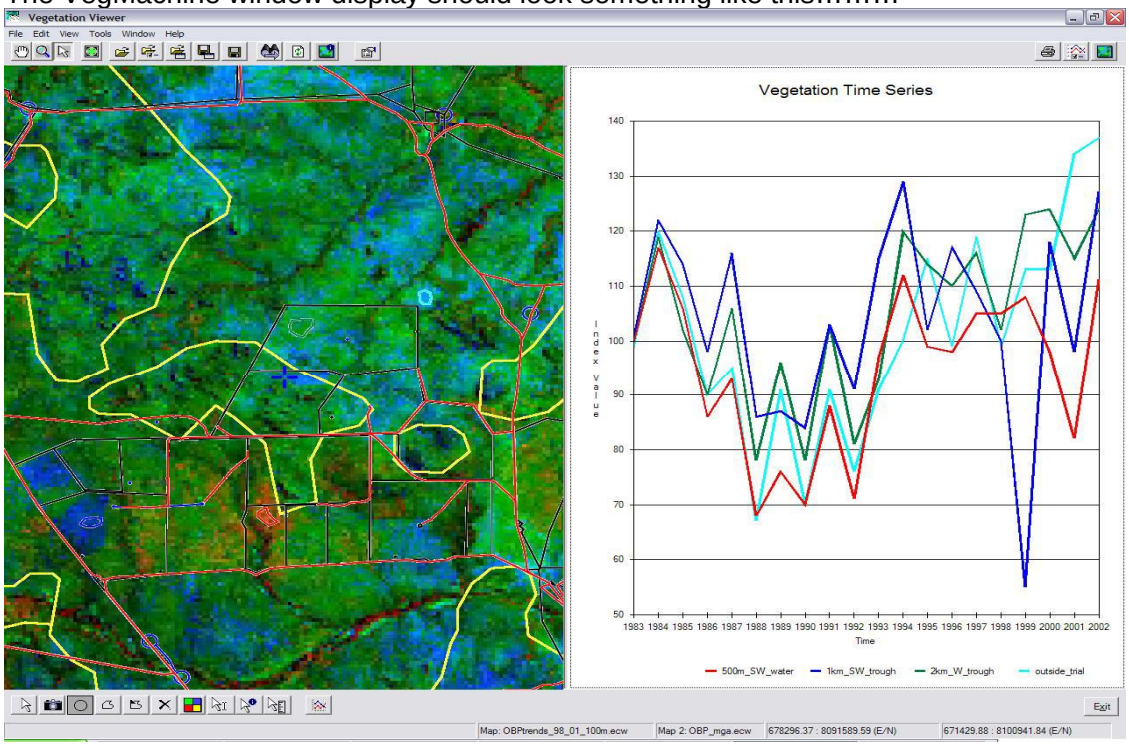
There are four polygons drawn on the image, the colours I have coordinated with the colour the analysis image is showing. Each is in a different paddock but within 500m to 2km from water, except the light blue polygon that is outside the trial area. Note that all are drawn within the same land system that is extensive throughout this area, that being gently undulating black soil plains or also known as the wavehill land type.

10. Once the areas you wish to investigate have been drawn using points and (or) polygons (you can have a mix of these if you wish), you can easily graph the results.



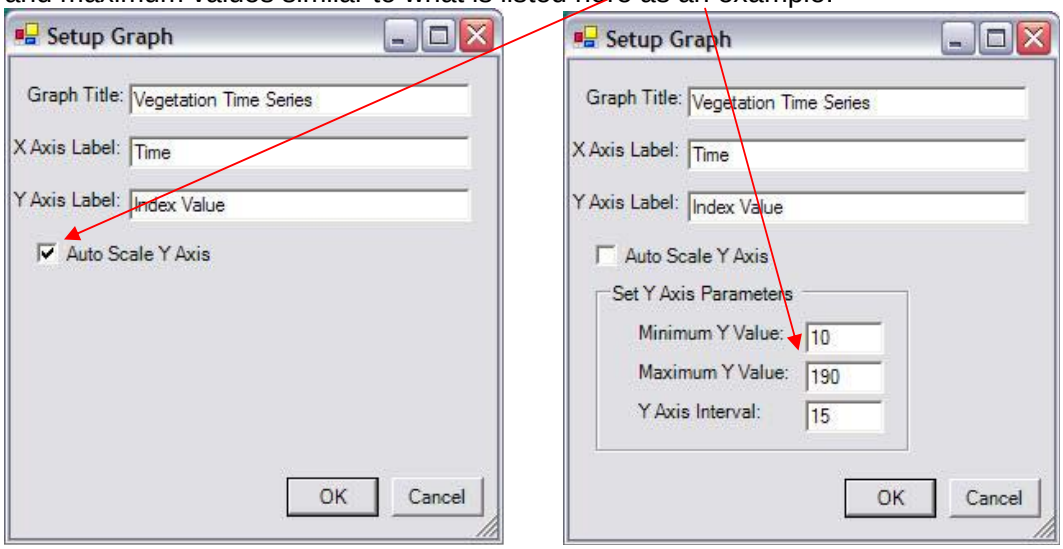
Move the cursor to the bottom left of the VegMachine window and select the ‘plot’ tool. A window will appear asking which file to extract this data from, in most cases there should be only one file to choose (timeseries.bil), select and ‘OK’. The graph will now automatically plot the relative cover levels for the point or an average of the pixels within the polygon boundary.

The VegMachine window display should look something like this…….

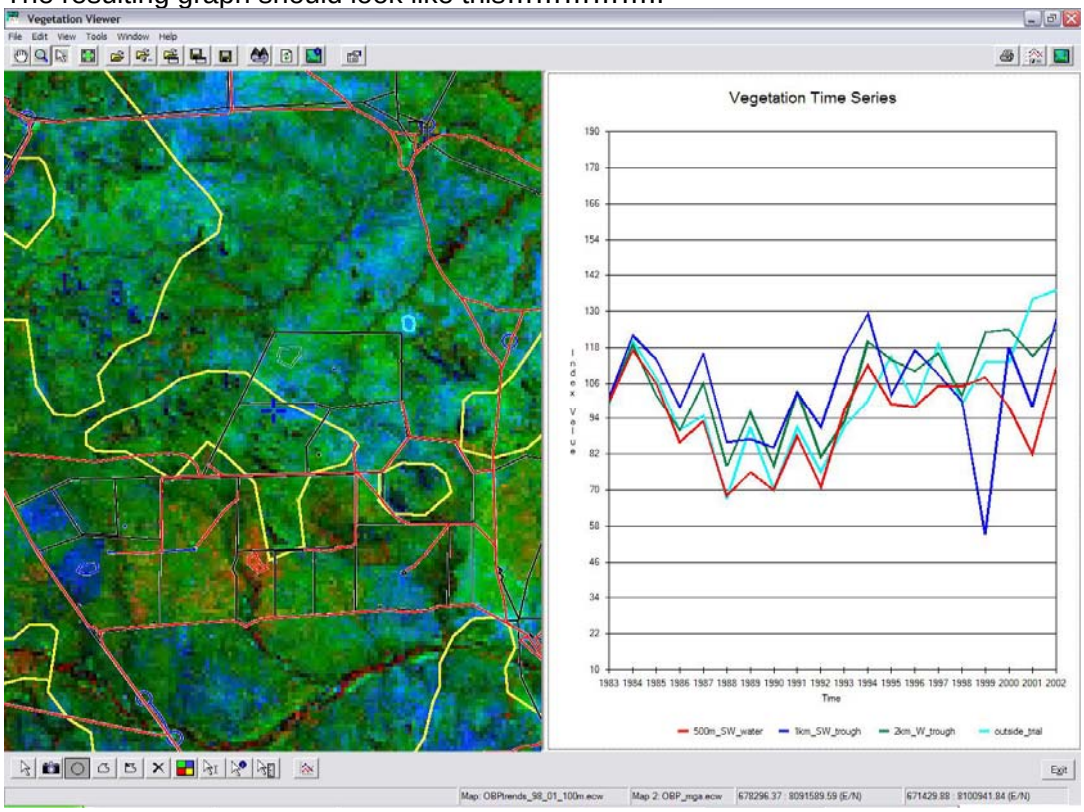


Depending on how many points or polygons you have drawn will determine how many lines are present on the graph. Too many lines and it can be difficult to view. To smooth the lines a bit more and make it easier to read, it is recommended to set the y-axis on the graph (Index value).

Move the cursor to anywhere on the graph and double-click the left mouse button and a window will automatically appear (left picture). Select and uncheck the 'Auto Scale Y Axis' box, and the window will change to that seen in the right hand picture. For best results we recommend to set the minimum and maximum values similar to what is listed here as an example.



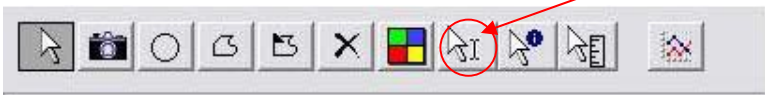
The resulting graph should look like this……..



Some initial observations can be made, all sites were adversely affected by moderate to heavy stocking rates and average to below average seasons for the years prior to 1991. A string of good seasons, changed management strategy and grazing pressure have led to an overall general increase in vegetation cover since 1991. See Appendix A (within this tutorial) for hints on how to interpret this graph as an example for interpreting your own graphs.

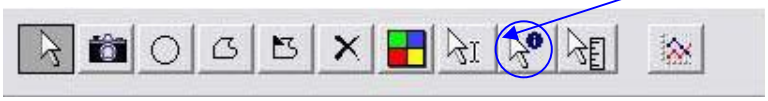
A useful tool is to be able to compare cover indices shown in the graph against the regional average cover for the land type being investigated. Move the cursor to the top right hand side of the VegMachine window and select the 'graph regional land type' tool. A window will automatically appear displaying a list of land types to activate to view. Select the land type you are investigating to use to display on the graph and be able to compare against cover indices generated by the user for areas of interest. The user may want to keep this graph for future reference and can be exported directly into Excel selecting the button on the top right tool bar. This is a good way to store monitoring results and be able to utilise Excel to add other information (rainfall, stock numbers or movements etc) or notes to assist the user in interpreting the causes and effects on vegetation cover.

11. If the user needs to delete or change the name or colour of a point or polygon, move the cursor to the bottom left toolbar and select the 'edit the label' tool. **Remember** to make sure you have selected the pointer in the top left toolbar so that there is an arrow for a cursor on your image and enable you



to select the point or polygon you wish to change. Move the cursor to the point or polygon you want to change and click the left mouse button and the vector window (same as you would have seen when first creating the point or polygon) will open allowing you to change the name and colour or delete.

If you have drawn polygons it is possible to view information about the polygon such as the area (km^2 and Ha) and perimeter, or name of the polygon to identify a land type (land type vector needs to be turned on). Select 'View label and area information of a polygon' tool in the bottom left toolbar.

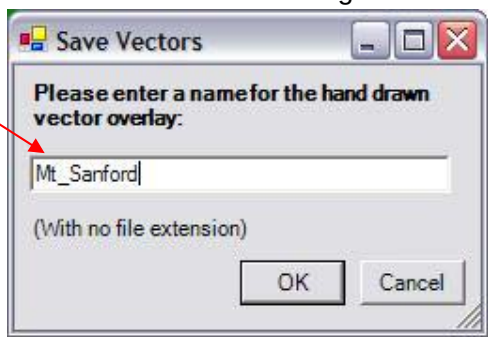


Remember to make sure you have selected the pointer in the top left toolbar so that there is an arrow for a cursor on your image and enable you to select the point or polygon you wish to change. Move the cursor to the polygon of interest and click the left mouse button, a window will automatically appear with the relevant information. Select 'Close' once you have finished with the information. This information can be used to give you an idea of how much of an area within a paddock is good, fair or poor condition based on drawing a polygon around an area of similar colour on the cover trend images.

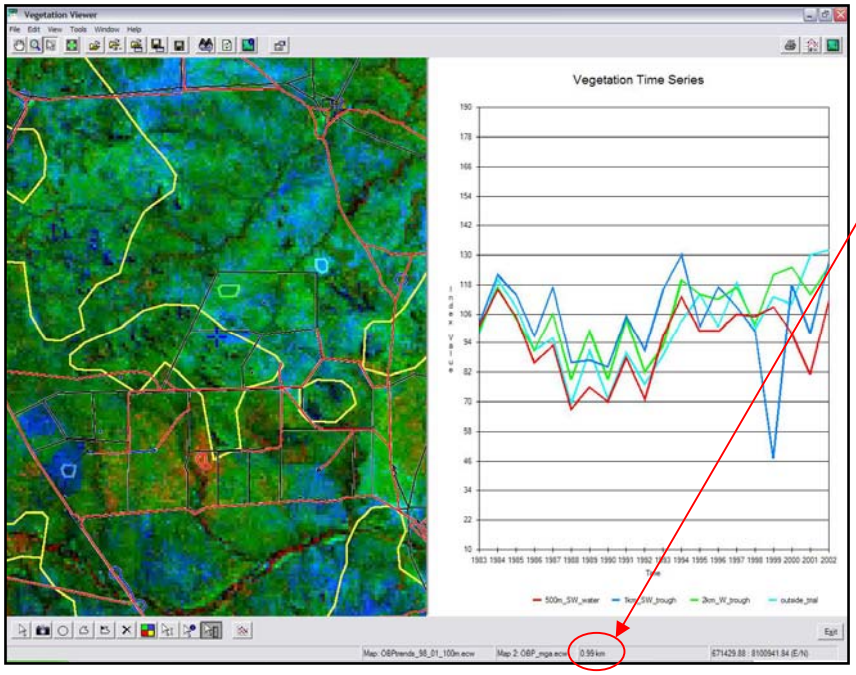
Hint: Creating a polygon can also be used to create the boundary of a new paddock, and the information will be able to tell you how big the paddock would be and the perimeter for fencing costs.

Delete Vectors: If you have no further use of the vectors you have drawn (polygon or point) you can delete all of them by selecting the 'clear' tool on the bottom left toolbar. This will clear all vectors that you have recently drawn.

If you would like to save the points or polygons you have drawn for future reference or use. Select 'save drawn point and polygons' and another window will automatically open, enter a name for this vector file which can contain a single vector or a group of vectors, and select 'OK'. You will now be able to turn these vectors on at a later date in the same way you select fences and roads to be viewed.



12. Measure the distance between points on the image using the 'measure the distance' tool on the bottom left toolbox on the VegMachine window. Select this option and make sure you have selected the pointer as your cursor. Move the cursor to a place on the image (ie bore), click and hold down the mouse button and drag the cursor to the point of interest and let the mouse button off. As you click and drag the pointer to location required and release mouse button, you will see a line appearing that will stay on the screen and the reading for the distance can be viewed at the bottom of the screen. The line will automatically disappear once you conduct a new operation.

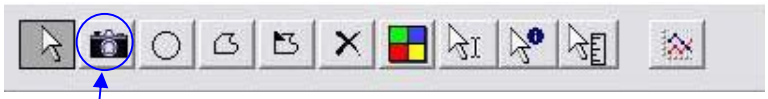


Handy Hint: When the measure tool is not selected the reading at the bottom of the screen will indicate the coordinates of the last position that was 'clicked' on the left hand image window whilst in pointer mode.

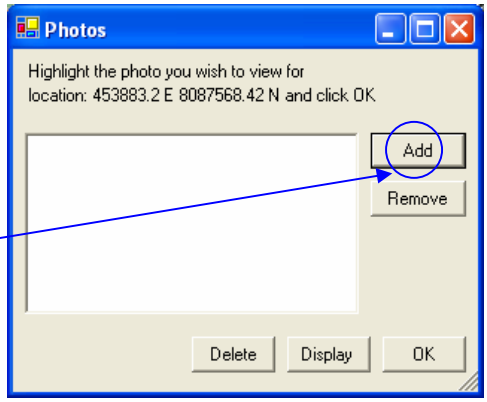
13. Go To a location on the image using known coordinates. Select the 'binoculars' button on the top left toolbar. A window will appear asking for the user to enter a Easting and Northing values. Select 'Go', and the image will move to locate the point of interest at the crosshairs in the middle of the left panel image. If you require to zoom into the location of interest but in doing so lose sight of the spot, repeat the Go To process and the values will still be active, simply select go and the image re-centres itself. Note that the point of interest needs to be within the viewing panel otherwise it can't be located.

If you find there are parts of vectors that are not fully displayed after a reasonable time has passed, select the tool 'Refresh vectors' on the top left toolbox of the VegMachine window.

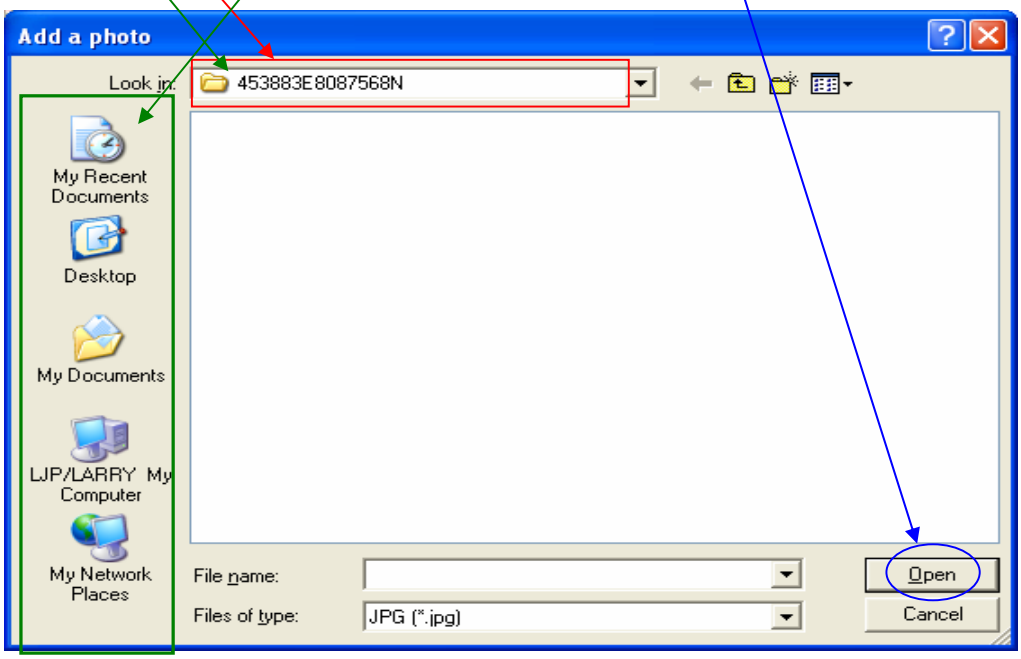
14. Record, store and view ground site photographs:
The camera icon function allows users to embed photographs that link to a known location for reference and assist with understanding what is actually happening on the ground and what is being viewed via the satellite data, or simply for visual reference. Using the zoom and roam tools, move to the desired area or location or use the 'Go To' function (see previous) if you have GPS coordinates. To check accurate location of site, the operator can select the pointer tool (top left function bar) and click on the map (left window pane only) and the coordinates will be displayed in the bottom right of the VegMachine window. There are two sets of coordinates displayed, the left side coordinates indicate where you 'clicked' on the map, right side indicates the coordinates of the centre of the image indicated by the blue crosshairs.



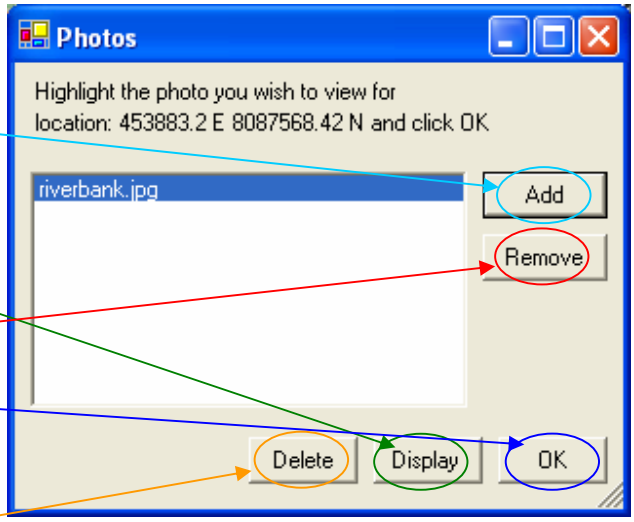
When operator has chosen the correct location, select the camera icon located at the bottom left tool bar. Move the 'arrow' cursor to the required location on the map (left panel only) and left mouse button 'click' to activate site. A window will appear, with GPS coordinates select 'Add' and a secondary window appears.



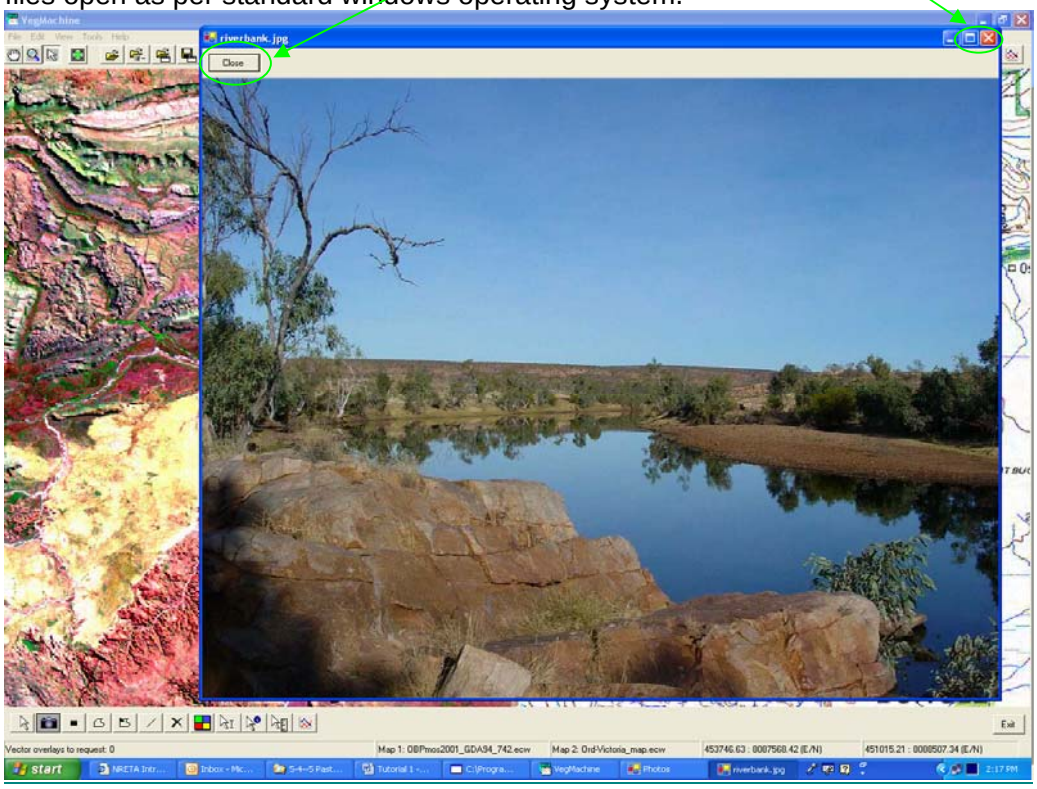
You will notice that VegMachine has already created a directory (GPS location defined) for where these photos will be stored under the VegMachine filing system. To locate the photo/s required use the drop down directory menu or other location functions within this window wherever they are stored on your computer and highlights the required file and select 'Open'. When 'Open' is selected the program will automatically store a copy of the photo file/s in the VegMachine directory structure defined by the GPS location.



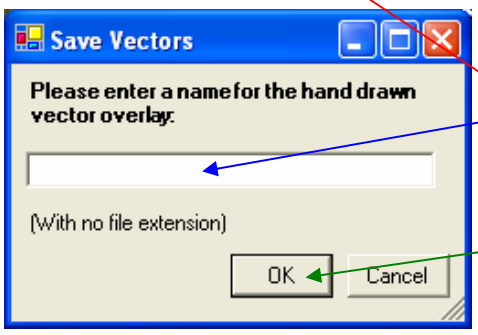
The original photo window will reappear (see right) with the list of photos linked to this location. If more than one photo is to be linked to this site, select 'Add' to repeat the procedure until all photo files required are linked to this location. If you would like to check the photo is correct select 'Display' and a window will appear with the photo (see below). More than one photo can be displayed at once, and a series of photos can be viewed simultaneously. If the photo is incorrect or is no longer required, 'click' to select and highlight the photo file from the list and select 'Remove'. Select 'OK' when all photos are linked, and a camera icon appears on the screen to note the location. To view the photos at the site, select the camera icon in the bottom left toolbox and left mouse 'click' on the camera icon indicating the site of interest on your map. If the site location is incorrect or the link no longer required, select 'Delete'. Follow the prompts and the icon displayed on the map and links to photo files will be removed.



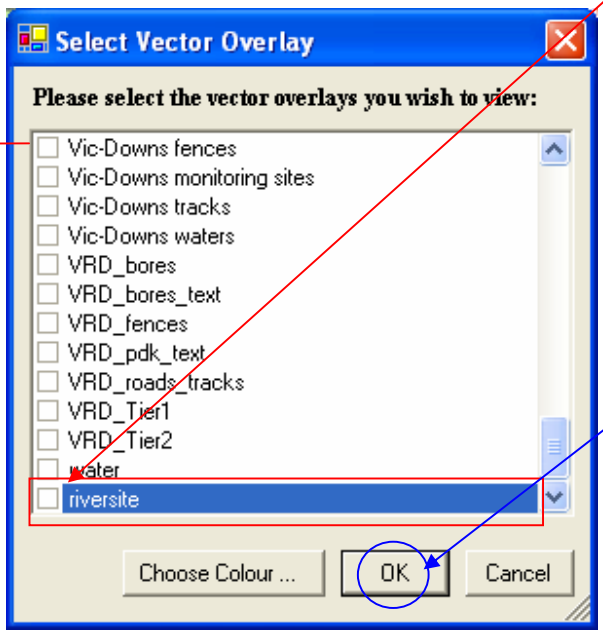
Close the photo display windows by selecting 'Close' or minimise using the standard windows procedure of selecting the button in the top right corner. Or simply click anywhere on the VegMachine main display window to bring to the front and the photo windows will be hidden behind. To bring the hidden photos back for viewing select the required photo to display from the list of all files open as per standard windows operating system.



To save this photo link as a vector overlay (camera icon) that can be turned on and off to display on the map when required, select the 'save drawn point or polygon vectors' icon on the top left function bar. Note if there is a group of photo sites related to a similar project or paddock for example, create all the site links and then save as one vector file so all sites can be displayed using a single file. A window will appear requiring a name whether it is a site, paddock or project, to identify the vector file for future reference, and select 'OK'. When required to view at a later date, select the icon on the top left function bar to 'Select vector files to display'.

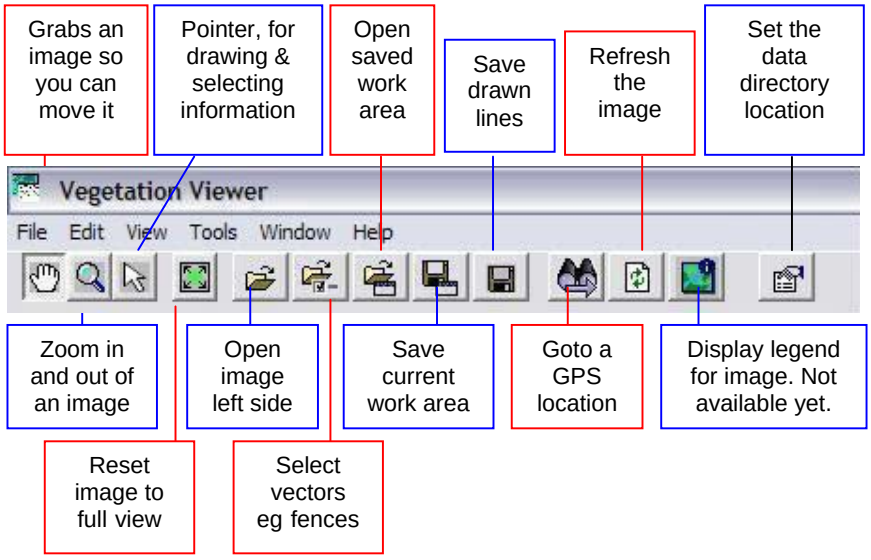


A window will appear with a list of available vector files to activate. Select file required from the list, a secondary 'click' will check the box (ticked) and select 'OK', more than one file can be activated at this same time. Choose colour is not available with photo overlay icons, this is only available for points, lines and polygons either imported or displayed. The camera icon/s will then display in the locations as pre-defined and to select and display, ensure the cursor is the arrow (top left function bar) and then choose the camera icon from the tool bar (bottom left function bar) and select the site to display by clicking on the camera icon displayed on the map As described previously when creating the site links, a window will appear with the list of available photos for display related to the site. Select the photo/s required for viewing and select 'Display' and resultant windows will appear with the photos. Note the size of the photos and display proportions are set by the original photo dimensions. If numerous photos are required to be viewed simultaneously it maybe required to reduce the size of the photo dimensions using a photo editing program.

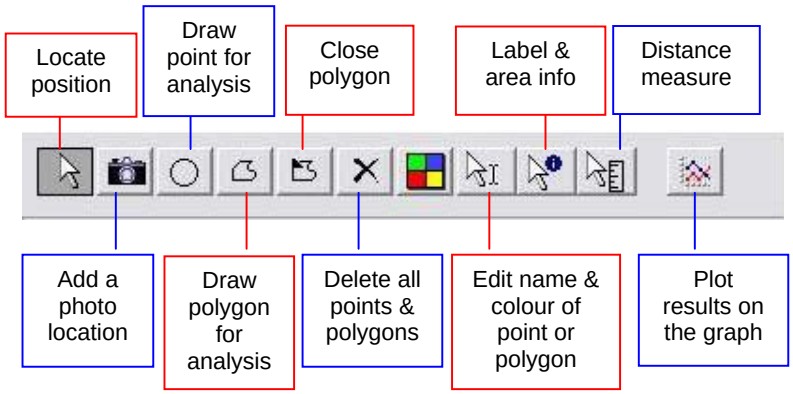


Appendix A: Hints and tips for VegMachine

Top Left Toolbar:



Bottom Left Toolbar:



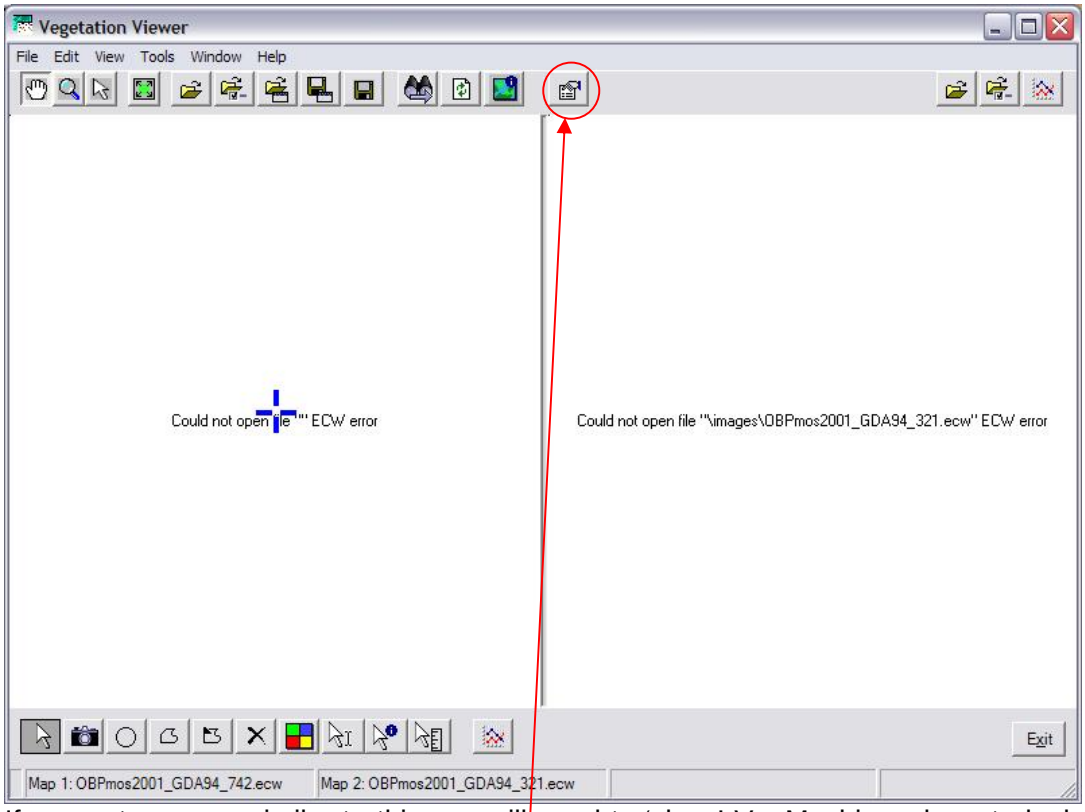
Top Right Toolbar:

When *image* is open on right hand side. When *graph* is open on right hand side

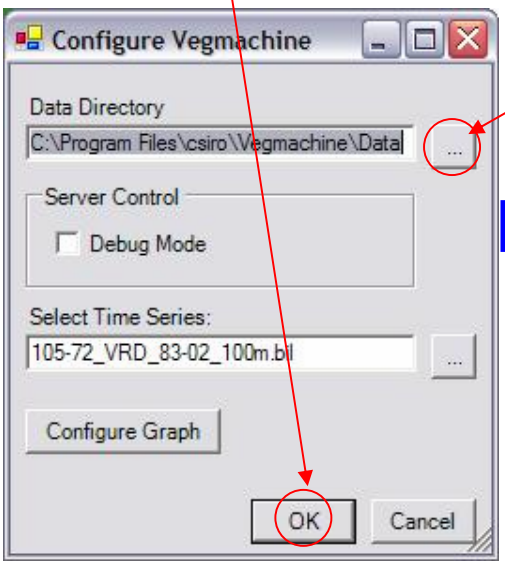
Bottom Right Toolbar:

Always use the Exit button to close down VegMachine, as it will shut down all operations, particularly the VegMachine server (small black screen) that is operating in the background.

Error - No Images:



If you get an error similar to this you will need to 'show' VegMachine where to look for the files on your computers directory. Select the 'Configure' tool, and another window will appear, you can either type in the exact words as listed in bold below, or select this button. If you typed the Data Directory in, then select "OK'.

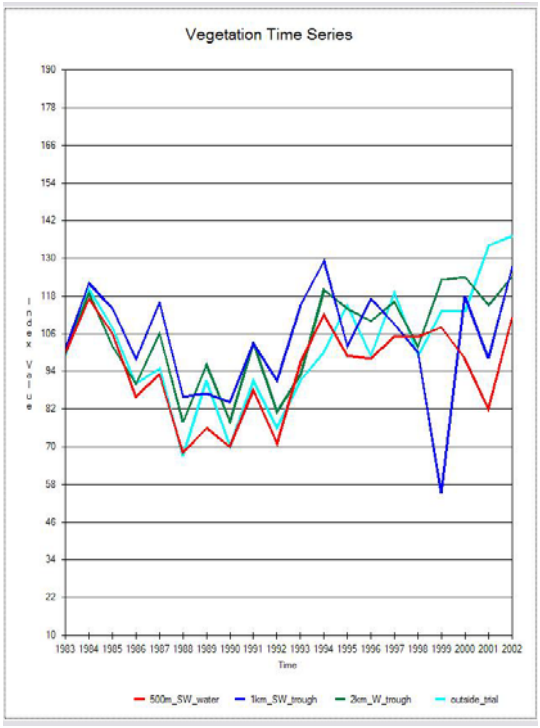


If you selected the button, another window will appear and you need to select down through your computer directory structure to the path listed below and select 'OK' to return to the 'Configure Vegmachine' original window and select 'OK' again.

C:\Program Files\csiro\VegMachine\Data

Interpreting the Graphs:
Using this graph as an example, interpretation of the graph and knowledge of the land type and past management practices can allow the user to make a judgement as to the state of land condition. The four areas chosen for time trace analysis (graph) were probably part of one large paddock watered at a number of points (man-made and natural). Since the changes in infrastructure with the introduction of the Mt. Sanford trials, the distance to water and grazing pressure for some of the areas has changed.

Some initial observations can be made, all sites were adversely affected by moderate to heavy stocking rates and average to below average seasons for the years prior to 1991. A series of good seasons, changed management strategy and grazing pressure have led to an overall general increase in vegetation cover since 1991.



The site represented by the red line has had a history of grazing due to its proximity to the drainage system and proximity to the Bore (4km). With the changes in fences and waters it is now only 500m from water, and the cattle probably graze between the trough and drainage line. Note the dates represented by the cover and trend image (1998 to 2001) and comparing with the graph, it can be seen that the cover was lower than most other areas and cover decreased over this time (as an average). Hence the red colour on the image for this area. Based on information from the cover trend image, graph, and some knowledge of the area of concern, the user can build an idea of the amount of cover and type of cover (perennial or annual) that could be expected on the particular land type in question. This area would seem to have a history of grazing more then the other sites from 1986 onwards. Cover levels increased during the 1990's and cover levels remained relatively the same, although the poor wet season of 2001 caused a drop in cover, only to recover to a higher level in 2002. This type of response would indicate an area that is currently in fair to poor condition due to its past grazing and seasonal responses, but has shown some increase in cover through the good seasons, hence some recovery of preferable species may have occurred. It is accepted that there will be areas of higher usage due to close proximity to a watering point. The cover trend images will help indicate if the area indicated increases, decreases or remains the same, hence monitoring the extent of utilisation over the time period analysed eg 1998 to 2003.

The area indicated in blue is slightly further from water than the red area. Until the changes in infrastructure, the blue area was of similar distance to water as the red area, but didn't have the drainage line and local water hole to attract the cattle to graze as the red area offered. This area was not utilised as much as the red area until the mid 1990's, and a fire in 1999 caused a reduction in cover, but the area responded well to the following good seasons, increasing in cover to nearly its highest level, although some of this could be attributed to an annual flush, possibly sorghum. This

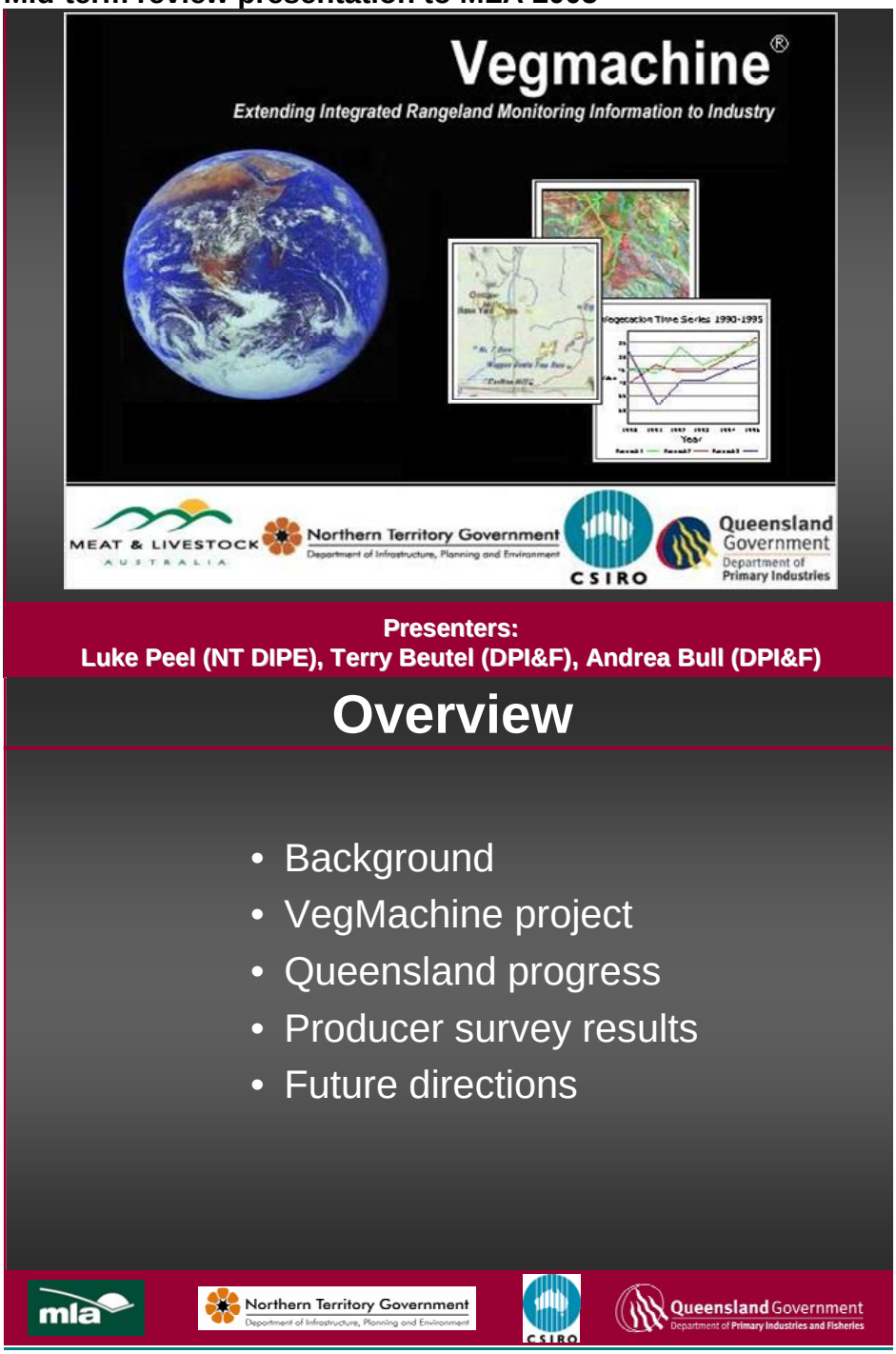
area would be currently in fair condition, given its past utilisation levels and response to good seasons indicating an overall increase in cover for the past 11 years. Considering its proximity to water cover levels are indicating that grazing levels are not reducing overall ability of the land to respond to the seasonal rainfall. Hence the stocking levels for this area could be perceived to be correct given the type of seasonal response to rainfall.

The green and light blue lines indicate areas of average to above average cover, with reasonably steady (green) to increasing (light blue) cover levels over the time period analysed (98-01). Historically these areas were subjected to similar grazing pressure as the other sites but due to the management changes in 1991/92 and favourable seasons, these sites have responded better than the red and blue sites. Due to the graphs for these two sites indicating a steady increase generally and fluctuations in the graph are not severe, this would indicate a viable stocking rate given all the conditions that were present after the management change. The reduced fluctuations indicate a fair to good presence of perennial plants providing a reasonably stable base level of cover, hence the sites would be deemed in fair to good condition.

The example provided does not show the regional average for the land type investigated. Users should include the regional average response for this land type to provide extra information and basis for understanding how well these actual sites are performing compared with the greater average. Knowing the effective rainfall season, management practices and regional land cover response for the land type investigated allows users a good understanding as to how the land is performing for short and long term periods.

Appendix 11 VegMachine Presentation

Mid-term review presentation to MLA 2005



Background & Components

Background:

- Based on 10 years of research and development (TS CRC, L&W Audit)
- Satellite data & analysis methods – robust and repeatable
- Producer interaction & feedback – 2 way communication
- Aim of VegMachine: Realise benefits for Producers

Components:

- Data
- Software
- People & Extension

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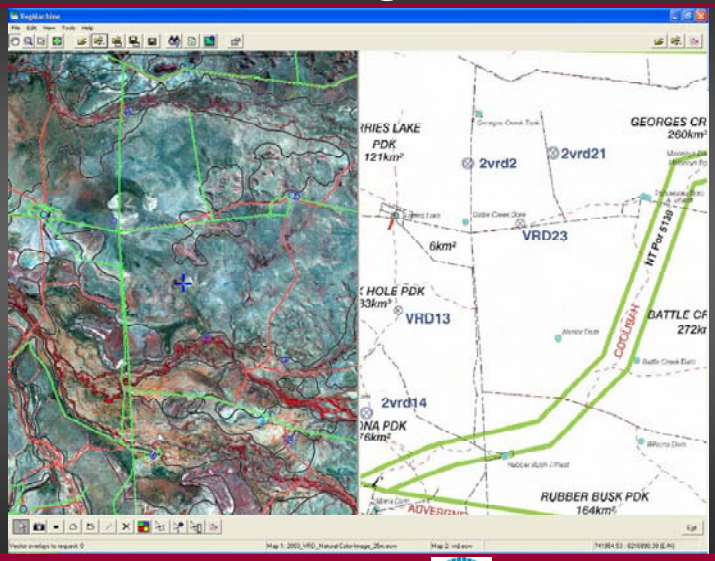
What is VegMachine



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People

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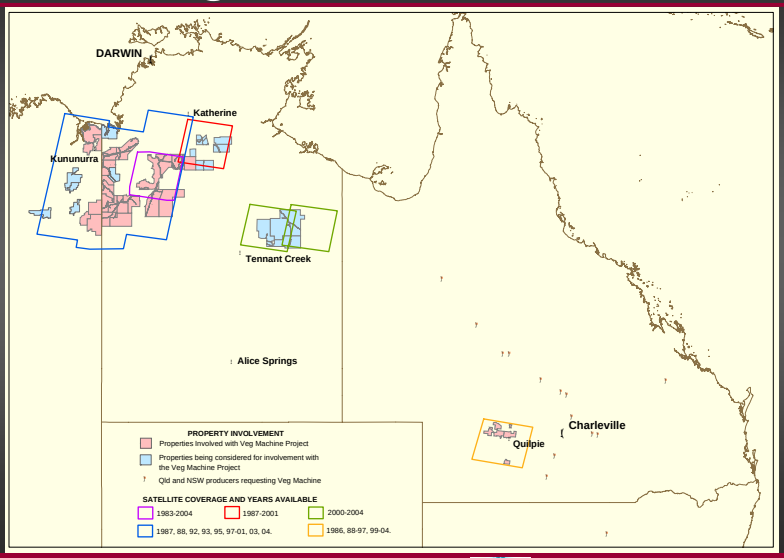
VegMachine Clients



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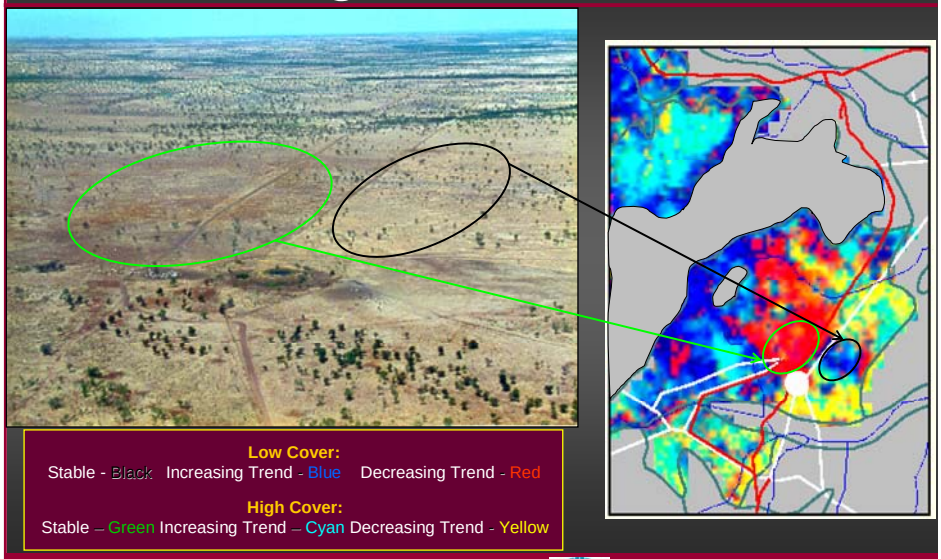
What VegMachine Indicates



Low Cover:
Stable - Black Increasing Trend - Blue Decreasing Trend - Red

High Cover:
Stable – Green Increasing Trend – Cyan Decreasing Trend - Yellow

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Objectives

1. Provide producers with the VegMachine software package so that remote sensing pasture condition information can be used in grazing management representing various biophysical environments and beef operations.
2. Ensure that pastoral properties in the VRD and southwest Qld can use VegMachine to benefit from the application of satellite-based monitoring products for pastoral land management.
3. Develop a land condition monitoring program in southwest Qld, based on time-series Landsat data and ground data related to landscape function.

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Milestones

Milestone	Due date	Summary	Done
Commence project / establish working group	09/02	Core VegMachine contract signed (03/03) VegMachine project coordinating group meet (07/03)	✓
DPIF workplan developed	10/02	DPIF contract (including workplan) signed (07/03)	✓
Develop prototype software.	07/03	First property receives software (07/03)	✓
Budget and progress report accepted by MLA		Budget and progress report submitted to MLA (07/03)	✓
Host a monitoring and field workshop in Qld	12/03	Monitoring and field workshop held in Quilpie (04/04)	✓
Final VegMachine product ready.	06/04	Final version of VegMachine was completed and distributed 11/04.	✓
Budget and progress reports accepted by MLA	07/04	Budget and progress report submitted to MLA (07/04).	✓
Over 20 Producers trained in VegMachine use	07/05	30 Producers supplied VegMachine software and data products and trained in VM use (06/05)	✓

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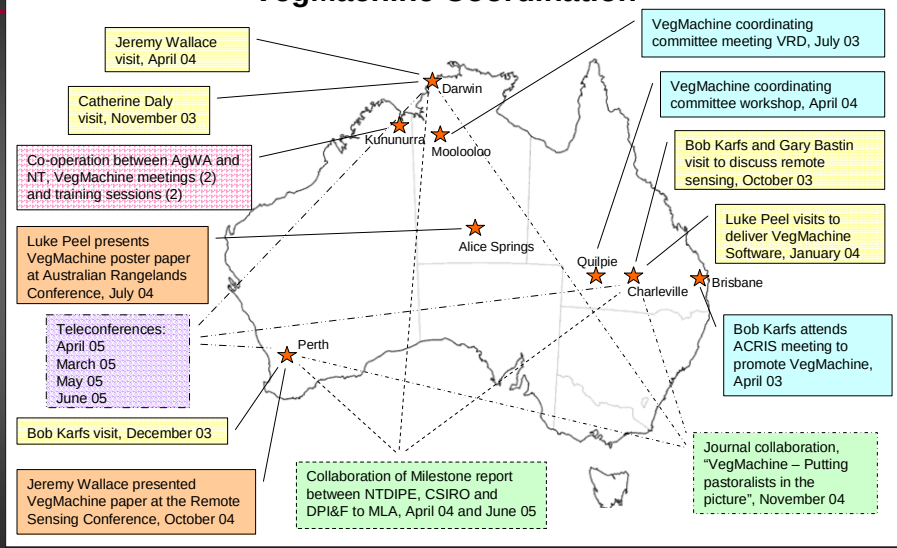
VegMachine Coordination



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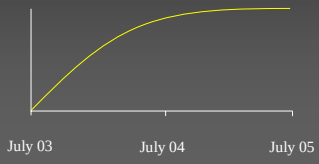
Technology Transfer

Operating independently within a year



The big lessons…

- Early support
- Producer engagement
- Data management

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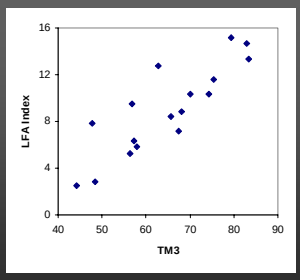
Monitoring in Queensland

The system…

- 40 sites for LFA & cover (2004)
- Tested 4 satellite cover indices
- Repeat monitoring (2005)
- Data sharing



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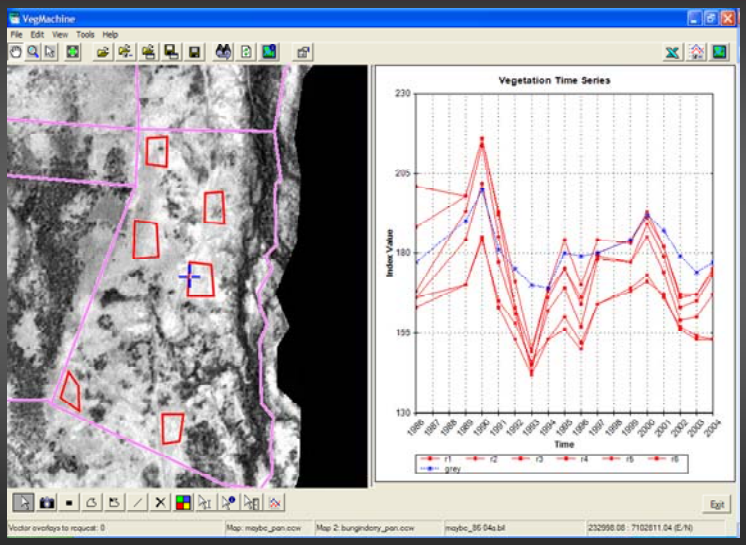
Case Example - Qld



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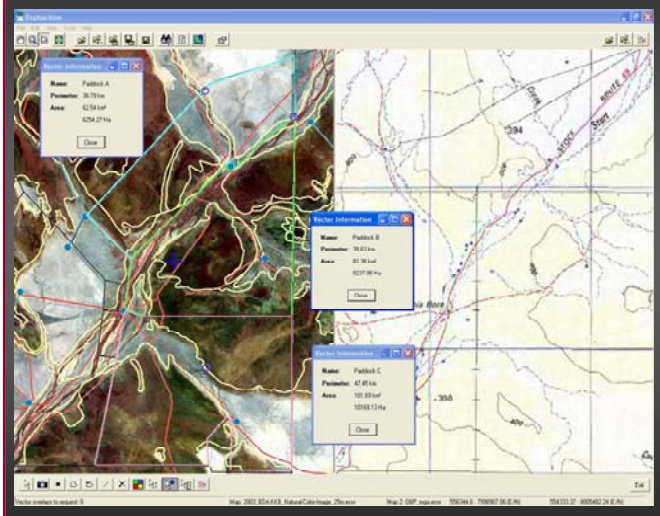
Case Example - NT



Information:

- Satellite products
- Land types
- Infrastructure
- Topography

Assist in Property Management

- Placement of infrastructure
- Stocking levels
- Monitoring
- Short & long term planning

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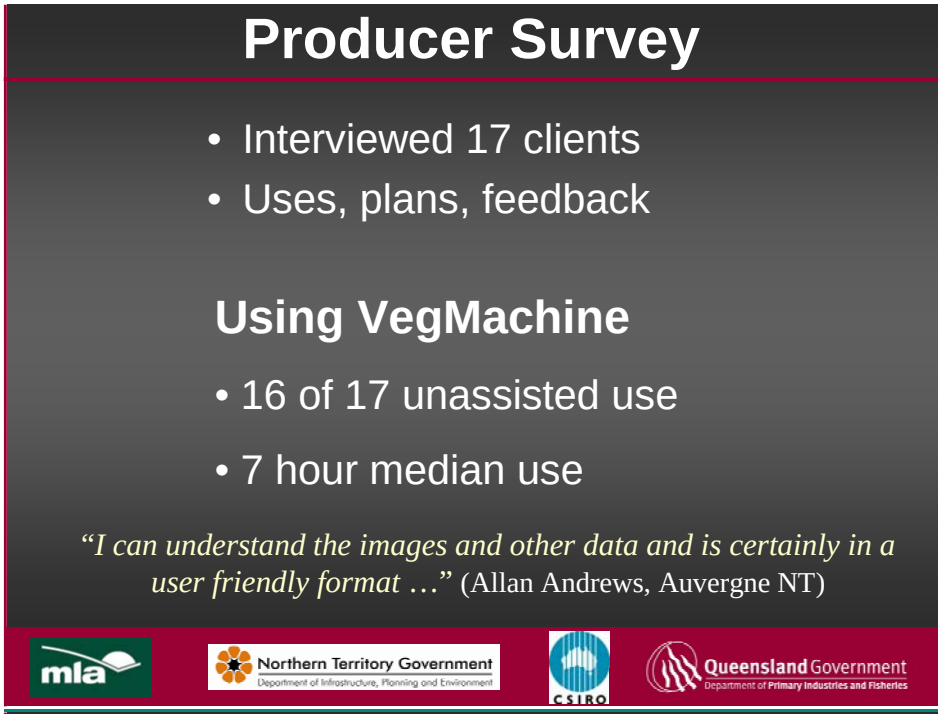
Producer Survey
• Interviewed 17 clients
• Uses, plans, feedback
Using VegMachine
• 16 of 17 unassisted use
• 7 hour median use
"I can understand the images and other data and is certainly in a user friendly format …" (Allan Andrews, Auvergne NT)
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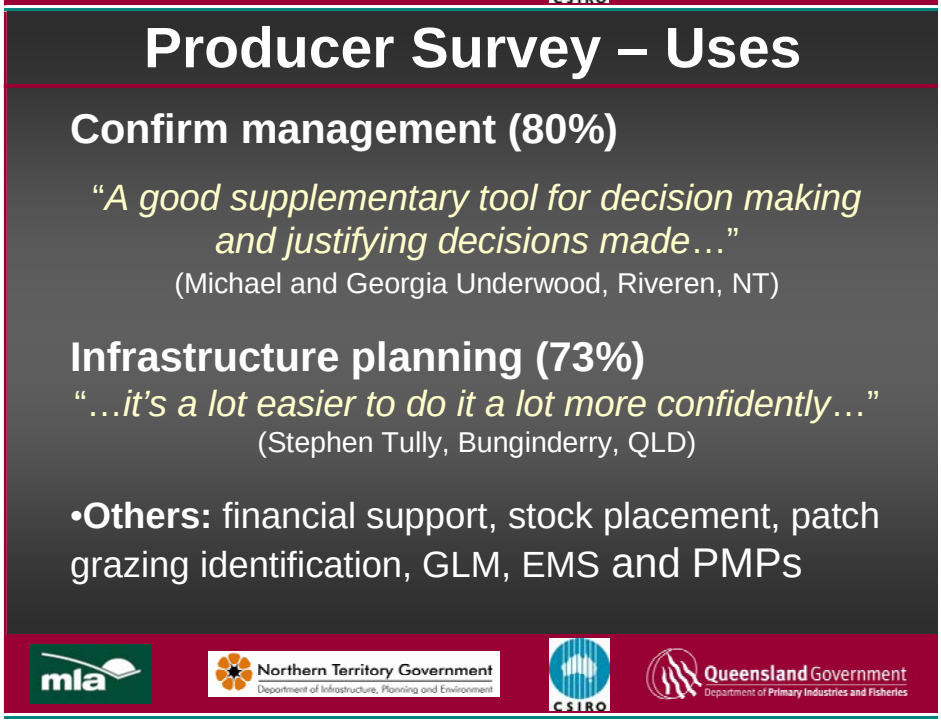
Producer Survey – Uses
Confirm management (80%)
"A good supplementary tool for decision making and justifying decisions made…"
(Michael and Georgia Underwood, Riveren, NT)
Infrastructure planning (73%)
"…it's a lot easier to do it a lot more confidently…"
(Stephen Tully, Bunginderry, QLD)
•Others: financial support, stock placement, patch grazing identification, GLM, EMS and PMPs
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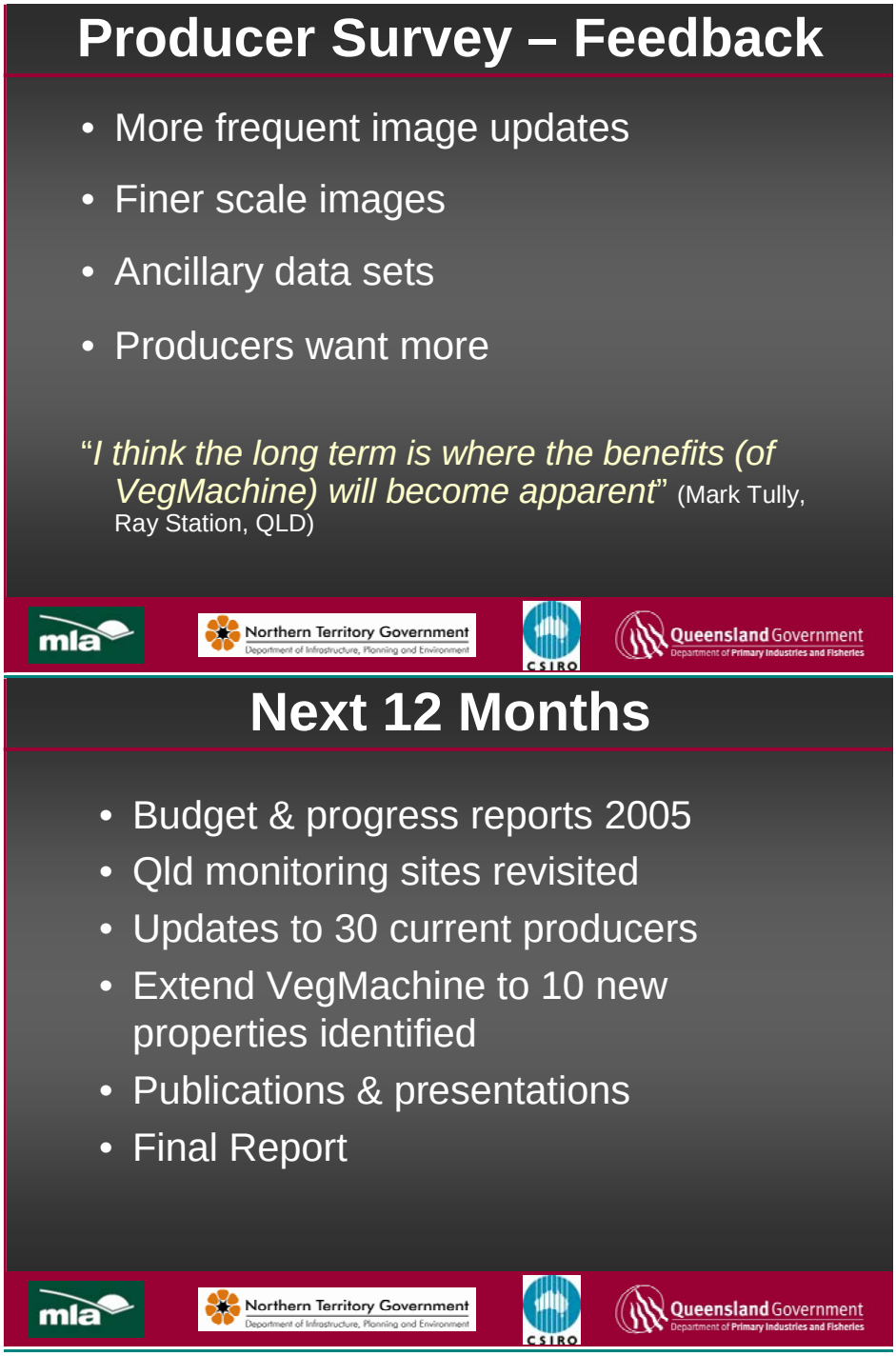
Producer Survey – Feedback
• More frequent image updates
• Finer scale images
• Ancillary data sets
• Producers want more
"I think the long term is where the benefits (of VegMachine) will become apparent" (Mark Tully, Ray Station, QLD)
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Next 12 Months
• Budget & progress reports 2005
• Qld monitoring sites revisited
• Updates to 30 current producers
• Extend VegMachine to 10 new properties identified
• Publications & presentations
• Final Report
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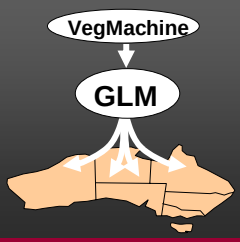
Future Directions

VegMachine National

- *ER Mapper*
- VegMachine online
- GLM extension
- Service Northern Australia
- Potentially Australia-wide



Supporters

- NT Landcare Council
- Kimberley NRM
- NT Landcare Council
- WA NRM R'lands Co-ord Grp
- Kondinin Group
- South West NRM
- Maranoa-Ballonne C'ment Mgt
- Bohemia Downs Pastoral Co

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The Future

Producers can demonstrate responsible stewardship of the land while increasing enterprise profitability

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