NRM SPATIAL HUB

The NRM Spatial Hub - underpinning better management decisions in the rangelands

Final Report, April 2016

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EXECUTIVE SUMMARY

The NRM Spatial Hub (the Hub) gives rangeland managers the capability to map, plan, analyse and monitor their properties infrastructure, land resources and ground cover to improve pastoral and natural resource management. The world-first technology underpinning the Hub will contribute significantly to the profitable and sustainable management of Australia's rangelands.

The Hub combines the latest cloud computing and geospatial mapping technologies with world-leading time-series satellite remote sensing, in a way that's not been available to individual landholders before. For the first time, pastoralists can use and compare their data with government data in a secure, consistent and interactive way.

Users can now analyse and report on seasonal trends in ground cover within a paddock or across their entire property in less than 30 seconds. This is an Australian first and has been acknowledged by members of the global scientific community as a breakthrough in sustainable agriculture. In January 2016, the Hub was the focus of a front page article by NASA titled "*Satellite data helps Australian ranchers meet the rising demand for meat in a changing world*".

The NRM Spatial Hub is the result of close collaboration between more than twenty Australian organisations. Stage one was supported by the Australian Government National Landcare Programme (Sustainable Agriculture Innovation Grant). Our partners include the Australian Rangeland NRM Alliance (14 NRM Bodies), Meat and Livestock Australia, the QLD, NSW, SA, WA and NT State Governments, the QLD Remote Sensing Centre and Joint Remote Sensing Research Program, TERN AusCover, CSIRO, Geoscience Australia, and the Cooperative Research Centre for Spatial Information (CRCSI).

Stage one of the Hub commenced in April 2014 with what were considered ambitious goals at the time - to develop the technology and test it on 40 properties, and to raise the level of knowledge on a further 240 commercial enterprises.

Due to the rapid development of the Hub infrastructure and the high level of interest shown by the grazing community, comprehensive demonstration of the technology was completed on more than 100 properties by late 2015, and more than 300 properties covering an area of more than 50 million hectares were using the system at the completion of this report in April 2016.

In a survey of landholders involved with the project, the Hub received the following feedback:

- 90% of respondents said they found the Hub easy to use.
- 95% said the Hub has the potential to measurably improve the productivity, profitability and sustainability of their property.
- More than 50% felt the Hub would save them between 10 and 30 labour days a year.
- 75% said it would measurably increase safe carrying capacity through better pasture utilisation.
- 72% rated this type of technology as important to making their business both viable and sustainable in the future.

The survey also revealed that about half the respondents considered their properties to be around 50% developed. If we took an average property size from our sample and assumed they used the Hub technology to guide their future investment in infrastructure development, they could conservatively increase annual revenue by more than 35% through improved pasture utilisation and increased stocking rates. This increase does not include the improvements in property value, risk management and labour savings that would also result.

While the NRM Spatial Hub is still in its infancy, our experience working with over 300 properties has clearly demonstrated the capacity to bring together a range of new technologies that can significantly improve how both big and small landholders invest in and manage their properties.

The initial development has been focused on property planning and sustainable grazing development. However, numerous other applications have been identified by users including drought assessment, regional and national monitoring and reporting, biodiversity management, fire management, pest and weed management, emergency management, and carbon markets.

There are opportunities for benefits across the full spectrum of grazing businesses, whether they are corporate, family or indigenous. The information flowing from the Hub tools allow land managers to make better investment decisions which will increase profitability and sustainability, and improve environmental outcomes.

The NRM Hub provides a step change in our capacity to manage and monitor Australia's Rangelands. In this way, it is a "national asset" that allows individual property managers, NRM bodies, industry, environmental and indigenous organisations, government and the broader community to make better informed decisions.

The challenge now is to transition to a self-sustaining business model that continues to foster collaboration, and provide long-term opportunities for industry growth and enormous efficiency gains across government.

The next stage of the NRM Spatial Hub is looking very exciting.

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BACKGROUND

The Rangelands cover more than 80% of Australia's landmass, and are home to less than 3% of the population. This provides challenges to land management and the uptake of new technologies. These challenges include the small size of the workforce, the relatively poor communication and internet services, and a lack of technical extension staff to build awareness and support land managers adopt the new technologies.

It is therefore crucial that any new technologies account for this by being inherently easy to use, require minimal training, be low cost, be robust even on weak internet environments, and offer real productivity and sustainability benefits to grazing land managers.

Australia's Rangelands are subject to long and profound climatic cycles. This means changes due to management decisions can be slow to reveal themselves, and hard to separate from natural variations. The huge areas involved make on-ground measuring and monitoring land health very difficult and financially unviable. The opportunity to use 30 years of existing satellite imagery to more accurately track these changes has always had enormous potential, however the sheer complexity of accessing and integrating the existing data from a suite of sources has made this impossible for even the most ambitious land manager.

That is until now.

The NRM Spatial Hub has overcome these technical challenges and proven the latest mapping technologies and satellite imagery does provide extremely useful information that can inform land managers who are making practical management decisions.

The key objectives of the Hub in its first two years were to:

- Build and demonstrate the necessary on-line spatial information systems to enable the development of best-practice (standardised) digital property and grazing plans for any location in Australia.
- Accelerate the development of simple dashboard tools to allow non-specialist users to access, analyse and visualise paddock-scale time-series indicators of land condition and trends.
- Train and provide technical support to land managers.
- Demonstrate the Hub's power so land managers can better understand and interpret spatial and temporal ground cover patterns. Then use this information to set ground-cover benchmarks and examine how those patterns are influenced by grazing decisions and climate variability.
- Evaluate other innovative uses of this information with pastoralists and land managers
- Evaluate the Hubs potential to better model biomass and ground cover products.

Added to these achievements, and with the support of extension and technical specialists, the Hub demonstrated its capabilities in each of the 14 NRM regions. It also developed best practice on-line digital property planning, and incorporated world-leading time-series remote sensing of ground cover that overcomes significant barriers to long-term assessment and management of landscape condition and productivity.

These objectives could not have been achieved without significant collaboration. The success of the Hub is the result of more than twenty Australian organisations working together to share ideas and technology. Our partners include the Australian Rangeland NRM Alliance (14 NRM Bodies), Meat and Livestock Australia, the QLD, NSW, SA, WA and NT State Governments, the Joint Remote Sensing

Research Program, TERN AusCover, CSIRO, Geoscience Australia, and the Cooperative Research Centre for Spatial Information (CRCSI).

The Hub received significant support through a Sustainable Agriculture Innovation Grant from the Australian Government National Landcare Programme.

The NRM Hub provides a step change in our capacity to operate, monitor and manage Australia's Rangelands. In this way, it is a "national asset" that allows individual property managers, NRM bodies, industry, environmental and indigenous organisations, government and the broader community to make better decisions.

Every component of the NRM Hub is based on the best-available science. It brings together both internally developed and off the shelf technologies to provide an open platform for organisations to build-on, and re-purpose into the future.

METHODOLOGY

Stage 1 of the development and application of the NRM Spatial Hub (the Hub) was structured according to 11 key activity areas, each of which are described below.

1. Development of the On-line Property Planning and Information System (OPPIS) including:
    a. Development of technical specifications for the Hub and validation with NRM Regions and a sample of land owners
    b. Release of specifications as a tender to the spatial technology development industry
    c. Development of the Hub in an "agile manner", and validation of each use case with a dedicated end user groups
    d. Delivery of the following 5 use cases for property planning
        i. Infrastructure Mapping
        ii. Land Type Mapping
        iii. Grazing Circle Analysis
        iv. Water Infrastructure Planning
        v. Reporting and Mapping
2. Procurement of high resolution imagery for infrastructure and land type mapping including:
    a. A review options for high resolution imagery data to meet the needs of project team members and Hub end users for infrastructure mapping
    b. Procurement of imagery and provision of appropriate access to relevant users
3. On-farm training in data management, farm mapping, mobile devices, GIS, GPS, Remote sensing analysis, on-ground monitoring including:
    a. Providing an overview for farm planning of current spatial technologies relevant to data management, farm mapping, mobile devices, GIS, GPS, Remote Sensing, image visualization techniques, analysis and on-ground monitoring methods.
    b. Development of training modules for the Hub as use cases become available online
    c. Undertaking engagement, awareness and training through extension workshops in each region to highlight capability and promote uptake of the NRM Hub
4. Development of a time-series satellite imagery work bench and analysis tools to allow land managers to access and analyse key remote sensing datasets including:
    a. Identification and review suitable products required using time series imagery. Ensuring these products are suitable for a variety of users based on input from farm planning and extension workshops.
    b. Integration of remote sensing data products and analytical tools to allow the delivery of the following two use cases in the Hub
        vi. Land Condition Analysis
        vii. Sustainable Carrying Capacity Analysis
5. Establishment of NRM-Hub trial sites within 14 rangelands NRM regions including:
    a. Identification of trial sites in each of the 14 regions to use as demonstration sites for the Hub
    b. Initial targeting to 40 properties covering 60,000km^2
    c. Selection in consultation with regional bodies and other stakeholders
6. Production of digital farm and grazing plans
    a. Completion of desktop Grazing Plan assessments for 40 properties, allowing properties to understand safe carrying capacity limits for each paddock
7. Demonstration of time-series satellite products in relation to regional benchmarking of ground cover including:

   a. Processing of full Landsat time-series fractional cover products for each demonstration site.
   b. Production of 3 monthly ground cover composites for the complete archive back to 1987
   c. Generation of land condition “products” for analysis and review during farm plan and grazing plan activity (Activity 6)
   d. Development of demonstration evaluation and reporting products.
   e. Linking with Activity 4 for delivery through the NRM Hub.
8. Evaluation and demonstration of the potential for integrating pasture biomass and ground cover products through an aligned Meat and Livestock Australia project including:
   a. A science review to provide stand-alone reports and input to Regional Extension Workshops
   b. Completion of a national expert workshop, science review and grazing trial analysis on remote sensing and modelling of pasture biomass, and ground cover
   c. Provision of recommendations to government, research communities and industry (MLA) on Research, Development and Extension (RD&E) strategies.
9. Regional extension and workshops, including:
   a. 2 day workshops in each region with a target of approximately 20 land managers to conduct demonstrations and training on the Hub.
   b. Undertaken after farm plans and scheduled to align with other regional extension wherever possible.
10. Evaluation of the usefulness of capabilities to end users and the innovative use of the tools and information at a number of scales (property to national)
   a. Formal evaluations and feedback collated through questionnaires completed during farm planning, training and extension workshops
   b. A consultation and review process undertaken with Regional NRM staff in each region.
11. Communication Strategy, Education and Communication Material
   a. Communication Strategy to address awareness and understanding of government, regional bodies, land managers and community
   b. Education and Training material produced for the Hub.

RESULTS

The following results were obtained against each of the activities listed in the preceding methodology section:

1. Development of the On-line Property Planning and Information System (OPPIS)

The Online Property Planning and Information System (OPPIS) had the first 'beta' release to around 40 users in April 2015, and was deployed to new users as the modules were developed. The OPPIS is now fully operational, with all 7 planned use cases (or modules) implemented, tested and improved based on user design and feedback. The current use cases include:

i. Infrastructure Mapping
ii. Land Type Mapping
iii. Grazing Circle Analysis
iv. Water Infrastructure Planning
v. Reporting and Mapping
vi. Land Condition Analysis
vii. Sustainable Carrying Capacity Analysis

All use cases underwent evaluation by key technical and producer user groups to ensure both accuracy and usefulness, and each use case in the system can be used both independently or as part of a sustainable carrying capacity planning process. This has been a very effective process that has led to the deployment of a very user friendly, easy to use system.

The time-series remote sensing capabilities (use case 6) have been developed well-beyond our initial expectations through exceptional collaboration with the Qld Remote Sensing Centre and TERN AusCover – with users having direct access to 30yrs of times-series data and world leading science products in a matter of seconds through a mobile phone connection. Through further collaboration with Geoscience Australia and our developers, the capabilities are being extended even further to include access to every new Landsat scene (every 16 days) across Australia on a three monthly rolling window. Putting these remote sensing capabilities in the hands of property managers is being acknowledged by NASA as a world-first. In January 2016, the Hub was the focus of a front page article by NASA titled "*Satellite data helps Australian ranchers meet the rising demand for meat in a changing world*".

Training has been delivered to land owners and NRM extension staff in all 14 rangelands regions. Feedback to date has been overwhelmingly positive, with our recent survey of users indicating that 90% of respondents found the system easy or moderately easy to use. A basic description of OPPIS can be found on the Hub website: http://www.nrmhub.com.au/mapping-2/.

The capabilities that have been developed through this project are also being considered as a primary platform for numerous other applications including: Precision Agriculture, banking, carbon trading.

A screen shot of the current online system can be found below.

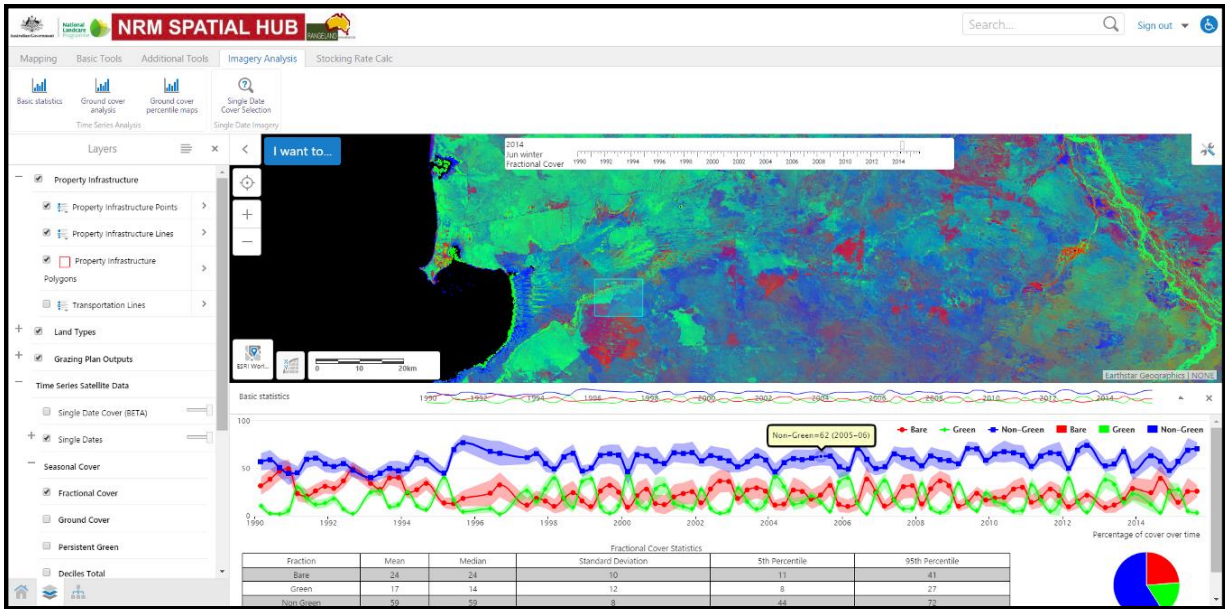

Figure 1. The OPPIS user interface showing a time-series fractional cover graph for a user-defined reporting area.

2. Procurement of high resolution imagery for infrastructure and land type mapping

Free imagery sources were used where possible. However, where these free sources did not contain up to date or high resolution data, the team used DigitalGlobe satellite imagery services for on demand access to high resolution imagery (https://services.digitalglobe.com). The imagery available through this service is generally less than 12-18 months old and very high quality (<=0.5m resolution). Access to this data as a service simplified the need to purchase large volumes of expensive data which may not have been required everywhere. Significant opportunities have been identified in increase access and reduce costs to users through coordinated access to commercial imagery archives.

Figure 2. An example of the high resolution imagery made available for mapping.

3. Training in data management, farm mapping, mobile devices, GIS, GPS, Remote Sensing analysis, on-ground monitoring

Training material for offline use was completed in August 2014 and was actively used on properties in QLD for one-on-one training. Lessons learned in Qld, such as providing very specific examples of tools and workflows, were used to revise material for broader use prior to moving into other States where this material has now been delivered using on-line approaches. One-on-one training has been undertaken with more than 125 individual property owners and managers.

Training material for OPPIS, including online, offline and video material, is available to all project participants and users; a YouTube channel has been created and training videos have been uploaded and updated here for use by all users. At the time of this report, the online videos had been viewed over 500 times, with an additional 300 memory sticks containing these same videos as well as other training material delivered to land owners and NRM extension staff for use as needed to avoid excessive use of limited download allowances in remote regions. The latter was a major issue in remote areas using satellite internet connections.

4. Development of a time-series satellite imagery work bench and analysis tools to allow land managers to access and analyse key remote sensing datasets

The Hub initiative has developed capabilities that are being acknowledged by NASA and others as world-first. For the first time, a user can analyse 30 years of seasonal time-series imagery at sub-paddock levels in less than 30 seconds, providing entirely new insights for most land managers. These capabilities are being extended even further to include access to every new Landsat scene (every 16 days) across Australia on a three monthly rolling window.

The development of these new time-series satellite imagery analysis tools for land managers have only been made possible through a close collaboration between the project team, Qld Remote Sensing Centre and the Joint Remote Sensing Research Program, TERN AusCover, CSIRO and Geoscience Australia. Importantly, the approach has minimised computational duplication and on-going maintenance costs, maximised data access and shared code development across these organisations. The model of using the Hub's Amazon cloud computing environment (https://aws.amazon.com/) in combination with governments less accessible High Performance Computing environments is now being seen by most as a model for the future.

The requirements for the Spatial Hub project provided a major impetus for the further development of the technology (i.e. Application Programming Interfaces - API) and systems which both the Hub and VegMachine-Online require. An existing API (VegCover) was in development and the requirements of the Hub and VegMachine-Online has fast-tracked the development of this API, enabling access to the services for both visualising and analysing large image data sets. These developments have also included the development and upgrading of the TERN AusCover servers and data storage, including the bringing online of required datasets and web services.

In addition, the NRM Hub contributed new capabilities to the globally popular open source image server, GeoServer. The new capabilities to dynamically serve colour stretched imagery to all GeoServer users around the globe has come from the Hub funded development.

A factsheet describing the products and tools can be found on the Hub website at: http://www.nrmhub.com.au/wp-content/uploads/2015/02/Remote-Sensing-Fact-Sheet.pdf

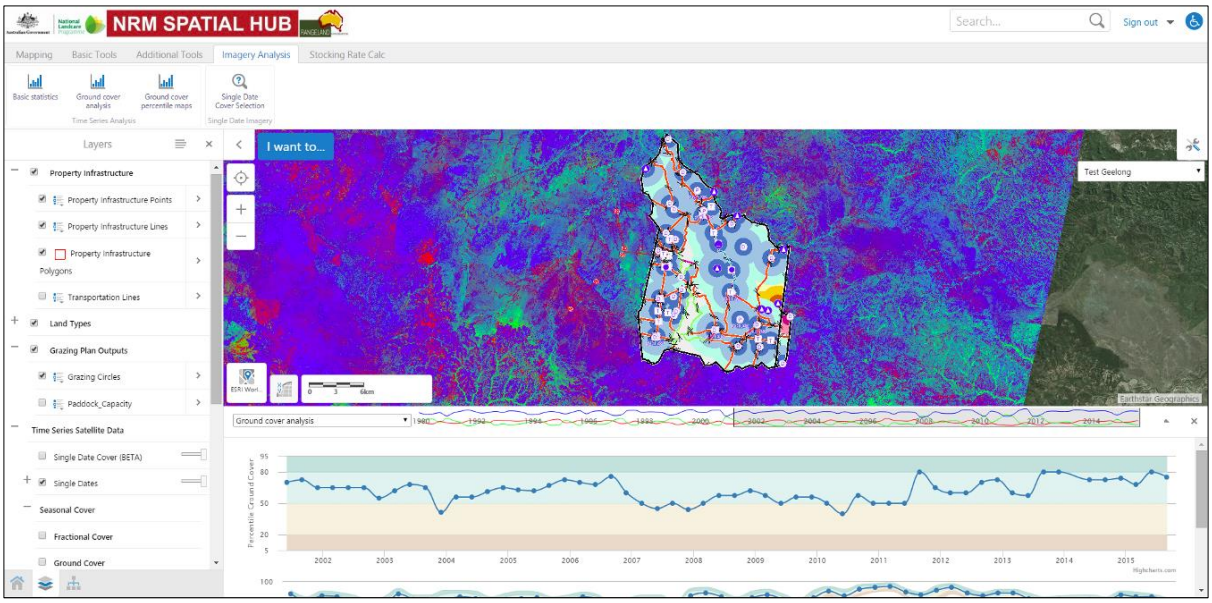

Figure 3. An example illustrating the time-series ground cover data, grazing circles and analysis

5. Establishment of NRM-Hub trial sites within 14 rangelands NRM regions

The "Super-Site" concept originally proposed evolved considerably following the initial project design which was based on a single focus area of groups (or clusters) of properties in each region to minimise satellite imagery processing (each Landsat scene covers ~185km by ~185km). Due to advances in the processing of time-series imagery and close collaboration with the Qld Remote Sensing Centre and TERN AusCover, we were not limited to focusing on groups of properties "clustered" within a few Landsat scenes, but instead were simply able to focus on ensuring a geographic spread across the regions. The resultant spread of demonstration properties required a minimum of 165 Landsat scenes to be processed covering nearly half of the entire mainland. Figure 4. shows the extent of the properties buffered by 50km to allow regional comparisons.

As a result of this expansion in imagery delivery, the Hub was able to scale from providing access to 40 properties, to having over 300 properties in the Hub at the time of this report. In addition, the project has properties covering more than 500,000km^2 (7% of Australia) in the system (as at March 2016), far out scaling the original target of 60,000km^2.

At the time of this report fractional ground cover products had been generated for the entire 30 year Landsat archive for the area in Figure 5. This was based on the QLD Remote Sensing Centre confidence in producing a "persistent green" product that is required to generate the ground cover product. In addition to the ground cover products the Hub currently provides access to a national coverage of fractional cover back to 2008 (Figure 6). Recent advances will see the ground cover product extended nationally in the coming months and made available through the Hub.

The Hub has vastly exceeded the initial expected deliverable, and extended to a "national" capability.

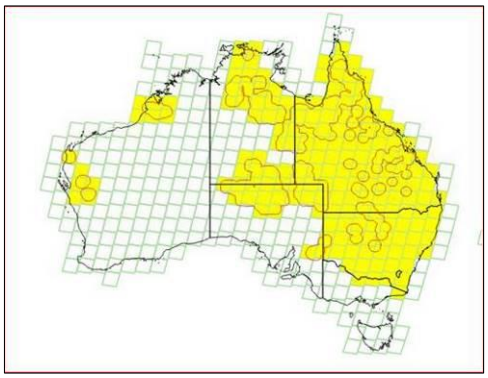

Figure 4. Extent demonstration properties buffered by 50km, and imagery products processed for the initial properties

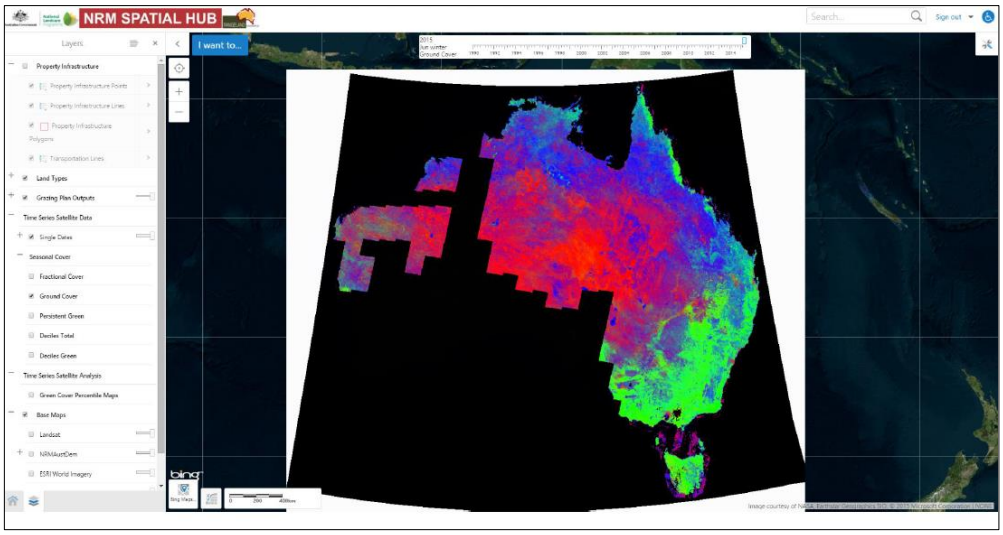

Figure 5. Area of fractional ground cover products generated from the entire 30yr Landsat archive.

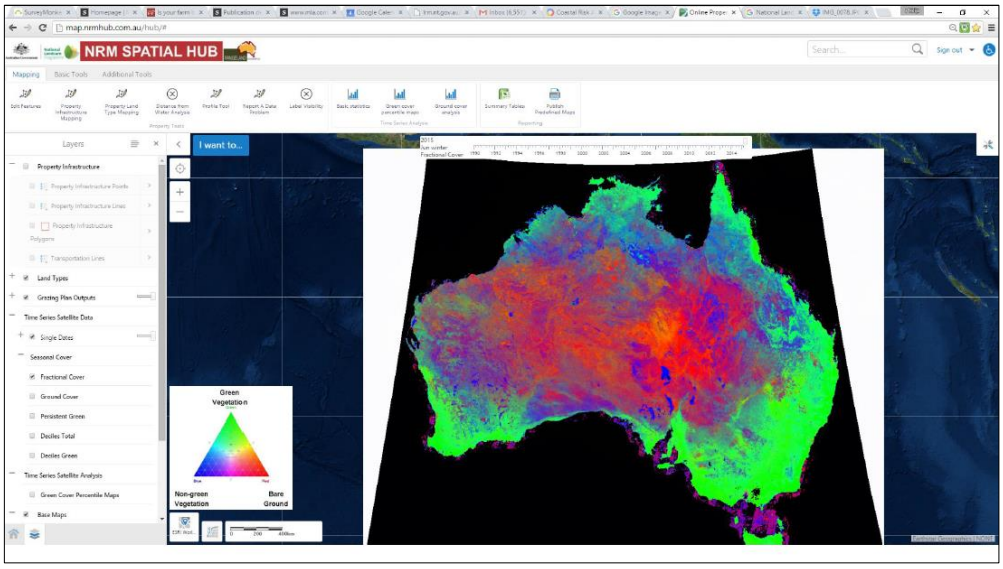

Figure 6. National coverage of fractional cover back to 2008. User can simply adjust the slider for any season.

6. Production of digital farm and grazing plans

Our original target of a minimum of 4 properties in each region and a minimum of 40 properties in total have been far exceeded. The project completed full infrastructure mapping for over 125 properties across the rangelands prior to March 2016, and this number is now increasing weekly as individual property managers are starting to undertake their own mapping of property infrastructure on additional properties. We have also extended the tools to provide users with a detailed asset register for property valuation and depreciation schedules. As at March 2016, over 300 properties were progressively mapping their infrastructure to the level required for a grazing plan to be completed.

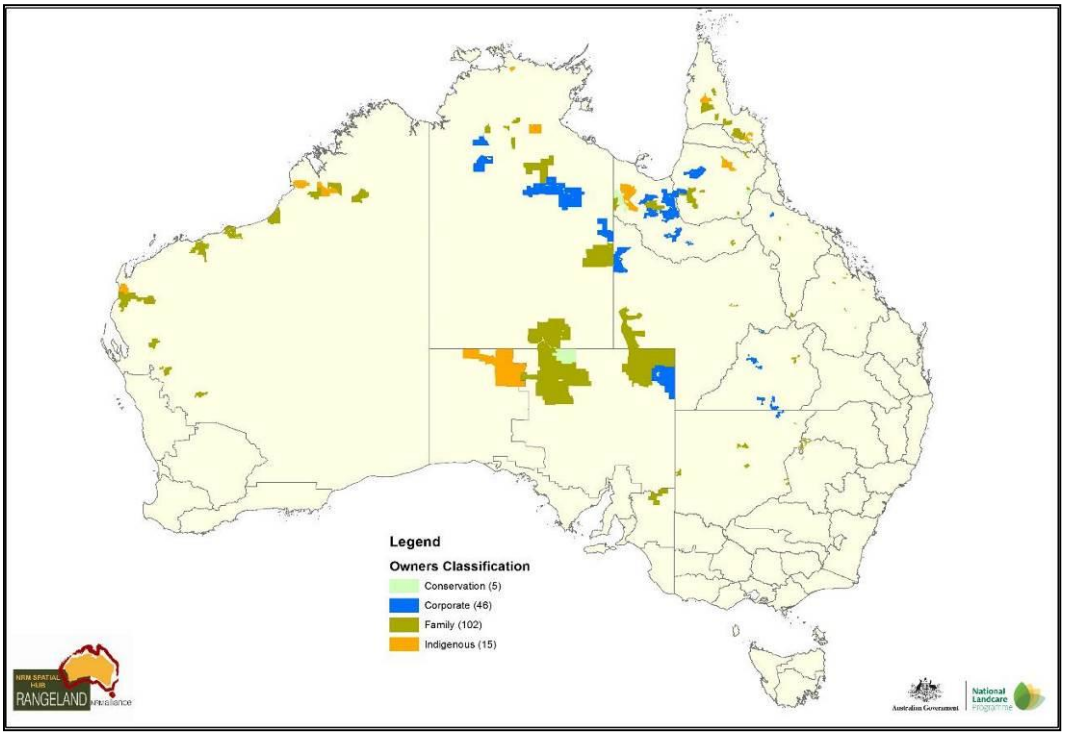

Figure 7. As at March 2016, over 300 properties are progressively mapping their infrastructure to the level required for a grazing plan to be completed

The digital property plans and grazing plans have a number of key elements: property infrastructure; land type mapping; water analysis and planning; land condition assessment (using the time-series satellite imagery) and long term carrying capacity assessment (LTCC). The first two are baseline datasets and the remainder is an iterative process with the property manager. This approach has been closely aligned wherever possible with the Grazing and Land Management (GLM) principles developed by the northern beef industry and the Grazing BMP frameworks.

The water analysis and planning tools have been very well received. Users have been typically running scenarios based on current infrastructure in wet and dry years to assess water availability and to plan new water infrastructure such as dams, troughs and piping using the profiling tools. OPPIS then calculates the net grazable area based on the water circles. Before the incorporation of this tool in the Hub, it was taking between 4 and 16 person hours for a specialist/consultant to create a water grazing circle analysis. With this capability incorporated into the Hub, users can create new scenarios for existing and planned infrastructure locations in minutes.

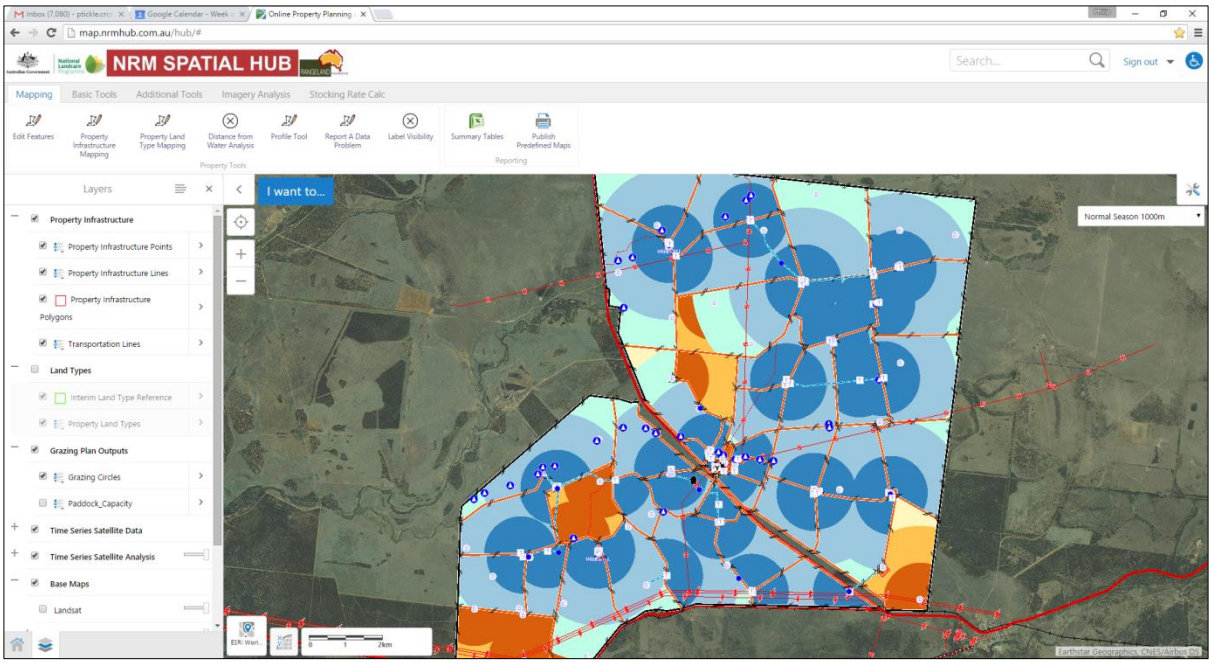

Figure 8. A grazing circle analysis showing perennial (blue) ephemeral (orange) and the estimated paddock utilisation

A land type is generally defined as an area of grazing land that has characteristic patterns of soil, vegetation and landform that is easily recognisable by a land manager. The land types inform landholders about an area's inherent capabilities in terms of its potential productivity, limitations and vulnerabilities. Land type mapping enables producers to identify areas of land that differ in their capability to produce forage (quality and quantity) and to determine how these differences will affect productivity and influence management options. Land type areas form management units for the purposes of property mapping and management planning. See the Grazing BMP Grazing and Land Management Module for more information.

The project has compiled the best available Land Type mapping from State agencies and found that in many cases significant work is required to make it suitable for property-scale carrying capacity assessment. At the present time only QLD has a suitable consistent state-wide Land Types dataset, with some areas of NT also suitable. Other states currently rely on regional scale (1:100,000 – 1:250,000 scale) Land System mapping which does not generally provide the necessary resolution for property-scale planning. Improved mapping has been identified as a national priority by collaborators and through parallel work supported by Meat and Livestock Australia (see activity 8) that needs to be addressed.

Land condition assessment has focused on analysing ground cover at paddock levels and getting the managers to work through an interpretation of how cover is varying relative to management decisions and seasons using the Grazing and Land Management (GLM) Land Condition framework. More details on this are provided in Activity 7.

QLD DAF and NT DPI were commissioned to assist with an assessment of potential carrying capacity for 32 of the properties (24 in QLD and 8 in NT) using the GRASP model. 24 of these are "desktop" studies in consultation with graziers to assess carrying capacity using the GRASP model. A further 8 are more detailed "property development plans" working with the property. Due to significant issues with the quality of existing Land Type data, the availability of data and knowledge to calibrate the GRASP model this work was significantly delayed. It is anticipated this work will run through until mid-2016.

Importantly the Hub Project has highlighted some major challenges in implementing "model-based" approaches to carrying capacity, largely due to the availability of data suitable for use at property scales. While producers have generally been very positive, the work has highlighted the need to take a pragmatic and "simple" approach. This approach must focus on harnessing the manager's knowledge and experience as the starting point, before investing in the data required for more detailed modelling approaches. Most importantly, given limitations of available data it is crucial to ensure that any modelling is validated using the manager's knowledge and experience as the baseline.

The team have responded to this challenge by developing a "safe carrying capacity calculator" module for OPPIS (see figure below). This tool is yet another Australian and likely world first, that allows all land owners with access to the Hub to undertake this work themselves. The tool uses landowner knowledge of past management and regional experience to estimate stocking rates for each land type based on historical knowledge of stock numbers and current land condition for each paddock. The tool then provides carrying capacity estimates for each paddock, along with the potential to increase productivity through improved land condition or infrastructure construction. As such, this tool now provides more than just a grazing plan assessment, but helps land owners strategically assess the effectiveness of different investment decisions on their property.

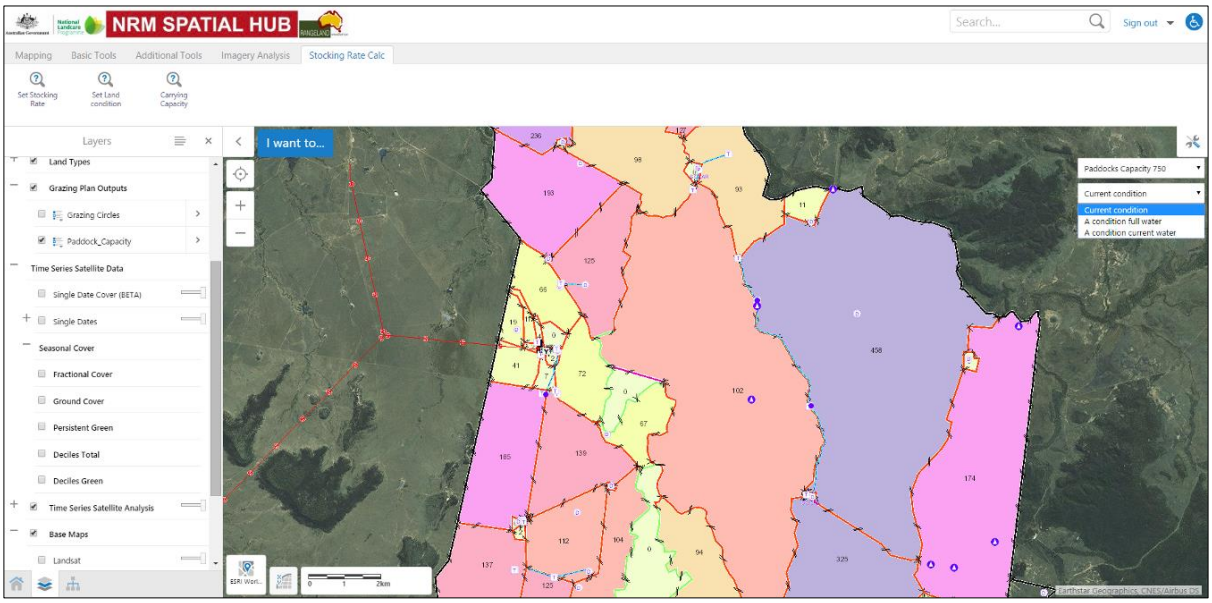

Figure 9. Output map from the safe carrying capacity calculator. Tables are also provided for display and download.

Importantly we have been in constant communication with the QLD Department of Agriculture, Fisheries and Forestry (DAFF) Paddock Modelling team to ensure our work is aligned and coordinated to maximise user uptake and minimise the duplication of work. Most recently we have also commenced discussions with the FutureBeef StockTakePLUS App team to scope opportunities for integrating the technologies in the coming year.

7. Demonstration of time-series products in regional benchmarking of ground cover

Working in partnership with the QLD Remote Sensing Centre the Hub has developed world-first capabilities for land managers to visualise, analyse and report on changes in fractional cover and fractional ground cover for any season over the last ~30 years. For the first time, anywhere in Australia

a user can analyse 30 yrs of time-series imagery at sub-paddock levels in less than 30 seconds. See the YouTube videos under Tutorial 6, parts 1, 2 and 3 for a demonstration of this work.

This work has highlighted the fact that while we are able to detect and quantify changes in bare, non-photosynthetic and photosynthetic cover, and changes in persistent green (woody) cover, only the property manager can reliably interpret what it means from a management perspective in the paddock. For example, in some cases high levels of green cover might relate to weed infestation, and have no relevance to available pasture. With the inclusion of this capability, property managers now have the tools to view and analyse the time-series satellite data, and maximise the value in the information at a property level. The tools allow them to understand how variable their paddocks are in terms of issues such as ground cover, condition and production, and to make more informed management decisions. Moreover, it will provide a mechanism in the future for regional, state and national reporting with direct interpretive input from land owners and managers (a platform for crowd sourcing on-ground information). The figure below is analysis of seasonal ground cover back to 1987 for a reporting area (the blue box), relative to a reference area comprising of a 50km buffer around the reporting area. This can be done for entire property, a single paddock or user defined area such as the example below.

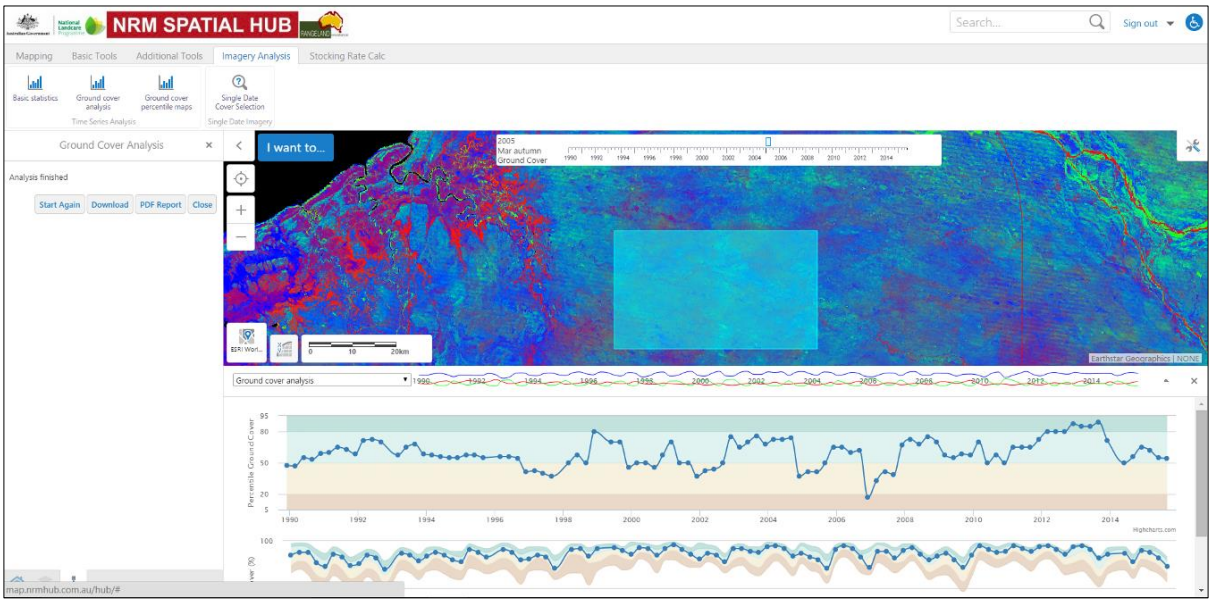

Figure 10. An analysis of seasonal ground cover back to 1987 for a reporting area (the blue box), relative to a reference area comprising of a 50km buffer around the reporting area.

South West NRM have recently provided ~200 property boundaries which have been imported into OPPIS for the Morven, Quiplie, Tampo, Woodstock, Wyandra and Mungallala property clusters. In the coming months these will be used to trial the Hub for benchmarking across properties and inside/outside the clusters. Again, this will be the first time this has been done at this scale in Australia. This initial work will form the basis for a future module in the Hub designed specifically for project and regional reporting of on-ground impacts by government funding agencies across all levels of government.

This project is the first time the vast majority of property managers have been exposed to this type of remote sensing information in a form that is relevant and accessible. It will be crucial to maintain support for raising the awareness of how these products can be used, and just as importantly, how government can take better advantage of property manager knowledge in the future. This interaction will enable other analytical tools to be developed in the future that meet specific needs.

In addition to being able to analyse trends in the condition of paddocks on a seasonal basis for the last ~30 years, we can also look at specific levels of cover every 16 days. The image below shows an area near Morven, Qld in June 2015. The red areas have more than 50% bare ground. The user can set any cover threshold they wish.

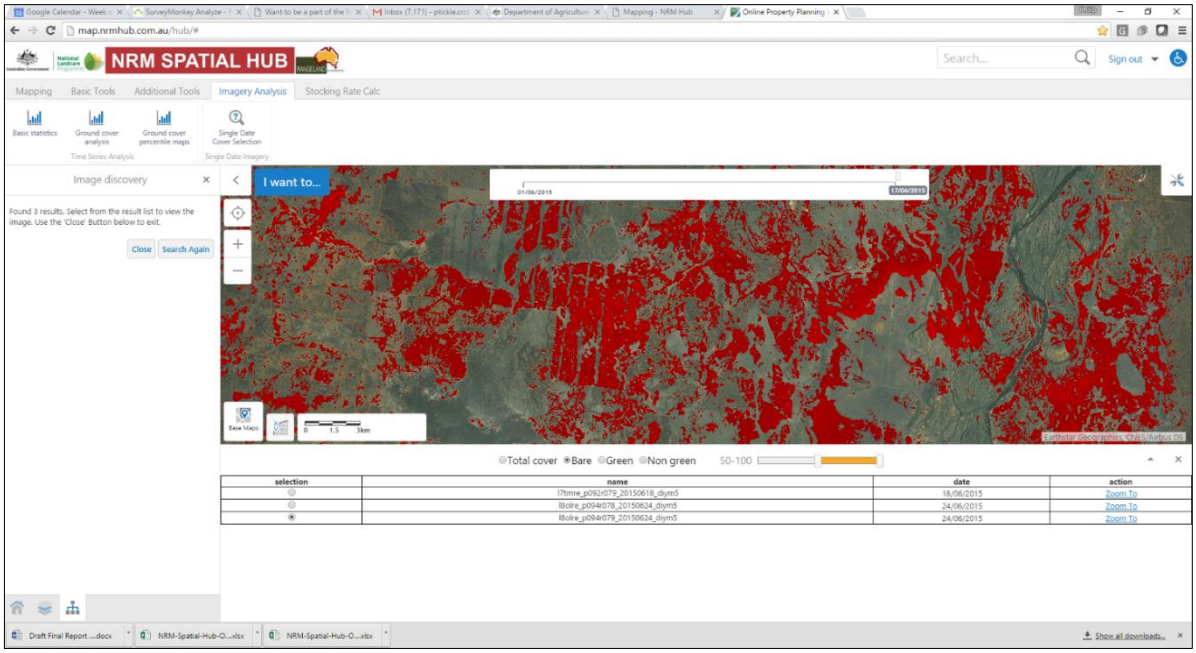

Figure 11. An area near Morven, Qld in June 2015. The red areas have more than 50% bare ground.

8. Evaluation and demonstration of the potential for integrating pasture biomass and ground cover products

Meat and Livestock Australia (MLA) funded a separate, but integrated project to review and demonstrate the latest science in the remote sensing of pasture biomass. The Hub Team hosted a workshop in November 2014, as a precursor to a major science review led by Gary Bastin (ex CSIRO) and Phil Tickle (NRM Hub Team), and an analysis of grazing trials led by John Carter (QLD DSITI). The major report entitled: *"Remotely sensed and modelled pasture biomass, land condition and the potential to improve grazing-management decision tools across the Australian rangelands"* puts forward 39 recommendations for prioritised investment and will be made available through the Hub and MLA websites. Simply search for project code: ERM.0098 or contact the Hub team for a copy. A snapshot of the topics covered by the report is provided below.

Pastoralists need reliable and timely information on forage availability in order to adjust the number of livestock in each paddock for current seasonal conditions. This should be a periodic, conscious (tactical) decision based on a calculated, strategic, safe carrying capacity. Seasonal grazing pressure should also take account of current land condition. The three components are linked (Figure 12.): getting the seasonal stocking rate right can improve land condition over time (provided a threshold of degradation has not been crossed) which, in turn, can increase the safe carrying capacity, based on current land condition. In reverse, prolonged excessive stocking variously degrades landscapes, depending on their inherent stability and resilience, which erodes long-term safe carrying capacity.

It is very clear that relevant technology, including timely, spatially extensive information about resource productivity and condition, can potentially contribute to the efficiency and improved profitability of sustained livestock production in northern Australia.

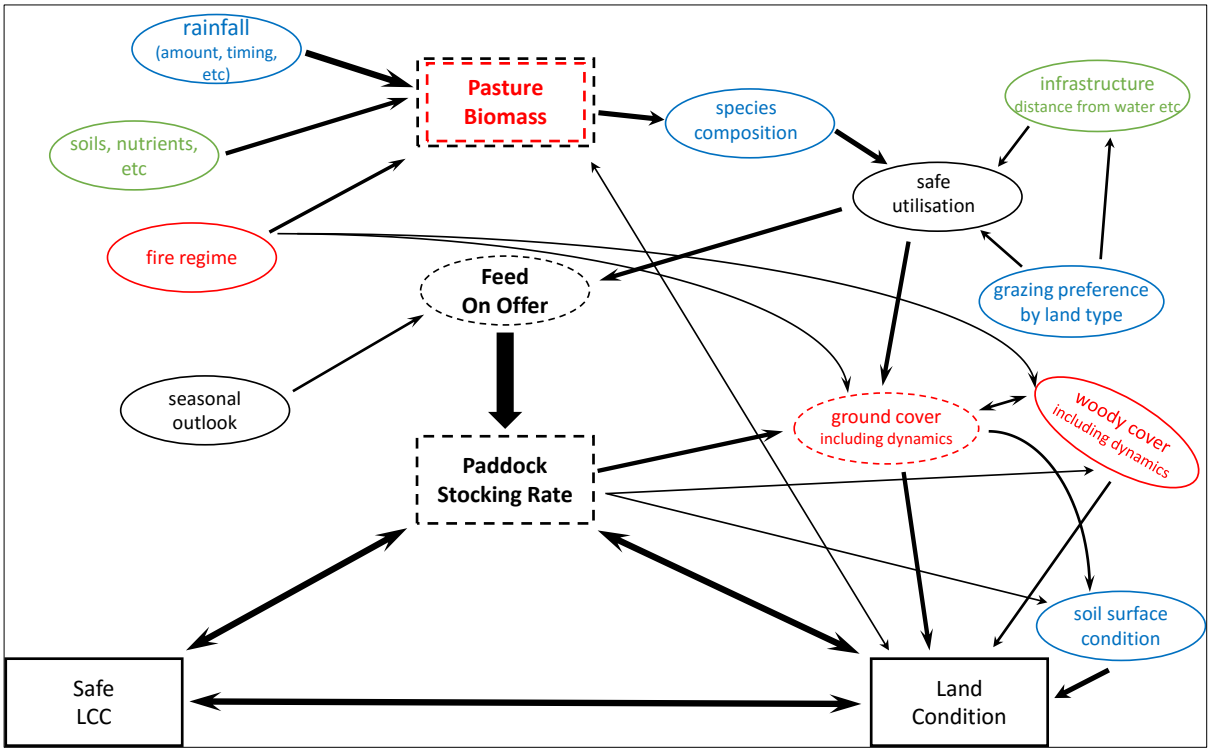

Figure 12. Stylized representation of the inter-related components determining paddock stocking rate and land condition. Components within boxes or ellipses with dashed lines represent 'fast' variables and are more commonly associated with tactical decision making. Corresponding shapes with solid lines indicate slower variables and strategic decisions. Blue text and shapes indicate essentially ground-based data, red font and lines are associated with remote sensing, green colouring shows GIS layers and black text / shapes describe mainly modelling components.

9. Regional extension and workshops

The Hub Team engaged with each of the regions, and helped to leverage existing regional events to provide training and information about the NRM Hub project. Given the drought conditions in many Regions, this was a challenging task with some regions having no appropriate events in the window. Exclusive NRM Hub workshop sessions were only undertaken where there was no suitable existing regional workshop in a particular NRM region. In addition to property visits, train-the-trainer sessions with regional extension staff, and regional workshops, the Hub Team has also presented at a number of forums. A list of workshops/forums given by the NRM Spatial Hub team is available.

The Project had a target of directly supporting the raising of awareness of 240 community members. We have managed to achieve nearly 3 times this with nearly 700 people being exposed to the Hub through direct training, industry forums, workshops and seminars by late February. Over 125 property managers had direct the one-on-one training in the system.

We expect to expose another 400 graziers at forums in the coming 2 months. NSW Local Land Services and South West NRM will be running NRM Hub Training in approximately 8-10 different locations for around 100 graziers through April-July 2016 with support from the Hub Team. We are also in coordinating with the MLA/AWI Pastoral Profit Program with plans to train another 100 industry champions in the coming 12 months, and expose more than 1000 producers to the system through webinars and seminars.

10. Evaluation of the usefulness of capabilities to end users and the innovative use of the tools and information at a number of scales (property to national)

An on-line survey was conducted on landholders participating in the demonstration phase. The survey was restricted to 163 users involved in the project prior to the end of 2015 across approximately 100 properties to target those with a reasonable level of exposure to the Hub. Only 3 weeks was provided to complete the survey. 45 comprehensive responses were received, many of which related to more than 1 property. A copy of the survey questions can be made available on request.

90% of respondents found the Hub easy to use; 95% said from their experience to date that the Hub has the potential to measurably improve the productivity, profitability and sustainability of their property.

Around half of respondents felt the financial benefit to their business over the next 5 years in financial and valuation tasks alone would be between $15,000 and $25,000. For example, simply providing up to date information on their assets to the accountants and banks. One producer said the Hub would provide their property with ~$0.5M benefit in the medium term. Other key findings include:

- more than 50% felt the Hub would save them between 10 and 30 labour days a year
- 75% said it would measurably increase paddock carrying capacity (half of whom said it would increase stock numbers by more than 10%)
- Around 70% thought there would be live weight gain improvements of more than 3% (assuming necessary capital was available)
- 72 % rated this type of technology as important to making their business both viable and sustainable in the future.

However, the full financial benefit to landholders could be significantly larger when it's considered that around half the Hub's survey participants considered their property was only 50% developed, and 85% were just getting started with the new technology. If we took an average property size from our sample and assumed they used the Hub technology to guide their future investment in infrastructure development, they could conservatively increase annual revenue by more than 35% through improved pasture utilisation and increased stocking rates. This increase does not include the improvements in property value, risk management and labour savings that would also result.

In summary, there are opportunities for significant impact across the board from small family operations to the corporates. And whether a property is in the early stages of development or fully developed, there are opportunities to improve investment decisions; optimise resource utilisation, improve sustainable production and monitor the impacts of decisions. This is supported by the fact that we have the full range of property types within the trial (corporates, family, indigenous). However, it is crucial to appreciate demonstrations such as this are always biased towards the early adopters. The challenges will always lie with the remainder of the industry in terms of adoption, and removing barriers to adoption.

Feedback from the regional NRM bodies has also identified a raft of potential regional and national applications including:

- A national standard of mapping as the default baseline data capture method for projects
- Consistent project planning and mapping, reporting and monitoring from paddock to regional levels
- Improved communication between NRM/Government agencies and land managers

- Streamlined approval and monitoring of land management changes e.g. native vegetation, infrastructure management and water affecting activities
- Interaction/integration with other platforms including Atlas of Living Australia (ALA), Bureau of Meteorology (BoM) and North Australia Rangelands and Fire Information (NAFI) and others.

Trials have already commenced on South West NRM Collaborative Area Management (CAM) properties on regional reporting and benchmarking.

Below are two quotes from participating land owners which highlight the benefits they have found from using the NRM Hub:

"The Hub has so much potential to assist and improve the management of Australia's regional landscape. It was so interesting to be able to view how your management is impacting on your patch of Australia, and the potential that is there for improvement."

"Land management starts and finishes at the soil's surface. If we have detailed imagery and analysis tools of the contours, the soil and vegetation types it makes development and management of that soil, that farm and that catchment so much more productive and regenerative that farms and communities can thrive and become profitable again."

11. Communication, Education and Communication Material

A communications plan was put in place as a working document. The Hub website has been running since March 2015, along with a quarterly newsletter. The newsletter currently has 218 subscribers. We expect this to go up substantially with the next newsletter that will be distributed in July 2016 to all recent new users.

A summary of media can be found at www.nrmhub.com.au/media and includes audio, print and online media from NASA, ABC Rural in QLD, NT and SA, ABC Landline, QLD Country Life, and various NRM communications. Full articles/interviews can be found at:

Social media interaction is on Facebook (www.facebook.com/NRMspatialhub) and Twitter (@NRMHub)

Training material for OPPIS, including online, offline and video material, has been made available to all project participants, A YouTube channel has been created and training videos have been uploaded and updated here for use by all NRM Hub users. At the time of this report, the online videos had been viewed over 500 times, with an additional 300 memory sticks containing these same videos as well as other training material delivered to land owners and NRM extension staff for use as needed.

DISCUSSION

The NRM Spatial Hub has provided rangeland managers with a unique solution to the challenge of making informed decisions about their land. For the first time, they have the capacity to efficiently map, plan, analyse and monitor their properties infrastructure, land resources and ground cover to improve pastoral and natural resource management. The world-first technology underpinning the Hub will contribute significantly to the profitable and sustainable management of Australia's Rangelands.

The Hub combines the latest cloud computing and geospatial mapping technologies with world-leading time-series satellite remote sensing in a way that's not been available to individual landholders before. For the first time, pastoralists can use and compare their data with government data in a secure, consistent and interactive way.

Users can now analyse and report on seasonal trends in ground cover within a paddock or across their entire property in less than 30 seconds. This is an Australian first and has been acknowledged by members of the global scientific community as a breakthrough in sustainable agriculture. In January 2016, the Hub was the focus of a front page article by NASA titled "*Satellite data helps Australian ranchers meet the rising demand for meat in a changing world*".

The adoption of the technology – which has surpassed all expectations - is concrete evidence that the Hub is meeting the needs of Rangeland managers. In the initial two years of operation the Hub has been demonstrated and used on more than 300 different properties covering more than 50 million hectares – which is equivalent to the size of Spain.

A survey in February this year further underscored its value to the graziers using it. Ninety percent of respondents found the Hub easy to use, 95% said it has the potential to measurably improve the productivity, profitability and sustainability of their property, and more than half estimated that it will save them between 10 and 30 labour days a year.

It is clear that there is a strong appetite in the rangelands for new technologies that lower costs, save labour, improve safe carrying capacity, increase profits, and improve the sustainable management of our natural resources.

However, our results – as impressive as they are – are strongly biased by the fact that new ideas are always embraced first by the early-adopters who typically are already the best and most advanced land managers. The true power of the Hub technology will be displayed when it is embraced by the remaining 80% of industry. Making this cohort aware and capable of applying the Hub technology is the challenge for the future.

Like so many other sectors, digital technology is likely to provide the largest opportunities for improved productivity and efficiency in agriculture in the next decade. We also know the rate of digital change in other industries has made it difficult for all participants to keep up. Government and industry clearly have a major role in ensuring that technical support and extension staff across the rangelands are able facilitate this tide of technical change. The Hub provides a powerful cost and time saving platform for extension staff to do this.

It is difficult to overstate how important collaboration has been to the success of this project. It not only provided opportunities to share resources and minimise duplication, it provided a crucial opportunity to leverage off 20 years of research and development into geospatial and remote sensing science in grazing.

The project also provided the opportunity to build on key Information and Communications Technology (ICT) infrastructure such as the Terrestrial Ecosystem Research Network (TERN), the National Collaborative Research Infrastructure Strategy (NCRIS), and related investments in high performance computing (HPC) by various government agencies. The open data policies of both state and federal Governments have also played a fundamental role in making data accessible.

However, it's important to recognise that the Hub has a slightly different agenda to the government instruments mentioned above. The Hub is maintained outside of public-owned infrastructure in commercial "cloud computing" environments. This reflects the fact that the Hub has to provide a "safe and trusted" environment where property managers can easily access the best available government data, and integrate it with their own private data and knowledge to make better decisions.

Despite the major investments in ICT infrastructure, mobile applications and cloud computing, there are still major hurdles to overcome in terms of our base data quality. Contrary to popular belief, there are significant limitations with using existing soil, terrain, climate, vegetation, and land type data at the property level in most regions. Significant investment in improved mapping is required to resolve this issue. The Hub, and other similar initiatives such as the Atlas of Living Australia, are in a unique position to assist with improving the quality of data available for both governments and land managers by actively engaging the land managers with data collection and management.

There needs to be a renewed effort by government to work with land owners to improve the quality of these fundamental datasets, and the Hub tools have the potential to provide a unique pathway for allowing this to happen.

The NRM Spatial Hub was founded on the Grazing and Land Management (GLM) principles developed through the northern Australian Future Beef program. Datasets such as the one's described above are fundamental to adjusting stocking rates within an acceptable tolerance around the realistic long-term safe carrying capacity; matching livestock numbers to available forage as a seasonally-variable stocking rate, and understanding the impacts of seasonal climate variability.

Our experience modelling carrying capacity during this project found that while land type mapping in Queensland generally provided a reasonable starting point for safe carrying capacity estimation, property-specific information provided by managers (such as inclusion of buffel) on pastures was crucial for reliable results. Information on land types or land systems in states other than Queensland was generally problematic for use at property scales. There needs to be a renewed effort from government to work with land owners to improve the quality of these fundamental datasets, and also to provide tools and mechanisms for land managers to improve the data to defined standards and provide this information back to government.

The parallel activity in relation to pasture biomass estimation (sponsored by MLA) assessed the potential to monitor land condition using remotely-sensed fractional cover products, and to improve biomass estimation, animal productivity, pasture growth models and grazing decision tools (e.g. safe carrying capacity) across the Australian rangelands. The work included an expert workshop; a comprehensive review of the state of the science; and an analysis of northern grazing trials sites. The focus of these analyses were to assess the utility of remote sensing of fractional cover for quantifying cover-mass relationships, and hence provide reliable estimates of total standing dry matter (TSDM).

A comprehensive review of current site-based, remotely sensed and model-based approaches to estimating TSDM and growth was undertaken. It is very clear that relevant technology, including timely, spatially extensive information about resource productivity and condition, can potentially

contribute to the efficiency and improved profitability of sustained livestock production in northern Australia.

This work found that an integrated system of modelled and monitored pasture biomass, complemented by adequate ground-truth data, should provide land managers with improved information to better manage their natural resources under continuing climate variability. As of now, we lack the ability and/or resources to comprehensively, accurately and consistently monitor pasture biomass across the diverse rangelands of northern Australia - both directly (i.e. field based) and remotely. However, there are examples identified through the review where results have been very positive, and these need continued investment. The allied report entitled: "*Remotely sensed and modelled pasture biomass, land condition and the potential to improve grazing-management decision tools across the Australian rangelands*" will be made available through the Hub and MLA websites. Simply search for project code: ERM.0098.

Stage 1 of the Hub's development has focused on getting the underpinning information and systems in place that would provide immediate benefits, and provide a platform for future adaptation and integration with other systems.

In a survey of land holders, property managers were asked what new capabilities they would like to see supported by the Hub in the near future. The top 10 priorities listed were:

1. Pasture biomass and budgeting (79%)
2. Integration with paddock record keeping systems (74%)
3. Land Condition Assessment (inc. more advanced methods, monitoring sites and photo points) (72%)
4. Improved land typing (67%)
5. Drought Assessment (65%)
6. Biodiversity planning and management (58%)
7. Carbon and ecosystem services (54%)
8. Land valuation (51%)
9. Biosecurity including pest and weed management (49%)
10. Fire planning 37%

This feedback provides a clear direction for investment in the Hub in the future. Notably the top 5 are in many ways intrinsically linked, and future development should address those needs in an integrated manner. There are already a number of paddock record keeping systems in the market place, and one avenue would be to develop partnerships with these providers. Clearly the demand for improved tools for estimating pasture biomass and pasture budgeting is high, and investment must continue as a matter of priority in this area.

Importantly, the priorities identified above are based on property manager responses spanning indigenous, family and corporate enterprises. The feedback from regional NRM bodies and extension staff has been very different, although there has been a high degree of commonality on the sort of applications they would see for the Hub tools:

- A national standard of mapping as the default baseline data capture method.
- Consistent project planning and mapping, reporting and monitoring from paddock to regional levels.
- Improved communication between NRM/Government agencies and land managers.
- Streamlined approval and monitoring of land management changes e.g. native vegetation, infrastructure management and water affecting activities.
- Interaction/integration with other platforms including ALA, BOM and NAFI.

Looking more broadly, some of the greatest benefits flowing from further government investment in the Hub will be enjoyed on a national scale. Some of the immediate benefits to the State and Commonwealth governments of Australia are:

- Providing standardized GIS mapping and reporting across all NRM regions.
- Consistency of mapping system from paddock/project level to national monitoring and reporting (SOE)
- Major savings in staff time and resources to achieve better results
- Better evidence of effectiveness of investment in the short and long term

While the NRM Spatial Hub is still in its infancy, our experience working with over 300 properties has clearly demonstrated the capacity to bring together a range of new technologies that can significantly improve how both big and small landholders invest in and manage their properties. There are opportunities for benefits across the full spectrum of grazing businesses, whether they are corporate, family or indigenous. The information flowing from the Hub tools allow land managers to make better investment decisions which will increase profitability and sustainability, and improve environmental outcomes.

The Hub provides a step change in our capacity to manage and monitor Australia's Rangelands. In this way, it is a "national asset" that allows individual property managers, NRM bodies, industry, environmental and indigenous organisations, government and the broader community to make better decisions.

The aim of the Australian Government Department of Agriculture and Water Resources Innovation Grants is to give farmers, fishers, groups and businesses more tools to implement sustainable practices, reduce farm costs and build productivity. The NRM Spatial Hub has met and significantly exceeded the programs objectives.

The challenge now is to transition to a self-sustaining service model that continues to foster collaboration, and provide long-term opportunities for industry growth and enormous efficiency gains across government.

FUTURE NEEDS FOR INNOVATION UPTAKE

There is in unilateral support from the Rangelands NRM Alliance members, and key industry stakeholders to move the Hub into a sustainable capability. There is also general consensus that while there is no doubt considerable commercialisation potential, the current key stakeholders want to ensure that the platform continues to provide "industry-wide" benefits.

Recent discussions with Rangelands NRM Alliance member regions, QLD and NSW Governments; National Farmers Federation, Meat and Livestock Australia; Australian Wool Innovation, Agforce; Department of Agriculture and Water Resources and Department of Environment have been very positive about the opportunity to maintain and develop an "industry capability".

The rate that the Hub has developed and the level of interest has created some significant challenges for the project team to complete the project and transition to an operational footing while maintaining continuity with constant requests from new users. The on-going fixed costs are extremely low relative to many existing capabilities, requiring less than five Full Time Equivalent (FTE) staff in the core team to maintain a world-leading capability that offers potential benefits across not just the grazing sectors, but the land-based sectors. Noting of course, this excludes our collaborators and regional extension staff.

The Hub has secured bridging funds to allow the operation to continue for a further 12 months, while the on-going arrangements and revenue streams are secured for a sustainable industry-wide capability. Australian Wool Innovation (AWI), and Meat & Livestock Australia (MLA) have formed an

alliance to contribute a significant component of the necessary funding. Importantly this funding will be focused on consolidating the service for MLA/AWI members; identifying another 100 industry champions in the south; supporting the joint MLA/AWI Pastoral Profit Programs; and providing a platform for future research investment. The agreement also involves the development of a business plan by mid-2016, including the development of a revenue model. The Rangeland NRM Alliance and the CRC for Spatial Information have also committed matching funds and in-kind resources.

Importantly the current level of secured funding will not be able to fully satisfy the opportunities we have identified for improving regional, and state-level investments and monitoring/benchmarking on-ground outcomes. Discussions are well advanced with NSW Local Land Service (NSW LLS) (state level) and the Rangeland NRM Alliance Regions, but ideally this would be a coordinated activity through the Australian Government to reduce transaction costs, and maximise opportunities for coordination and collaboration.

The Hub offers numerous opportunities to support efficiency gains in government program delivery and monitoring; and numerous other land-based sectors from both a public good and commercial perspective. The business plan will explore potential business structures that may include a not-for-profit company structure to deliver minimum core services to landowners; regions and government; and commercial entities to develop retail channels.

APPENDICES

Landholder Survey Responses – Quotes from Users

The following quotes were provided by respondents to a user survey conducted in March 2016.

Technology taking Landholders forward.
A brilliant tool that everyone can access and use. Too often we need new software, files converted and updates to software we use only occaisionally. There is none of this with the hub. It's so much more user friendly.
Pastoralists Moving Through The 21st Century As Land Conservationists
Access to so much more valuable information about our property'
A wonderful initiative that has huge scope in the rangelands
Think about tomorrow and not only about today.
This tool has the potential to integrate rangeland monitoring and management from the specific point or patch to paddock, to property, to catchment, to region. Anonymous
The Spatial Hub has the potential to be the most exciting tool for geographically isolated pastoralists to benchmark their own operations for property and business planning but like all things in remote areas, the internet capability and data restrictions has limited the usage to its full potential. Like all of these 'tools' quality data at reasonable rates will determine the viability of access long term.
Reinforces and expands understanding of property's horizons.
Land management starts and finishes at the soils surface. If we have detailed imagery and analysis tool of the contours, the soil and vege types it makes development and management of that soil, that farm and that catchment so much more productive and regenerative that farms and communities can thrive and become profitable again.
The online mapping is far and above the best I have been involved with, it is very easy to use and enormously helpful for property planning.
The Hub has so much potential to assist and improve the management of Australia's regional landscape. It was so interesting to be able to view how your management is impacting on your patch of Australia, and the potential that is there for improvement.
If you don't measure, its hard to manage and mapping allows to measure.
This technology is a great asset for our business for planning for the future and to be able to further utlize it to budget pasture/ground cover will be a huge benefit for us
This type of program will become extremely useful and necessary in the future for agriculture in Australia.
We have to get the North productive and have the potential to increase from 10 hectares per head to 1 head per hectare if our planning and water infrastructure can be developed. To do this we need data to make our case, this tool should help us get there.