International Grassland Congress Proceedings
21st International Grassland Congress / 8th International Rangeland Congress

Information Technologies for Rangeland Monitoring: What Is Available and What Will Be Available in the Future?

Craig D. James
Desert Knowledge Cooperative Research Centre, Australia

M. R. C. Ashley
Desert Knowledge Cooperative Research Centre, Australia

G. N. Bastin
CSIRO, Australia

A. J. Bubb
Department of Primary Industry, Fisheries and Mines, Australia

The 21st International Grassland Congress / 8th International Rangeland Congress took place in Hohhot, China from June 29 through July 5, 2008.
Proceedings edited by Organizing Committee of 2008 IGC/IRC Conference
Published by Guangdong People's Publishing House

Information technologies for rangeland monitoring : what is available and what will be available in the future ?

C .D . James[1] , M .R .C . Ashley[1] , G . Bastin[2] , and A .J . Bubb[3]
[1] *Desert Knowledge Cooperative Research Centre , PO Box 3971 , Alice Springs , Northern Territory 0871 , Australia . E-mail : craig .james@ desertknowledgecrc .com .au .* [2] *CSIRO Sustainable Ecosystems , PO Box 2111 , Alice Springs , Northern Territory 0871 , Australia .* [3] *NT Department of Primary Industry , Fisheries and Mines , PO Box 8760 , Northern Territory , 0870 , Australia .*

Key points : We discuss technologies and the systems associated with them that can enhance decision making by rangeland managers . We focus on technology and systems that are publicly available to assist land managers as opposed to those used in research arenas . Technology can provide data that allows informed management decisions across large scales and more repeatably through time . We discuss three groups of technologies and information management systems : (i) technologies to acquire spatial information (e .g . remote sensing) and the software that turns that data into useable management information ; (ii) technologies for remote control and management of infrastructure , livestock and natural resources (e .g . telemetry , automatic drafting systems) ; and (iii) information systems for planning and reporting at larger scales and at typically governmental levels of decision making .

Key words : monitoring , technology , satellite , remote sensing , telemetry

Introduction

This paper outlines the extant and emerging technologies that support rangeland managers' information of current patterns , trends and thresholds . We focus on systems of technology and the outcomes that are achievable with them rather than the technologies themselves . A primary reason for developing technologies and using them is so that managers have information on which to make decisions more precisely and more accurately in time and space . Spatial and temporal precision is becoming increasingly necessary for several reasons . As rangeland landscapes change due to human use and longer term climate change , critical thresholds of change need to be detected and managed (e .g . environmental change , or animal condition) . Running a profitable business in the 21st century requires that livestock are marketed effectively and that business costs are managed precisely . Finally , a rangeland production system is an interrelated system of performance of livestock set against the background of climatic variability , fluctuating market prices , and spatial variability of relatively large land holdings . Markets aside , pastoral land managers need better ways of capturing and integrating information about land and livestock condition when , currently , contact with these can be infrequent and not comprehensive .

Traditionally , monitoring of rangelands landscapes has occurred for livestock production (cattle , sheep , goats , camels , yaks , etc) . Animal growth rates , condition , and reproductive output are all constantly assessed along with environmental conditions . The experienced eye of a pastoralist integrates current information with his or her accumulated knowledge of environmental trends and responses to make management decisions . However , increasingly managers are experiencing forced change to the production system (costs of production affected by environmental certification , rising fuel prices , animal safety concerns , consumer trends) or scale at which it is operated (changing economies of scale) . Under such trends , other sources of expert data are useful to supplement personal observations . Technological advances have provided data that allows more precise management of enterprises in many sectors (e .g . dairy , wine , transport industries , supply chain logistics , and agriculture) . Rangelands pastoral enterprises have been slow to adopt new technologies that could bring more precision and hence efficiency gains , and yet they operate on scales and in environments where technology can make a substantial difference to profitability .

As well as technologies for monitoring , society (through governments) requires that land use is sustainable . A higher-level synthesis of information is thus required to understand change , why change is happening and what its implications are . Not all monitoring done at enterprise or regional scales can be scaled-up to larger scales (e .g . biodiversity) and the challenge for reporting at large scales is being actively tackled . As the final part of this paper , we report on some of these national-level reporting systems .

In this paper , we present technologies and the systems associated with them that can enhance decision making by managers . Much of what we discuss is technological application that is under development and therefore not well publicised . While we have attempted to find examples from many countries , the reality is that most examples are drawn from our knowledge of developments occurring in Australia .

How and why monitoring data are acquired and used

Technologies discussed in this paper provide increased amounts of data and have the potential to improve management precision . In some cases raw data are directly interpretable for management decisions : Is a remote water pump running and does it need checking , yes or no ?" In other cases the technology supplies huge amounts of data that must be analysed to extract management information . There are three broad ways in which information from technology is useful : (i) greater environmental safety , (ii) reduced costs of operating , and (iii) increased productivity , hence profit" . These three areas are applicable to the wide range of uses that rangelands are subject to , including livestock production , conservation , cultural homelands , and lifestyle living , and they can operate at several scales . We organise the wide range of technologies and information management systems into three groups set out below : (i) Technologies to acquire spatial information (remote sensing , e .g . digital satellite images showing vegetation cover) , (ii) Technologies for remote control and management of infrastructure , livestock and natural resources , and (iii) Information systems for planning and reporting . In the examples below , we focus on the systems that are being developed for application with managers rather than those that are research tools .

Technologies to acquire spatial information

Satellite imagery has long been used by researchers and government agencies . Cost of acquisition , training and the sophistication of computer hardware and software needed to make use of satellite imagery has limited its use by rangeland managers . However , there are emerging trends now to open up the use of satellite imagery for regular monitoring of the vegetation resource . These trends are driven by the availability of inexpensive sources of satellite data (especially MODIS-see below) , and development of tools that convert satellite data into useful management information , and that bring that information to managers . Satellite data , suitably processed so that useful management information is drawn out , is mostly used for the purpose of managing for environmental safety through assessment of rangeland condition and trend (e .g . Bastin et al . 1993) , and biodiversity patterns (Salem 2003) . However , as remote sensing information is made more available to managers , its uses will expand to increase productivity through the precision it can bring to understanding forage availability and forage quality (through greenness) and the rate of change in these .

Satellite data have been improving in spatial resolution , increasing in variety and generally decreasing in price . MODIS currently provides the satellite data of choice for monitoring vegetation and land condition on large properties (seehttp :// modis .gsfc .nasa .gov/ , accessed 5/1/2008) . Pixel size varies between ~250-m and 1-km . Spectral bands cover the visible and near infrared wavelengths allowing derivation of several vegetation indices and image capture is daily . Significantly , images are free to access . MODIS (and other satellite data) is extremely useful for rangelands monitoring because it regularly covers larger areas than is possible by managers with direct surveillance (e .g . by car , helicopter , aeroplane) , and can link to historical archives (to the mid 1970s) so that trends through time can be analysed .

Apart from MODIS , there are now sources of archival digital satellite imagery available at relatively low cost that can potentially assist land holders in managing their natural resources . For example , the Australian Greenhouse Office has made its rectified and radiometrically calibrated archive of Landsat TM and MSS data available such that one year's imagery for all of Australia can be purchased for less than A $ 1 ,000 (see http ://www .ga .gov .au/acres/prod ser/agosuite , jsp , accessed 6/1/ 2008) While such purchases are mainly in the realm of government , it is feasible for pastoral companies (or their advisers) to obtain archival imagery showing historical changes in cover due to seasonal variation (e .g . drought) , land degradation (erosion or woody thickening) or management practices (fire , changed water-point locations , subdivisional fencing , etc) .

Google earth (http ://earth .google .com/) is another free source of remote sensed information that may well be useful for rangeland monitoring . At this stage most people's use of it is for looking at earth views , and we are not aware of analytical tools that assist pastoralists or other sorts of rangeland managers to understand changes , trajectories and thresholds . This may , of course , change rapidly in the future .

While inexpensive and potentially useful , satellite remote sensing data are not necessarily accessible to land managers because of the technical challenges of converting the vast amounts of data into useable management information . Privately owned and run holdings (as opposed to government) need this information because management decisions are made daily with limited spatial viewing of their properties , and potentially limited temporal records of historical treatments and trends . A number of approaches to developing software that processes satellite images into useable information have been instigated , though few are yet at a fully developed stage (i .e . commercial) in the rangelands . The approaches include :

Pastures from Space (http ://www .pasturesfromspace .csiro .au) . This system estimates the biomass of annual-based pastures during a reasonably regular growing season from remotely sensed data . Estimates of pasture biomass (or Feed On Offer") are combined with climate and soil data to produce estimates of pasture growth rate (Sneddon et al . 2001) , which farmers can access through a web-based subscription . In many rangelands areas , spatial complexity of vegetation types , tree cover and highly variable growing seasons preclude the derivation of robust statistical relationships between remotely sensed estimates of vegetation cover and pasture biomass , hence other approaches are being developed (see below) .

The AussieGRASS model (Rickert et al . 2000 ; Carter et al . 2003) simulates pasture biomass based on interpolated rainfall (in 0 .05 degree grid cells) , regionally appropriate pasture growth models and regional estimates of grazing pressure (see http :// www .longpaddock .qld .gov .au/AboutUs/ResearchProjects/AussieGRASS /index .html) . AussieGRASS products contribute to regional understanding of rangeland conditions, particularly with regard to drought declaration, and subsequent administration (see the National Agricultural Monitoring System, http://www.nams.gov.au/index.cfm?fa=nams.home, accessed 5/1/2008). The various rangeland jurisdictions have contributed to the development and testing of AussieGRASS products, and at this stage the information is largely used by government managers.

Of particular relevance here are Software tools that allow land managers to determine trends in vegetation cover over time, and to separate trends due to their management from those due to climatic variability are particularly useful. VegMachine (http://www2.dpi.qld.gov.au/sheep/12979.html, accessed 6/1/2008) allows Australian pastoralists to view temporal sequences of imagery for areas of interest, but more importantly, generates maps showing areas with positive, neutral and negative trends in cover. Spatial patterning in these maps can then be interpreted with regard to land type, recent seasons and management actions. Trends in cover can also be viewed graphically. In a similar project, MODIS data were processed in conjunction with wool-producers to show contemporary trends in green cover at paddock, whole property, and regional scale (Bastin el al. 2006). The additional information available from remote sensing was welcomed by pastoralists, and web delivery was endorsed. As with VegMachine, the tools have not yet been made available commercially.

Fire monitoring through remote-sensed information (MODIS and NOAA AVHRR) is becoming a major tool for pastoralists in fire-prone areas. In Australia, Sentinel (http://sentinel1.ga.gov.au/acres/sentinel/index.shtml; and http://www.firenorth.org.au/nafi/app/init.jsp) provides up-to-date information about where fires start and how they are progressing so that suppression actions can be taken.

The use of remote sensing to identify weed infestations in agricultural and non-agricultural land allows for greater precision and accuracy specific to the problem areas. The use of remote sensing technology can also result in weed infestations being identified and eradicated in a shorter time frame than previously available (Shaw 2005). Once again, the use of remote sensing in this case is in the domain of government and quasi-government agencies, rather than enterprise managers.

Humanitarian organisations are also using data collected through remote sensing satellite imagery to monitor and assess the extent of current conflicts. Amnesty International's *Eyes on Darfur* uses commercially-available high resolution satellite imagery" (http://www.eyesondarfur.org/satellite.html) to survey villages, identifying destroyed huts, water storages and the presence or absence of livestock as indicators of raids or attacks.

Technologies for remote management and control of infrastructure, livestock and natural resources

Several areas of technology are relevant to this topic: telemetry systems that bring information about remote infrastructure back to the station house, and in turn relay control instructions back to remote equipment; and automatic identification systems that record the identification of individual animals or the type of animal and information about their status as they pass control points. Generally these technologies are being developed for their ability to reduce cost of production and for the increased productivity that can be gained per animal.

Telemetry refers to radio frequency transmissions from one point to another. Telemetry is increasingly useful in rangeland situations for monitoring infrastructure and livestock that are distant from the station house on a frequent basis without the need to drive to that point to visually inspect the situation. An example of the early use of telemetry has been the use of Ultra High Frequency (UHF) radios to transmit information about the level of water in a water tank and start or stop pumps (e.g. http://www.observant.com.au). When this information is transmitted back the station house, it reduces the number of times that a person has to visit a watering point, thus saving on the costs of labour and transport and freeing employees to do other tasks. Such systems can link dozens of remote water points back to the station house via repeater links and eliminate thousands of kilometres of driving per year. Recent work has shown that the cost of these systems is often recovered in less than 12 months due to substantial savings (Ashley et al. 2008).

Future advances in this area will be the use of WiFi and WiMax (IEEE 2007) radio frequencies in place of UHF to allow the transmission of greater volumes of data. Wireless broadband transmission protocols will allow pastoralists to install video cameras and other bandwidth-intensive remote devices for more comprehensive information (see below).

The ability to remotely identify individual animals greatly increases management options available for conservation or production purposes. Radio frequency identification devices (RFID) are now widely used in many animal production systems as a response to consumer requirements for traceability of products. RFID add to the cost of production but increasingly are required as part of a regulated livestock management system to gain access to markets. Producers can capture additional management information once individual identification is possible, such as semi-regular recording of live weight (see below). The remote monitoring of wild animals using global positioning systems and radio or satellite transmitting devices (www.lotek.com) is also possible, but as far as we are aware this usage of technology remains in the research domain and is yet to become a tool for management in commercial operations.

Apart from reducing costs as noted above for telemetry, precision information about where animals are located and how they are performing through time has the potential to increase productivity. Combined with the next generation of telemetry, these systems can gather and store or transmit information such as an animal's unique identification number (from RFID tag) and its live weight via Walk-over-Weighing (WoW) scales (http://www.sheepcrc.org.au/index.php?id=143) The advantage of gathering this information daily (or thereabouts) at the station computer is that trends in weight gain can be tracked and forward selling of livestock achieved with more precise estimates of weights by a certain time. In parallel development with WoW is remote automatic-drafting apparatus. Animals that have been identified as varying excessively from expected weights (or identified for other reasons) can be drafted to a holding pen by transmitting a list of ID tag numbers to the auto-draft controlling processor, where they can be medicated, supplemental fed, transported or managed in other ways. While these integrated remote animal monitoring and management systems are under development, their usefulness to pastoral managers will require the development of software that turns large amounts of data into useful management information.

The incorporation of machine vision into monitoring represents a significant increase in the level of management that can be applied to a landscape including identification of feral animals and weeds, the condition of pasture and the health of animals. This is particularly important in places where a variety of grazing animals compete with domestic livestock for water and forage, and predators are a problem. Remote video identification of the species combined with auto-drafting will enable the separation of economic species from non-economic ones, thus improving productivity, although the system is still under development.

Spatial location information from Global Positioning System receivers is being used to develop the concept of virtual fencing whereby animals are contained to areas without the need for wire. This is achieved through programming coordinates into a collar which livestock carry, and cueing livestock to respond to (or shy away from) the virtual boundary by audio and electroshock cues (http://www.ars.usda.gov/Main/docs.htm?docid=5564&pf=1&cg_id=0). These systems are not yet widely used in commercial operations.

Information systems for planning and reporting

We have focussed on those technology solutions that are aimed at managers (rather than researchers) and made reference a number of times to the need for tools that process data into useable information. In this final section we briefly discuss systems that allow disparate monitoring to be collated for high-level reporting. These systems are generally needed at higher government levels so that obligations to manage resources on behalf of the citizens of a state or country and the global community can be discharged. Such obligations usually involve conservation of biodiversity and sustainable use of rangeland resources, but also cover climate monitoring and forecasting services.

Systems such as the Australian Collaborative Information System (ACRIS-http://www.environment.gov.au/land/management/rangelands/acris/index.html, accessed 6/1/2008) aim to facilitate data collection and documentation for reporting on regional and national changes in the rangelands. This system is well underway and reported on in a separate paper presented at this meeting (Friedel et al. 2008). ACRIS gathers data from state governments to periodically provide updates on change at broader scales. Improved management of natural resources at the enterprise scale should translate to improved regional and national outcomes.

In the last decade, climate status and forecasting systems have been developed to give seasonal context and expected direction of change. Examples include:

- The Australian Bureau of Meteorology and Queensland government climate forecast web sites (http://www.bom.gov.au/silo/; http://www.longpaddock.qld.gov.au/SeasonalClimateOutlook/).
- The US government SCAN network provides data and interpretation based on climate variables, soil moisture, snow conditions, and biomass (http://www.wcc.nrcs.usda.gov/scan/).

Conclusions

We have summarised how technologies and systems of data management are being developed to assist rangeland mangers. We shy away from technologies per se and focus on those technologies that are being used in conjunction with systems that turn data into useful information for management decisions. Much of the technological development in the research domain has not yet been brought to this management end point. We have organised the paper around the concept of precision pastoralism having more spatially and temporally precise management information-and we divide the technologies and systems reviewed into three categories: technologies to acquire spatial information (repeatedly through time), technologies for remote control and management, and information systems for planning and reporting.

References

Ashley, M.R.C., Bubb, A.J. James, A.R. James, C.D., & James, C.H. 2008. 21st Century Pastoralism—Remote management innovations for sustainability in arid rangeland pastoral production. In: International Rangelands Congress, *this*

volume .
Bastin , G . , James , C .D . , & Brook , A . 2006 . Wool producers with remote control : new tools for whole of property management . Available at : http ://www . landwaterwool . gov . au/land-water-and-wool/managing-pastoral-country/projects/wool-producers-remote-control-new-tools-whole .
Bastin G . , Pickup G . , Chewings V . & Pearce G . 1993 . Land degradation assessment in central Australia using a grazing gradient method . Range . J . 15 , 190-216 .
Carter J .O . , Bruget D . , Hassett R . , Henry B . , Ahrens D . , Brook K . , Day K . , Flood N . , Hall W . , McKeon G . & Paull C . 2003 . Australian Grassland and Rangeland Assessment by Spatial Simulation (AussieGRASS) . In : Science for Drought , Proceedings of the National Drought Forum 2003 , (Eds R . Stone and I . Partridge) . Queensland Department of Primary Industries , Brisbane . pp 152-159 .
Friedel M . H . , Bastin G . N . & Smyth A . K . 2008 . Indicators of sustainability for production and biodiversity conservation in Australian rangelands . In : International Rangelands Congress , *this volume* .
IEEE . 2007 . Institute of Electrical and Electronics Engineers 802 .16 Work group . Available at : http ://www .ieee802 .org/16/ (accessed 10 Jan 2008) .
Rickert K .G . , Stuth J .W . & McKeon G .M . 2000 . Modelling pasture and animal production . In : Field and Laboratory Methods for Grassland and Animal Production Research . L . 't Mannetje , R .M . Jones , editors . CABI Publishing , New York , USA . pp 29-66 .
Salem B . B . 2003 . Application of GIS to biodiversity monitoring . J . Arid Environ . 54 , 91-114 .
Shaw , D .R . , 2005 . Translation of remote sensing data into weed management decisions . Weed Science Society of America ,53 , 264-273 .
Sneddon , J . N . , Donald , G . E . , Edirisinghe , A . and Henry , D .A . 2001 . The delivery of remotely assessed pasture growth rate and feed on offer information to farmers in Western Australia . Geospatial Information and Agriculture , Incorporating Precision Agriculture on Australasia Annual Symposium . 17-19 July , Sydney , Australia , pp 620-626 .