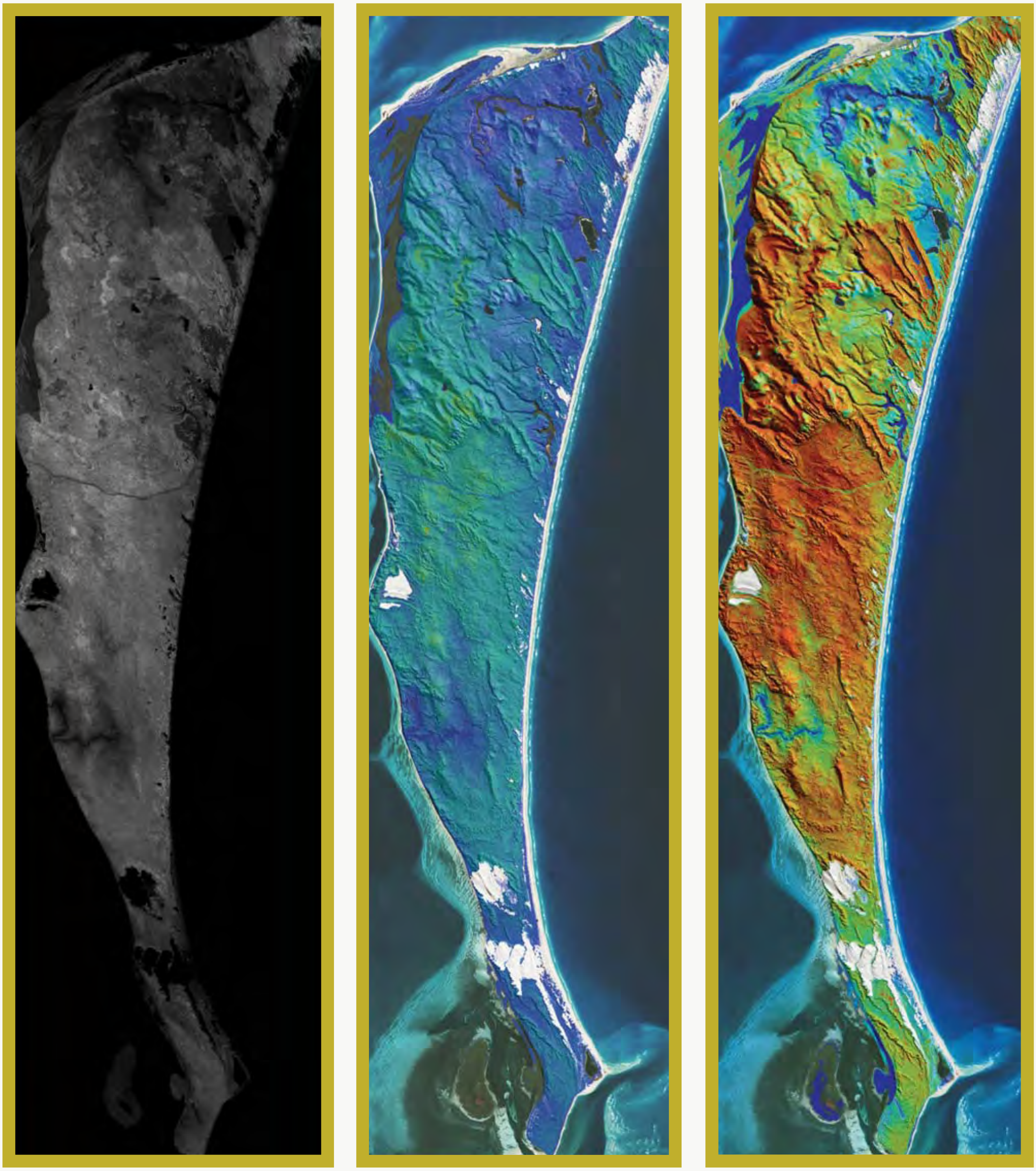
FUEL MONITORING SYSTEM PROJECT REPORT
BRISBANE CITY COUNCIL

A Spatial Data Project by Water and Environment and Rastermatics



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INTRODUCTION

BETWEEN OCTOBER 2009 AND MAY 2010, BRISBANE CITY COUNCIL UNDERTOOK TO IMPLEMENT A HIGH RESOLUTION BUSHFIRE FUEL MONITORING SYSTEM

The system, previously trailed at Karawatha Conservation Reserve (2007), employs a range of remotely sensed data in concert with meteorological data, in order to calculate and illustrate hazard levels associated with standing vegetation within the Local Government Area (LGA).

The Rastermatics Fuel Monitoring System (RFMS) uses remotely sensed data, including LiDAR and Landsat, to generate fuel models (Accumulated fuel and Elevated fuel), which are adjustable according to bushfire activity, rainfall, vapour pressure and ambient temperature.

The RFMS, in terms of update cycles, consists of two major parts. Firstly, reasonably static components, such as terrain derivatives and fuel rasters, require significant processing time frames and data resources. These data form the structural basis of the system and should be updated in a two – three year cycle. The second part focuses on more dynamic components such as fuel volume and condition which are affected by fuel reduction process (e.g. bushfire) and meteorological data. These data can be updated in monthly and daily time steps respectively.

The RFMS outputs bring together data on fuel loads, forest structure, terrain, bushfire history and meteorological conditions into a single point of reference that provides a comprehensive analysis of bushfire fuel hazard output as a high resolution interpretative spatial dataset. System outputs can be generated and distributed according to operational requirements and are suitable for web delivery.

Intended operational uses of system outputs are; monitoring bushfire hazard levels associated with vegetation, planning of bushfire mitigation activities and as a tool to assist with coordinating bushfire response actions. Additionally, highly detailed, data about canopy and understorey is available across the entire LGA for further vegetative analysis projects.

The project was undertaken by Water and Environment (City Design) using RFMS methodology under the terms of a deed of licence agreed between BCC and Rastermatics (system developer).

THE BRISBANE CITY COUNCIL BUSHFIRE FUEL MONITORING PROJECT FOCUSED IN FOUR BROAD AREAS

1. Production of system requirements for the LGA including processing more than a billion LiDAR records to produce primary inputs - Digital Canopy Model (DCM), Surface Moisture base data (SM) and Multi-grid Composite data (MGC). In addition to this, the USGS Landsat archive was accessed in order to extract a ten year bushfire scar database, as well as long term average and trend vegetation reflectance information.
2. Collection and collation of existing BCC bushfire history data including merging of disparate data and the rationalisation of location and extent information for comparative analysis against Landsat derived bushfire history data.
3. Capture of Field data about fuel loads and forest structure as a means to validate and calibrate desktop modelling.
4. Initiation of update cycle by providing crucial algorithms and training to City Design spatial data personnel.

DATA

2009 LIDAR

LiDAR for this project was sourced through a 'whole of government' acquisition project commissioned by Emergency Management Queensland and Facilitated by the Department of Environmental Resource Management (DERM). LiDAR data was captured by AAMHatch for the SEQ Area from a fixed wing aircraft during thirty flights conducted between March 25th and June 9th, 2009. Acquisition over tidal areas was undertaken within +/- 2 hours of low tide. Laser strikes were classified into ground and non-ground points using a single algorithm across the project area and manual checking and editing of the data classification further improved the quality of the terrain model. Non-ground points were filtered by removing points within 0.2m of the ground surface to reduce incidence surface 'noise'. Points classified as non-ground may include laser strikes on the surface of water bodies.

The LiDAR scanner used was the ALTM Leica ALS50-II flown at an average height of 1700 metres, with a swath range of approximately eighteen degrees from nadir, with a swath width of approximately 850 metres and 25% overlap. The pulse footprint average was 0.34 metres, with a pulse rate frequency of 126 kHz.

LANDSAT

136 Landsat TM and ETM+ scenes were accessed through the USGS EROS Global Visualization online interface, covering the period from June 2000 to February 2010. These data were radiometrically corrected and resampled to GDA94/MGA56.

USGS provides standard data products from the entire Landsat archive to all users at no charge. The products are processed to Standard Terrain Correction (Level 1T) – which provides systematic radiometric and geometric accuracy by incorporating ground control points and employing a Digital Elevation Model (DEM) for topographic accuracy. Geodetic accuracy of the product depends on the accuracy of the ground control points and the resolution of the DEM used:

- Ground control points used for Level 1T correction come from the GLS2005 data set. DEM sources include SRTM, NED, CDED, DTED and GTOPO 30

Landsat TM image data files consist of seven spectral bands. The resolution is 30 meters for Bands 1-5 and Band 7. Band 6 resolution (thermal infrared) is a collected 120 meters, but is resampled to 30 meters. The approximate scene size is 170 km north-south by 183 km east-west.

Landsat ETM+ image data consist of eight spectral bands, with a spatial resolution of 30 metres for bands 1 to 5 and band 7. The resolution for band 6H/6L (thermal infrared) is 60 meters, resampled to 30 metres. The resolution for band 8 (panchromatic) is 15 meters. The approximate scene size is 170 km north-south by 183 km east-west.

INITIAL RASTERS

LIDAR PROCESSING WAS UNDERTAKEN IN ORDER TO DERIVE INITIAL DATA AS FOLLOWS

- Digital Elevation Model (DEM). (Figure 1)
- ABVGRD data calculated as the vertical distance between a bare earth Digital Elevation Model (DEM) and non-ground classified LiDAR strikes.
- Digital Canopy Model (DCM), which is derived from ABVGRD data by limiting the influence of non-vegetation LiDAR strikes. (Figure 2)
- Multi-Grid Composite (MGC) data, which is derived from ABVGRD data, where vegetative LiDAR strikes between 0.6 metres and 4 metres were grouped into height classes, gridded and combined in RGB thereby providing a 24-bit colour, interpretative dataset describing structural elements of understorey vegetation. (Figure 3)
- Surface Moisture (SM) base data, which is derived using an iterative combination of directional flow and cost distance algorithms and is used as a spatially explicit descriptor of surface moisture gradients. (Figure 4)
- Bushfire Hazard Terrain (BFHT) data was derived from the DEM and calculated using adjusted slope and aspect data. (Figure 5)

LANDSAT PROCESSING WAS UNDERTAKEN IN ORDER TO INITIAL DATA AS FOLLOWS

- Normalised band ratios were produced and combined chronologically so that a 24-bit RGB colour image containing data from three consecutive capture dates was produced for each capture date for the purpose of generating fire scar data.
- False colour images using the band combination (421) were produced as reference images.
- Seven year average Normalised Difference Vegetation Index (NDVI) was produced as an input to the Accumulated Fuel Model (AFM).

Bureau of Meteorology gridded data was accessed in order to produce meteorological inputs. 24 hour rainfall, vapour pressure and temperature data was downloaded via FTP link for the period 01 September 2009 to 28 May 2010.

- 24 hour rainfall was used to calculate Antecedent Precipitation Index (API).
- Vapour pressure was accessed as monthly averages on an as required basis.
- Temperature data was accessed as monthly averages on an as required basis.

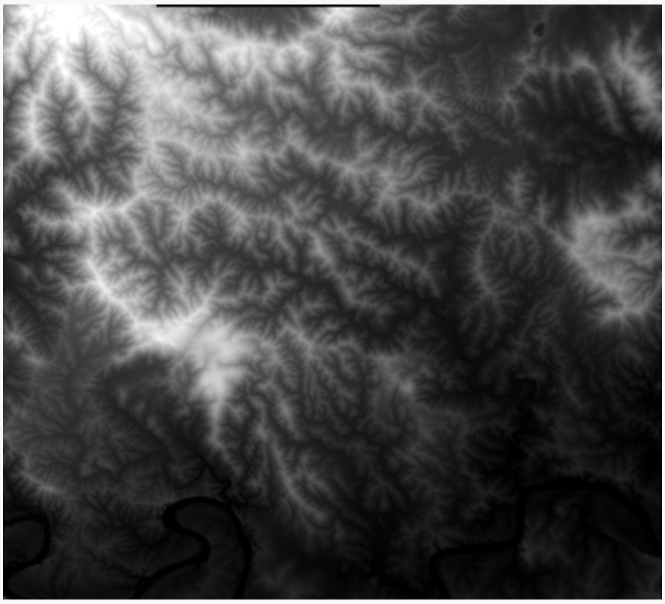


FIGURE 1

Digital Elevation Model (DEM).

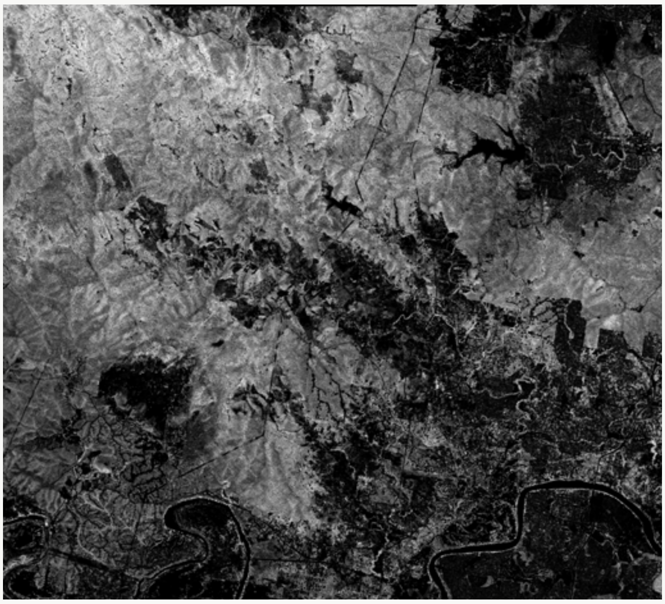


FIGURE 2

Digital Canopy Model (DCM), which is derived from ABVGRD data by limiting the influence of non-vegetation LiDAR strikes.

FIGURE 3

Multi-Grid Composite (MGC) data, which is derived from ABVGRD data, where vegetative LiDAR strikes between 0.6 metres and 4 metres were grouped into height classes, gridded and combined in RGB thereby providing a 24-bit colour, interpretative dataset describing structural elements of understorey vegetation.

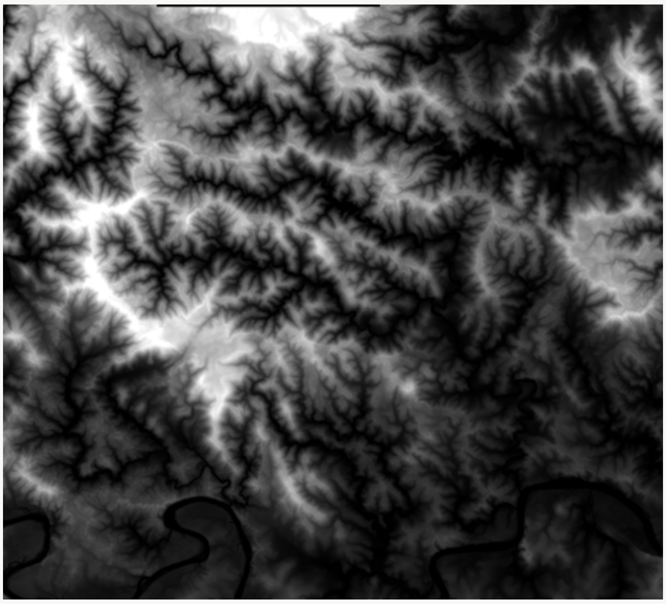


FIGURE 4

Surface Moisture (SM) base data, which is derived using an iterative combination of directional flow and cost distance algorithms and is used as a spatially explicit descriptor of surface moisture gradients.

FIGURE 5

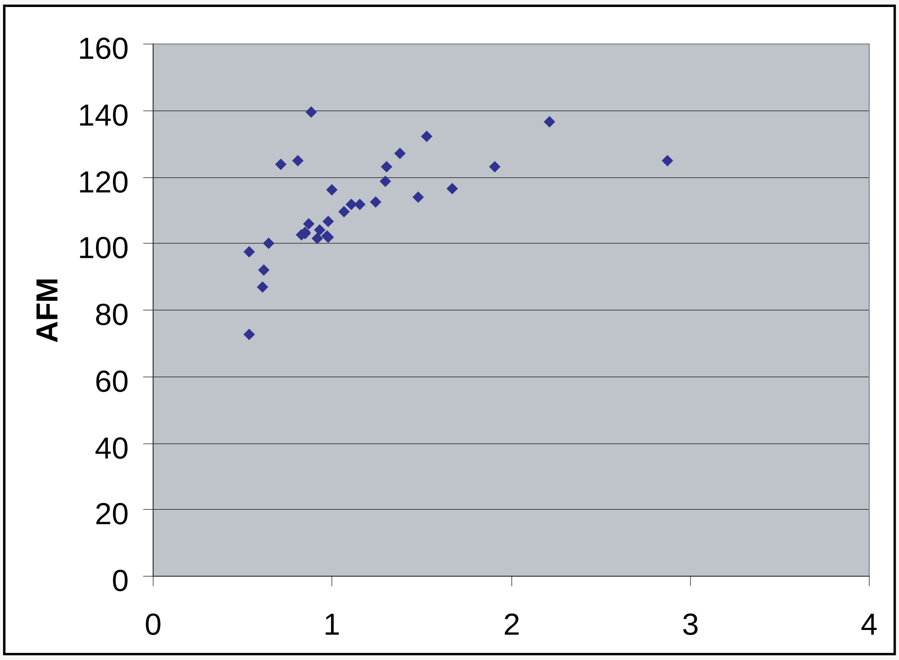
Bushfire Hazard Terrain (BFHT) data was derived from the DEM and calculated using adjusted slope and aspect data

FUEL RASTERS

ACCUMULATED FUEL MODEL (AFM). (Figure 6)

The AFM accounts for litter fuel at the forest floor. The model has consistently yielded very good results for SEQ environments since it was initially developed in 2006. This fuel class contributes to hazard levels at a fundamental level. Litter fuel (or flash fuel – US) provides fuel continuity and facilitates the fire front. The volume and condition of the class are key indicators of bushfire hazard, with moisture content, which is highly dynamic and very sensitive to humidity and rainfall, providing the most important risk factor in terms of fuel hazard.

This data is derived as the combination of long term average NDVI, DCM and SM base data. The specific equation is not shown here however, results of regression analysis for this data show that the numeric relationship between field samples (adjusted for moisture content) and the AFM is reasonably linear.



REGRESSION STATISTICS

Multiple R
0.935183741

R Square
0.87456863

Adjusted R Square
0.8400858872

Standard Error
0.439093427

FIELD DATA (KG/SQM

Although the sample (n) in this instance is relatively small (30 observations), results are reflective of other AFM data generated for the SEQ region (e.g. Gold Coast 2005, Redlands 2009 and Logan, 2010).

ELEVATED FUEL MODEL (EFM) (Figure 7)

The EFM accounts for understorey fuels. This fuel class has the capacity to contribute significantly to hazard levels as it acts as a fuel ladder and can accelerate flame development and rate of spread. The EFM data is derived from MGC data, which provides a crucial point of reference for mitigation planners. Temporal analysis of these data, particularly with reference to bushfire history, provides an insight into the dynamic behaviour of understorey. For example, analysis of these data was found to support the view that the inappropriate use of fire in the landscape can lead to an increased bushfire hazard in the longer term.

Based on anecdotal field observations made by SEQ bushfire management personnel, a prescribed burn conducted under conditions that promote the consumption the fuel bed to the A-horizon (organic soil), has a propensity to adversely impact floristic composition. It has been observed that a number of prescribed burns of this character have resulted in the replacement of grassy understorey with successional understorey species such as black wattle or lantana. Temporal analysis of MGC data in concert with bushfire history data adds weight to these observations as it can be used to show a clear link between specific bushfire events, antecedent meteorological conditions and longer term outcomes in terms of understorey dynamics.

The EFM is derived as a combination of MGC data.

COMBINED FUEL HAZARD (CFH)

As the name suggests, this data set is derived as a simple linear combination of AFM and EFM. The only additional processing undertaken at this step is to adjust the output in order to account for the reduced hazard associated with estuarine wetlands.

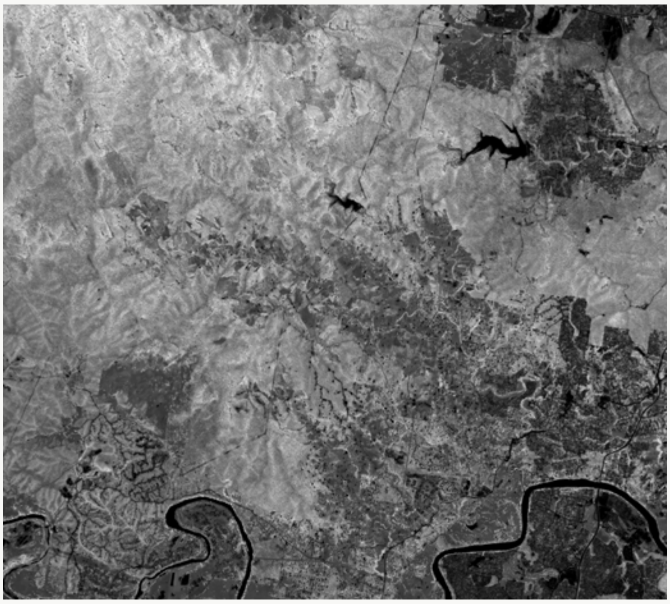


FIGURE 6

Accumulated Fuel Model (AFM).

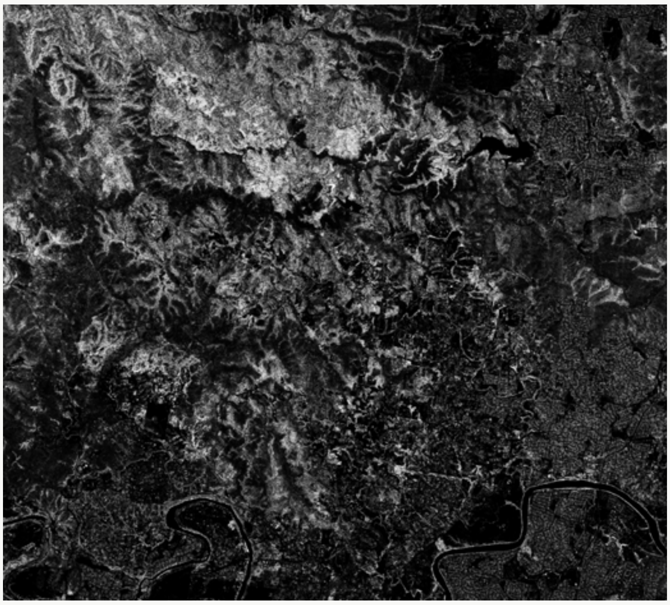


FIGURE 7

Elevated Fuel Model (EFM)

BUSHFIRE SCAR MAPPING

Incidence of bushfire, whether wildfire or prescribed burn, produce a consequential reduction of fuel hazard. The RFMS considers this in the calculation of hazard levels by generating raster data describing both the extent and (inferred) intensity of antecedent bushfire activity for the LGA and modelling the residual effect using an algorithm based on Olsen's (1968) negative exponent. In this instance bushfire history data was generated using USGS/EROS Landsat data (2000 – 2010), which was compared with BCC historical bushfire data for the same period.

LANDSAT FIRE SCAR MAPPING

Rastermatics fire scar mapping methodology was employed in order to develop a ten year bushfire history for the LGA. In general terms, the process uses temporally sequential Landsat to generate 24-bit raster data to build a combined "before and after" dataset relating to each capture date. This approach allows the use of multi –date change detection focussed in a specific normalised band ratio with a relatively narrow target range. The process lends itself to automation, however recurrent remote sensing issues such as signal anomalies, cloud cover and data gaps require operator intercession via a decision tree interface.

574 discrete spatial objects describing bushfire events were generated for the LGA covering the period 02/06/2000 to 22/02/2010. Figures 8, 9 and 10 overleaf show a general description of the scar extraction process.

BCC BUSHFIRE HISTORY DATA

City Design GIS obtained both electronic and hard copy data relating to bushfire history for the LGA. The data, supplied by various internal and external sources, was collated and converted to spatial points and polygons depending whether events could be identified by specific extent or by general location.

Each record contained the attributes - ID, Date, Source, Type, Suburb, as well as a field for comments. ID was consecutive numbering, Date was the date of the event with as much detail as possible (preferably day/month/year, but sometimes only year was available, these were recorded as 01/01/YEAR), Source indicated the data supplier, Type was whether the fire was a proscribed burn or a wildfire, Suburb was the suburb which contained the centroid of the object, Comments detailed whatever extra information was available as well as uncertainties connected with the record.

The BCC fire history collation yielded 313 polygon objects and 418 point objects.

DATA COMPARISON

Retrospective fire scar mapping using agency based record is, in many cases, inherently fraught with difficulty. Record keeping can be uneven, incorrect or incomplete. For example, in some cases historical data reflects of the land management intentions rather than actual results and in others cases prominent bushfire events appear not to be recorded. Further, no single agency records bushfire activity for the whole LGA. The resultant level of inconsistency, duplication and omission yield a reduced level of confidence associated with data collated from disparate sources. In view these issues comparative analysis was undertaken by limiting analysis to data extracted from a handful of conservation areas so to minimise disparities attributable to anthropogenic bias and jurisdiction.

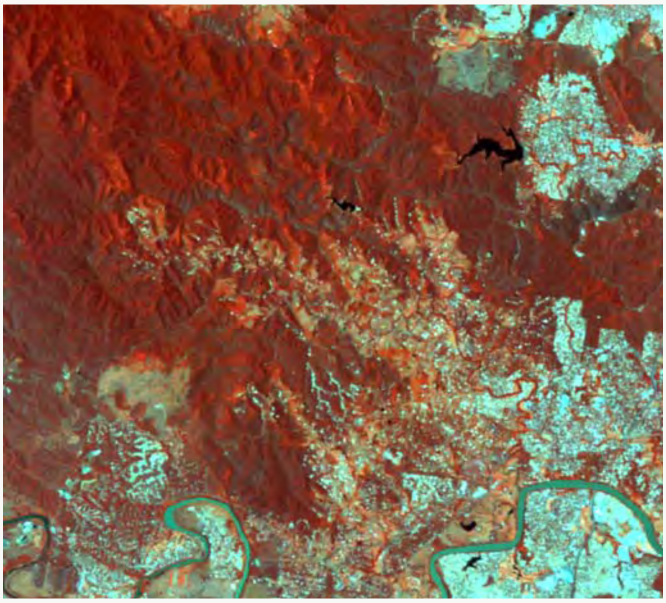


FIGURE 8

Landsat TM

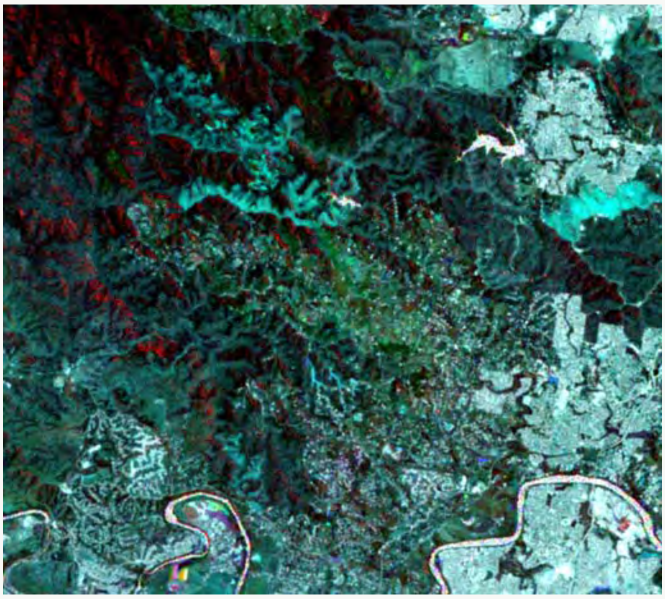


FIGURE 9

24 bit composite band ratios

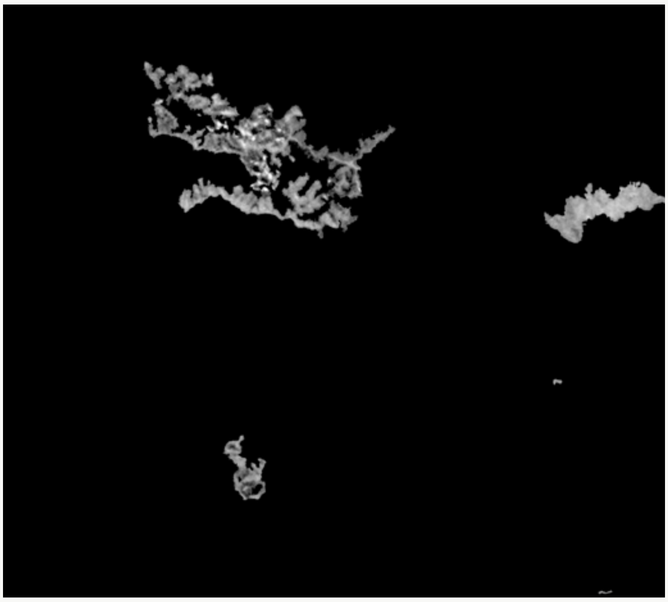


FIGURE 10

Fire scars isolated

Data was extracted for the following areas:

- Mt. Cootha Conservation Reserve (MCCR)
- Karawatha Conservation Reserve (KCR)
- Brisbane Forest Park (BFP)
- Enoggera Military Reserve (EMR)

Results of Comparative Analysis

	LS AREA	AGENCY AREA	DATE ACCORD (BY DATE CLASS)	OVERALL SCORE
MCCR	678.441ha	1706.08ha	76.334%	0.5805
KCR	1163.81ha	1134.95ha	82.1694%	0.8984
BFP	7532.02ha	7845.34ha	81.0674%	0.8853
EMR	802.122ha	1006.22ha	88.4377%	0.8407

Comparative analysis of Bushfire footprints and date classes (LS capture dates +- 9 days) shows an overall accord of around 80% based on the four areas examined.

Although the confidence level associated with these results is relatively low due to the issues outlined above, this method of generating bushfire history data represents the best available option. Landsat fire scar mapping produces fire scar data in 8 -16 day cycles, however this means that some scars produced in this way may be an amalgamation of two or more bushfire events. Also, the method does not accurately define so called 'cool' burns conducted under closed canopy. Further, extended periods of cloud cover, uncertainty and anomalies associated with the scanners and a spatial resolution of less than 12 pixels per hectare, means that it may be reasonably expected that fire scars will inevitably be missed.

ADVANTAGES OF LANDSAT FIRE SCAR MAPPING INCLUDE:

- Cross jurisdictional data capture
- Spatial extent and inferred intensity (useful for modelling purposes)
- Spatial and temporal statistics for large areas.
- Retrospective capability
- Low data costs
- Narrow update cycle

From a practical point of view, bushfire history should be captured using a combination of agency based reporting, independent differential GPS and remote sensing. This kind of multiple source reporting would enable the establishment of a robust system, which could quickly identify anomalous data and afford a reasonable level of data confidence.

MODEL INTEGRATION

CFH data is adjusted in a two stage process to produce Total Fuel Hazard (TFH) data (Figure 11). This is achieved by simple multiplication using the outputs two specific models:

- The Reduction Calculator is employed to generate an 8-bit integer raster with a 0 – 255 data range using Landsat derived fire scar rasters as input data. The model considers all bushfire scar data (for the antecedent seven year period) by date and calculates a single output based on the time elapsed since the each fire event.
- The Surface Moisture multiplier is generated as a 32-bit floating point raster with a data range close to 0 – 1, using a combination of Rastermatics SM+ data and gridded API, The specific equation also uses vapour pressure and temperature, however the exact form is not shown here.

These two multipliers are applied in a final transformation step to generate Total Fuel Hazard (TFH) data, which is post scripted with the create date. A standard colour lookup table is applied and the data is output to 8-bit TIFF format with an accompanying world file.

An additional algorithm including BFHT data outputs a Bushfire Hazard (BFH) raster, which describes fuel hazard in combination with terrain variables so that an interpretative image current bushfire hazard levels is also produced. This data also has a standard colour look up table applied and is output to 8-bit TIFF format.

MODEL OUTPUT

The final function of the RFMS is to generate interpretative RGB image data that is easily transferable and optimised for web display. In this context the TFH and BFH TIFFs are merged with RGB image data and grey scale relief imagery using a specific set of 8-bit image transformation routines so that the only variable in the process is the TFH or BFH TIFF inputs. The Interpretative Image Data (TFH_IID and BFH_IID) output in this step are georeferenced using world files and translated to a compressed 8-bit format such as JPEG2000 or ECW (Figures 12 and 13).

CONCLUSION

Access to timely information about fuel volume, structure and condition as interpretative image data, offers land management agencies encapsulated analysis in a form that it instantly perceptible.

The fuel hazard monitoring system outlined here (RFMS) was developed by Rastermatics and the algorithm (including models and sub-models) is subject to copyright. All intellectual property rights associated with the RFMS are vested in Rastermatics. Brisbane City Council has a limited right to utilise the system under the terms of a Deed of Licence agreed between Rastermatics and Brisbane City Council.

City Design GIS has the tools and expertise required to update the dynamic components and generate model outputs.

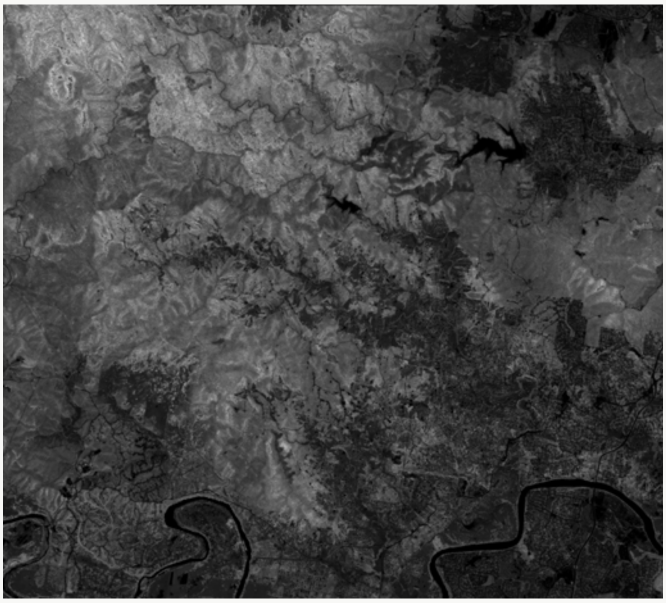


FIGURE 11

Total Fuel Hazard data (TFH) 1 May 2010

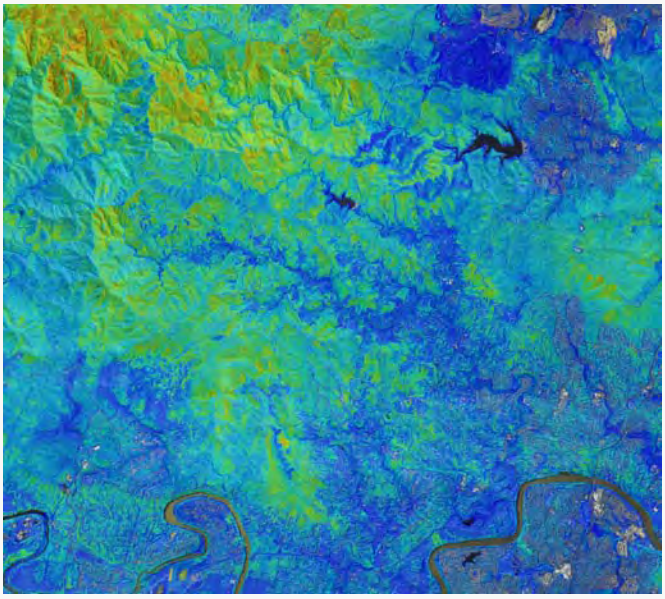


FIGURE 12

Interpretive Image data (TFH_IID) 1 May 2010

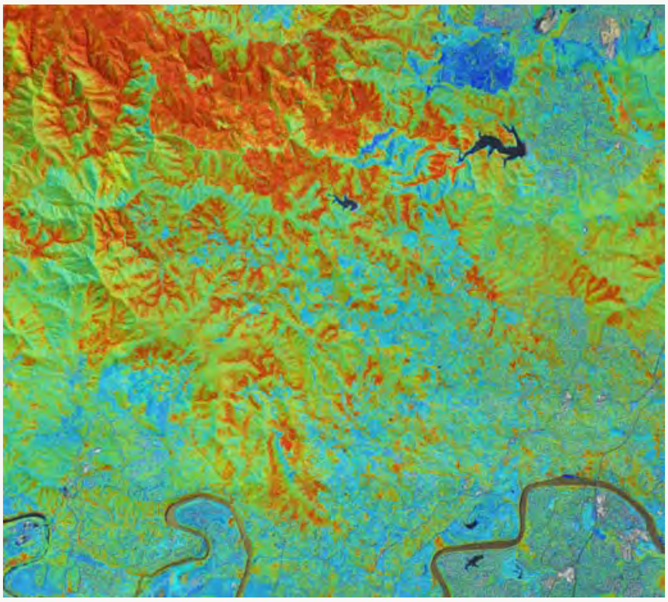
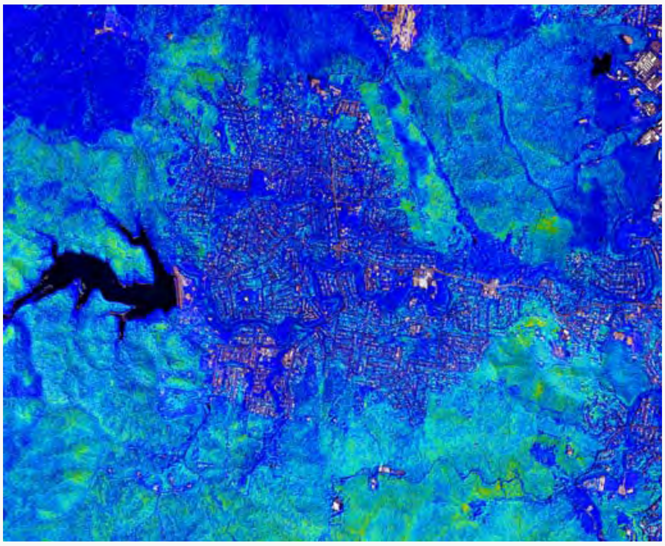


FIGURE 13

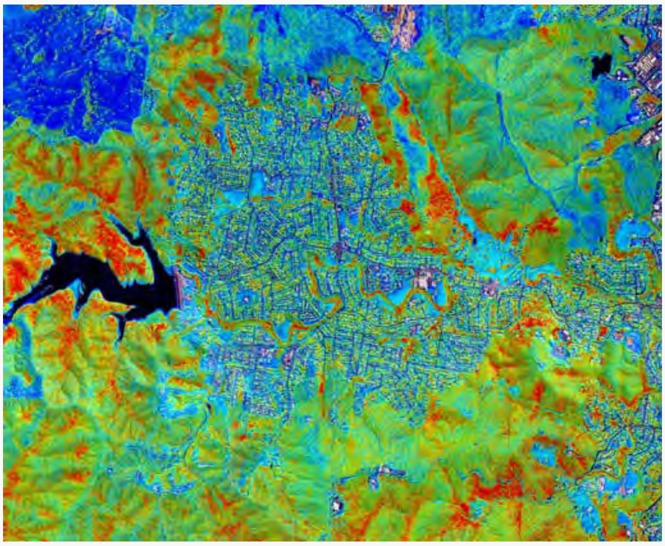
Interpretive Image data (TFH_IID) 1 October 2010

See more detail on Page 13



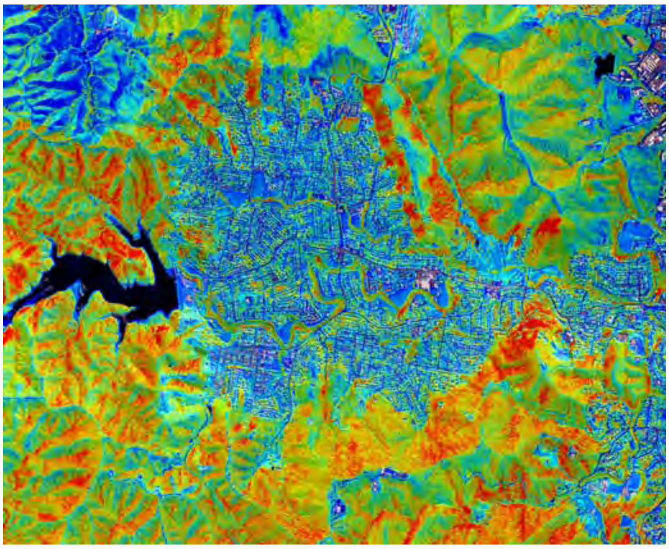
TOTAL FUEL HAZARD
INTERPRETIVE IMAGE DATA

1 May 2010



TOTAL FUEL HAZARD
INTERPRETIVE IMAGE DATA

1 October 2009



BUSHFIRE HAZARD

1 October 2009