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Integrating Airborne Hyperspectral Sensor Data with GIS for Hail Storm Post-Disaster Management.

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Abstract

Emergency planning requires spatio-temporal information on a large scale on urban areas at regular intervals. Hyperspectral remote sensor data may be analysed and integrated with GIS data for providing current spatio-temporal data in urban regions. The overall shape of a spectral curve and the position and strength of absorption bands can be used to identify and discriminate different surface materials. The paper demonstrates a methodology of classifying hyperspectral image data in order to identify different roofing materials, which may have varying resistances to the hazard of hail stones. The hazard of hailstorm poses a huge threat to the people as well as property in Sydney, Australia. Several regions, which are dominated by less resistant roofing materials, may be more affected by hailstorm damage than others. Post disaster operations must focus on allocating dynamic resources to the areas, which may be more susceptible than others. Generating a spatial scenario in near real time of vulnerable areas is important in order to despatch limited dynamic resources to such areas, which may be affected by hailstorms in Sydney, Australia. Remote sensing data, particularly hyper-spectral data consist of fine spectral bands, which have great potential to distinguish between urban surface materials such as roofing materials and other man-made features. A spectral library of surface materials from urban areas was created by using a spectroradiometer FieldSpec®Pro under artificial illumination. The Image was processed and the image spectra was calibrated to the reference spectra by employing the empirical line technique (Bhaskaran et al, 2000). A spectral angle method (SAM), which is an automated method for comparing image spectra to library spectra, was performed to derive a classification map (Bhaskaran et al, 2001) which shows different types of roofing materials possessing different resistances to hail stones. The accuracy of the classified image was tested with high resolution aerial photoimages and field checks.

The paper demonstrates a methodology to integrate hyperspectral data with GIS data in order to develop a spatial decision support system. Spatial overlay technique was performed in a GIS environment where several types of cartographic data such as special hazard locations, population density, less mobile people, street network were overlain to derive decision support systems which have the potential to assist in post damage emergency operations (Bhaskaran et al, 2001). This integrated database has vast potential to assist emergency organizations, city planners, decision and policy makers in formulating plans and strategies.

Key words: Emergency operations, vulnerable areas, roofing materials, resistances, spectral bands

1. Introduction

The hazard of hail storms results in high number of casualties and damage to property in Sydney, Australia. While the prevention of hailstorms is a myth, the management of dynamic resources for rescue and post disaster operations is an important issue. Current Information about the vulnerable portions of the city of Sydney is vital for emergency preparedness. Hailstorm vulnerability can be assessed by the type of roofing material used for houses and other structures. The roof is the first point of impact from the hailstorm and thereafter severe damage is caused to the houses and property resulting in financial losses to the tune of millions of dollars. The degree of resistances of roofing materials vary according to the material composition and these roofs are distributed in varying proportions over the Sydney metropolitan region which may be hit by hail storms in the future. A spatial distribution of roofing materials may be a valuable indicator to gain insight into regions of susceptibility from hail stones, which may be detected by remote sensing images. The heterogeneity of urban surface materials added to the limitations of few spectral bands makes most of the available broad-band sensors such as Landsat, SPOT incapable of detecting urban surface features (Hieden et .al, 2001). However, hyper-spectral remote sensing data due to their fine spectral resolution have the potential to distinguish between various surface materials (Roessner et.al.,1998). The overall shape of a spectral curve and the position and strength of absorption bands in many cases can be used to identify and discriminate materials in an urban area. This was demonstrated by (Bhaskaran et.al, 2000) where a spectral library of endmembers was created using a spectroradiometer (FieldSpec® Pro) under artificial illumination.

2. Objectives

The main objective of this paper is to examine the potential of Hymap to create a surface material distribution map of vulnerable regions, which may be susceptible to the threat of hailstorms.

Specific objectives may be summarised as follows

a) To create a laboratory spectra of urban surface materials especially roofing materials by using a FieldSpec under artificial illumination and natural light
b) To force the laboratory spectra to the image spectra by employing the empirical line calibration technique
c) To perform a supervised classification of selected roofing materials by the Spectral Angle Mapper (SAM) technique
d) To perform spatial overlay analysis using available cartographic (GIS) data and provide intelligent information which may be useful to emergency organizations for strategic resource allocation.

3. Methodology and Analysis

Collection of Samples: Various samples of urban surface materials mainly consisting of roofing materials and pavers were gathered from different sources. **Table 1 below** shows some of the different surface materials used in the analysis.

Terracotta Tile	**Vegetation**	**Clay Brick (Red)**
Concrete Paver	**Wood**	**Birch**
Brick	**Metal**	**Concrete Brick**
Bitumen	**Slate**	**Basalt**
Sandstone	**Corrugated Fibro**	**Marble**

Extraction of Spectra: A full range (350nm-2500nm) spectro-radiometer fig 1 was used to extract reflectance values from selected urban surface materials mainly consisting of roofing materials ranging from terracotta to concrete and bitumen.

Fig 1 (FR) Fig 1 Spectroradiometer Full Range and HyMap details (FieldSpec® Pro

<u>FieldSpec®Pro & some of the components</u>

Pistol Grip

Trifurcated Fibre Optic cable

Spectrometer with internal battery

Reflectance conversion by the Empirical Line Method and calibration: The reference spectra were then forced with the spectra from the Image by employing the empirical line technique. A linear regression was calculated between the reference spectra and the image spectra. The regression line was used to predict the surface reflectance spectrum for each pixel from its original image spectrum (ENVI user manual, 2001). Therefore a known target's spectra (terracotta tile) was selected from the image and used in the empirical line calibration technique.

Supervised Classification: The spectral angle mapper (SAM) classification was used for comparing image spectra to library spectra. The image data was converted to apparent reflectance in order to ensure that the reference spectra and the image spectra were in the same units. The SAM algorithm determines the similarity between two spectra by calculating the spectral angle between them as unit vectors in spectral space with dimensionality equal to the number of bands (ENVI user manual, 2001). A classified image was produced which assigned each pixel to a class (roofing material).

Accuracy Assessment: The study area around the Concord bay region was examined in detail for the material composition of roofing materials. This information was input onto a high spatial resolution aerial photo image Fig 5. A point layer was created and attribute information was added to each point about the material composition of the roof type. The classified HyMap image was cross checked against the database from the aerial photo image.

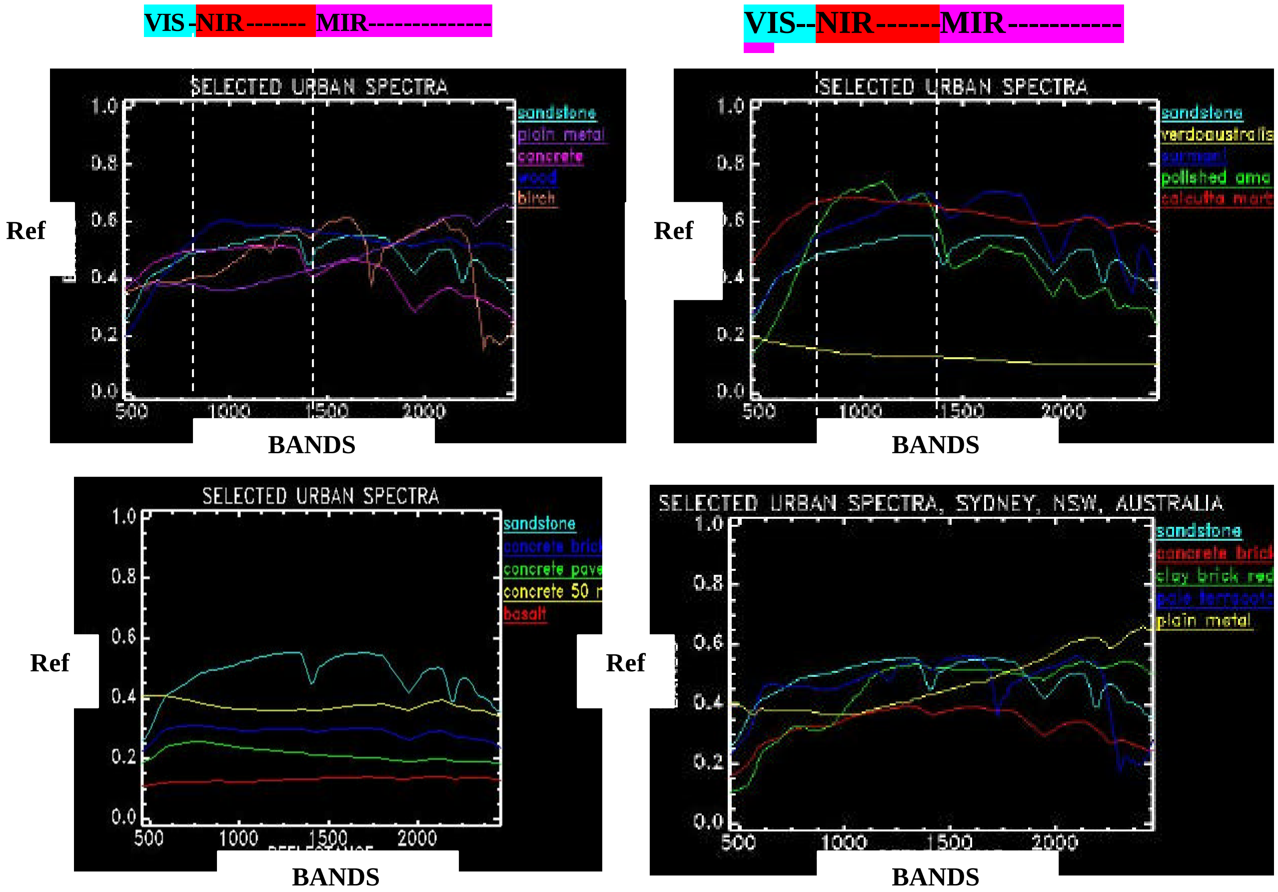

Fig 2 SPECTRAL PLOTS OF URBAN SURFACE MATERIALS

The classified image was geo-referenced to the UTM zone 56 projection system. An understanding of the composite vulnerability of a certain region is vital for emergency operations and strategic allocation of dynamic resources such fire fighting staff and equipments. The census data provided by the Australian Bureau of Statistics (ABS) was used for creating new layers such as population density, percentage of less mobile people. These layers were projected to the UTM projection system and overlain on the classified image fig 2. This data source may provide valuable decision support system (DSS) for carrying out emergency operations and allocation of strategic dynamic resources. In the event of a hail storm threat vulnerable areas may be detected and necessary planning for post damage operations may be carried out.

4. Study Area

The Concord bay region (fig 2, 3) in western Sydney was selected as the study region. This region has a wide variety of roofing materials in close proximity, which is ideal to check the capability of the hymap data for the distinction between urban surface materials.

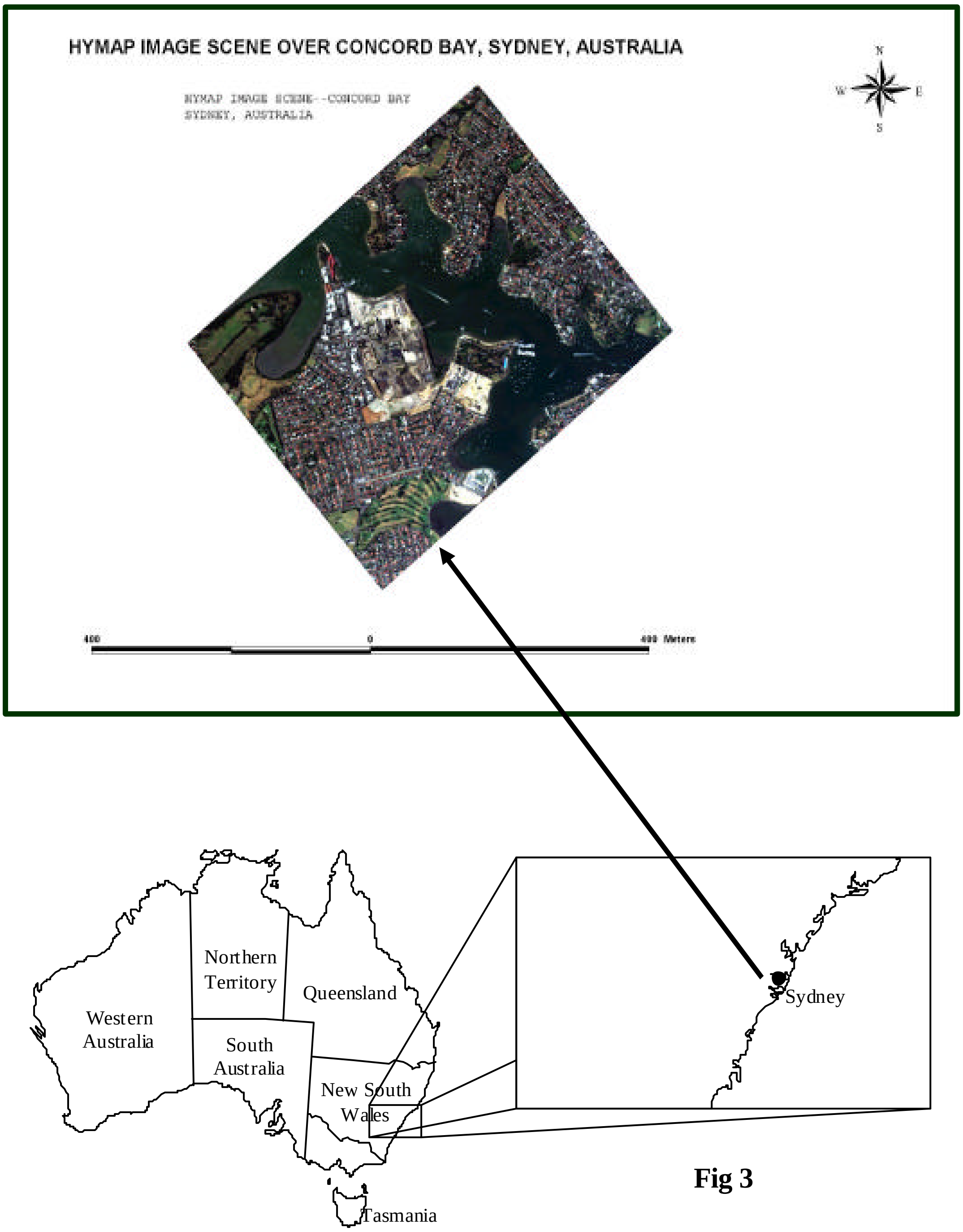

Fig 3

5. Result and Discussions

Surface truthing with the aid of current aerial photo images exposed over the study area revealed 90% accuracy. It is impossible to prevent a hailstorm but there is ample scope to alleviate the hardships faced by residents in a crisis situation presented by the damage caused from hailstones. Appropriate measures in the form of emergency preparedness may be employed to ensure maximum protection and safety from such natural threats quite appropriately christened the active god. Existing technology in the form of RS&GIS may be used to reduce the effects of such unpredictable disasters.

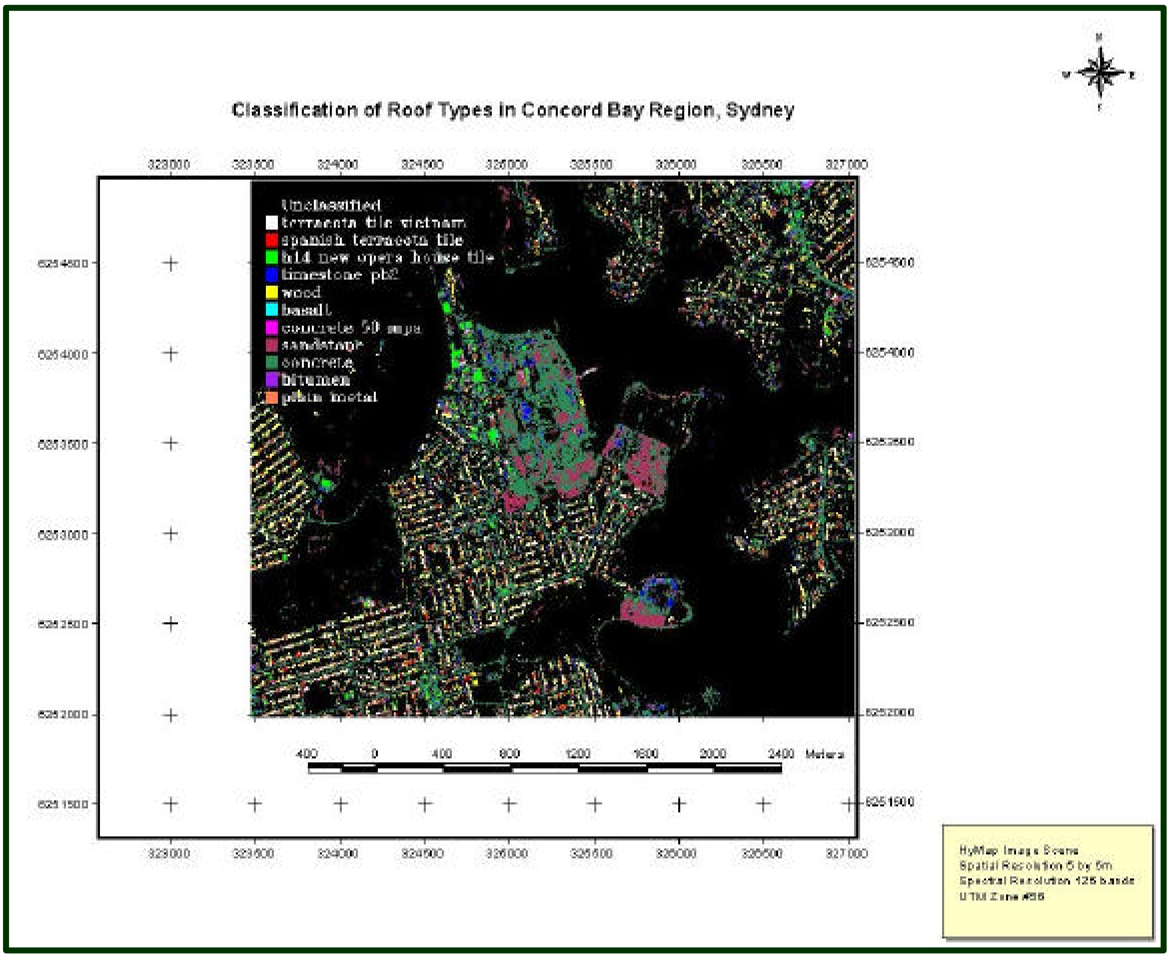

Fig 4 Spectral Angle Mapper Classification

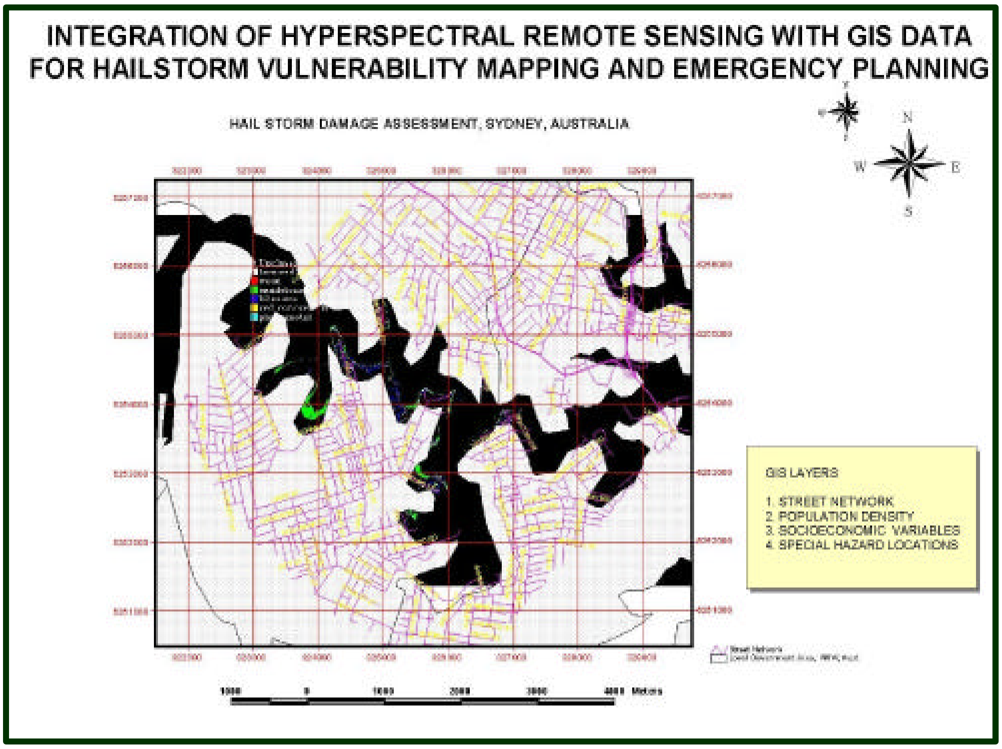

Fig 5 GIS Analyses

6. Future Investigation and Research will focus on the following issues:

a) Calibrating image spectra to reference spectra by using known targets: In this study several known targets such as sandstone, terracotta and vegetation were used during the SAM technique. All these images came up with different percentages of roofing materials. For instance, when terracotta tile was used as the known target during calibration the SAM yielded a high percentage of terracotta tile in the output classification. This percentage came down when other known targets such as sandstone and vegetation were used. This clearly indicates that to classify particular roofing material the best option would be to use the same feature as the known target for calibration. Further investigation and surface truthing of results will be taken up to confirm these facts.

b) Analysis with high spatial resolution hyper-spectral data: Present spatial resolution of airborne hyper-spectral sensor data does not enable spectral unmixing especially in this study where the roofing materials occur spatially in a juxtaposed manner. Resultantly, a single pixel at a 5 by 5m spatial resolution results in spectral confusion in heterogenous urban areas. A better much improved spatial resolution will result in identification of pure endmembers and a more accurate database.

At the moment hyper-spectral sensors are carried on aircrafts. The future will see earth observations by these sensors from space-borne platforms. The proposed spatial resolution is rather broad to be useful for much urban analysis in particular, but it is expected that the resolution will improve in due course of time. The cost of acquiring hyper-spectral data is a also a factor in its widespread use. Since urban areas consist of many heterogenous materials broad band sensors will not be very effective in many applications, therefore hyper-spectral remote sensor data holds the key to future analysis of urban areas.

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