Application of Remote Sensing and Social Media to Mitigate Bushfire Threat in Regional Australia

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ABSTRACT: *Bushfire behaves as an integral part of forest regeneration cycle, but when it comes to the point of a natural disaster, the impact on human settlements and the environment is massive. In Australia, bushfires have become the most disastrous natural hazards. According to the Australian Bureau of Criminology, bushfire damage recorded from 1967 to 1999 have an estimated cost about $2.5 billion excluding losses to the forest cover and the environment. After the disastrous 2009 Black Saturday bushfire in Victoria, public attention to bushfire took a new peak. The Black Saturday bushfire has killed 173 people and injured about 500 people. However, about 50% of 54,000 average annual Australian bushfires occur due to suspicious and deliberate reasons. Due to this grave situation, scientists are regularly exploring various methods to mitigate the damage from bushfires. This study focuses on a low-cost safety measure that can be powered by widely available free satellite images and social media to mitigate the bushfire disasters, particularly in regional Australia. The prime focus of this study is to educate rural communities about the behaviour of the bushfire using semi real-time MODIS satellite imagery. These satellite imagery based bushfire contents or Media GIS contents will be available for local communities through social media to encourage people in participate of disaster mitigation efforts. MODIS data can be linked with Google high-resolution images and information gathered from participatory GIS to deliver precise and latest bushfire information. Collected Participatory GIS (PGIS) data can be used to enrich the GIS database to improve the safety of rural communities in bushfire hazards. Also, PGIS can be used as a tool to widen the discussions among local communities in natural disasters.*

Keywords: Bushfire, Rural communities, MODIS, Media GIS, Participatory GIS (PGIS)

Introduction

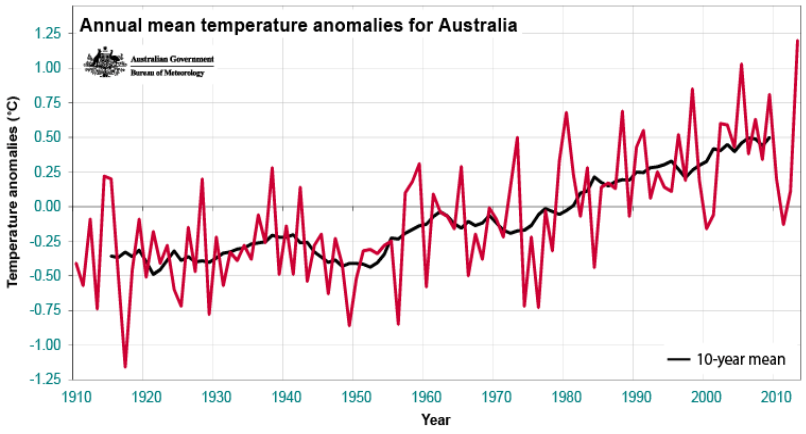
Bushfires (local term for forest fires) have been part of the Australian environment since before human settlement established on the continent. Some Australian flora and fauna have evolved to coexist with bushfires, and in the case of eucalypt forest, fire forms an integral part of its regeneration cycle (figure 1). The Australian climate is hot, dry and prone to drought. In the south-east of the country, strong winds often associated with summertime cold fronts can lead to very high fire danger. According to the Australian bureau of meteorology, vast areas of Australia suffer from bushfire threat (BOM, 2009). These bushfires have become the dominant phenomenon in Australian natural hazards. Australian Bureau of Criminology published a bushfire damage recorded from 1967 to 1999 and estimated the cost as about $2.5 billion, excluding forestry losses (AIC, 2004). During this period, bushfires have killed 223 people and injured another 4,185. The public attention to

bushfire disasters reached a new peak, after the deadly Black Saturday bushfire in Victoria, occurred in 2009.

Figure 1. Bushfires and grassfires are common throughout Australia (Source: http://www.ga.gov.au/scientific-topics/hazards/bushfire/basics/gallery).

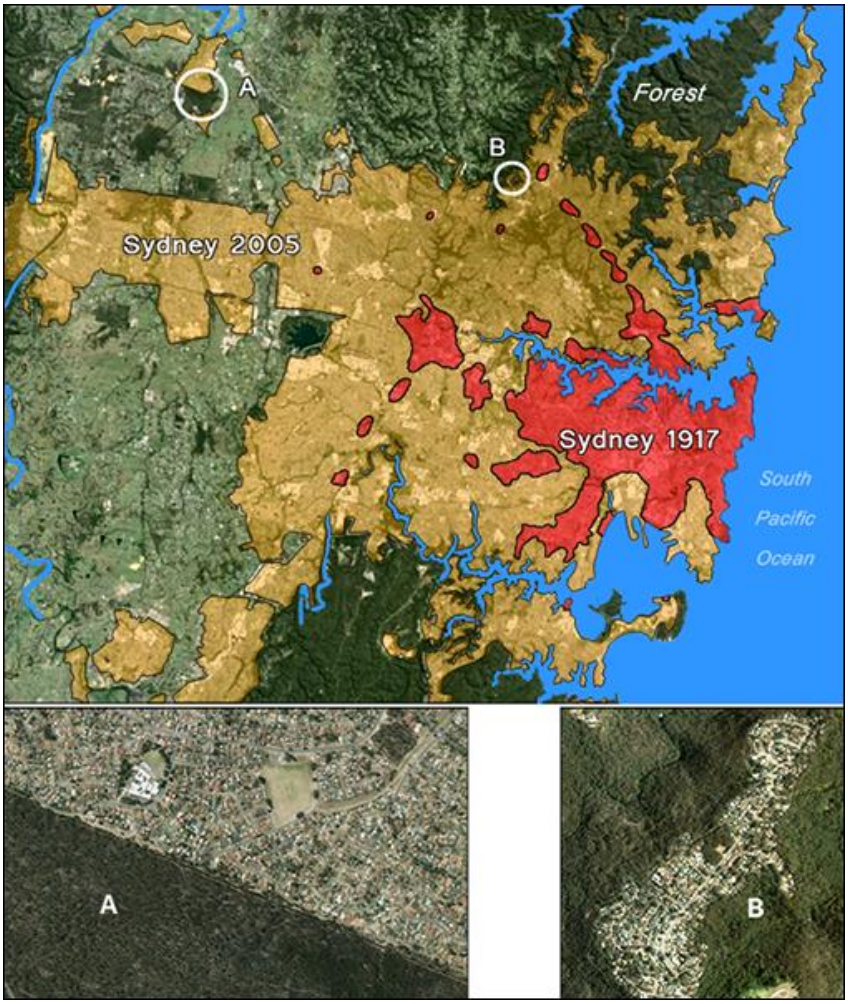
The Black Saturday bushfires killed 173 people and injured 500 more and cause over $2.5 billion in damages while destroying over 2000 homes (Disaster Assist, 2010). Annually, fire authorities respond to an average 54,000 bushfires in Australia where up to 50% of these fires are deliberately lit or start in suspicious circumstances. Even the bushfire is not severe enough to cause significant life or property damage, they are always costly, due to the cost for involvements of the related services to contain the fire (AIC, 2009).

Figure 2. Annual mean temperature anomalies for Australia (compared with 1961–1990 average) together with 10 year moving average (black line) (source: BOM, 2013).



In 2013, Australia recorded the highest annual temperature since the record began in 1910. The growing increasing trend in the average annual temperature of Australia (figure 2) indicates the possible adverse impact on the temperature to cause more bushfires (BOM, 2013). Ironically, locations of some of the Australian urban and other residential areas have added a higher risk to occur larger damage from bushfire. Figure 3 presents how the residential areas have expanded into the forest in Sydney within last 100 years. Close-up images A and B in figure 3 shows residential area are located in very closer to the forest.

Figure 3. Expansion of human settlements into bush (forest) in Australia has widened the threat bushfire. Images show how some residential areas in Sydney are next to (A) or surrounded by forest (B) (Source data, Google images and Transportsydney, 2014).



In this bushfire risk elevating background, authorities and researchers are taking various actions to mitigate the risk. Apart from ongoing direct measures to mitigate the bushfire damage, this paper discusses the prospects of application of satellite imagery combined with

GIS (Geographic Information Systems), participatory GIS to support such disaster mitigation efforts, through the use of social media.

Research objectives

Australia has a broad range of activities to combat bushfire disasters (Queensland Government Rural Fire Service, 2017, NSW Rural Fire Service, 2017). Fire warnings, online maps, and various bushfire related facts are available through these services and authorities are spending a substantial amount of resources to maintain these valuable services. The aim of this research is to add another avenue to integrate local communities with bushfire mitigation efforts. The primary research objects of this study are;

1. Combine freely available MODIS satellite imagery and other GIS data to produce semi-real time media contents on bushfires
2. Use social media to link media contents and local communities
3. Encourage local communities to participate in bushfire mitigation activities

MODIS imagery in environmental monitoring

MODIS (Moderate-resolution Imaging Spectroradiometer) sensors mounted on Terra and Aqua satellites deliver satellite imagery highly useful for a range of applications on the earth surface and atmosphere (Barnes et al., 2003, Friedl et al., 2002; Hall et al., 2003; Zhan et al., 2002). Terra MODIS and Aqua MODIS monitor the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands (NASA, 2015). Both satellites were launched and maintained by NASA (National Aeronautics and Space Administration). MODIS data including NDVI (Normalized Vegetation Index) (MODIS web, 2015; Perera & Tsuchiya, 2009; USGS, 2007) and true color imagery (Gumley et al., 2003; MODIS web, 2012; NASA Rapid Response, 2014) are freely available through NASA web site. MODIS has the capability to show some of the natural disaster incidents within 24 hours. This study uses freely available pre-processed MODIS products to merge with GIS data to create Media GIS contents.

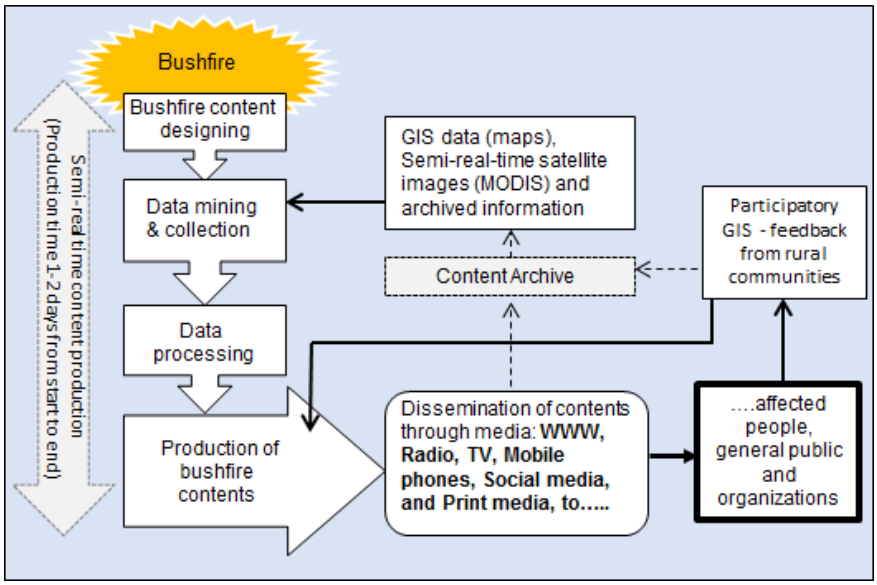
Characteristics and aims of Media GIS

The power of a GIS comes from its capability to relate different information (data) in a spatial context to conclude relationships among used data layers (USGS Geography Publications, 2008). Media GIS explains in this report can be considered as a sub-division of GIS. It is a computer-based content production system that involves; collect, store, analyse, produce, and distribute, graphic contents of natural disasters and other spatially significant incidents with a

high aesthetic quality, in semi-real time. When creating contents; optimising the primary graphical variables such as size, value, texture, hue, orientation, and shape, are not compromised. With regards to bushfires, Media GIS content starts with the brake of bushfire news. The concept of the production flow including the involvement of participatory GIS presents in figure 4. Under the case study section, a sample end product is visualised based on a bushfire incident occurred in 2015. The goal of the Media GIS is to enrich the understanding and awareness rural communities in bushfire disasters, to encourage people to participate in disaster mitigation efforts.

The Media GIS content production has to focus on six basic standards, i.e.; *accuracy, high esthetic quality, speed, low cost, reusability* (Perera & Tateishi, 2008) *and encourage user participatory*. The content maker must have some level of basic knowledge in; GIS, remote sensing, graphics, and multimedia portals, to maintain these standers. The content making can be established in government authorities or through volunteer participation.

Figure 4. The production flow of semi-real time Media GIS contents



Accuracy of the contents

Media GIS contents pass firsthand information to the public; therefore the geographical and informative accuracy of the contents is paramount. This accuracy can be maintained when the content production is based on geo-rectified MODIS satellite image products. The geographical accuracy of the content is paramount when merging with other GIS data including archived data layers. However, if the media GIS content needs publish urgently, geographic registration can be compromised some level.

High aesthetic quality

The use of colors (hue), fonts (type, size, color, and orientation), and symbols in media GIS contents must be carefully selected to match the with target age groups. Graphics should not hinder the valuable information in the image. Font sizes must be large enough to read easily and balanced to optimize the visual quality. Graphics should have smaller file sizes (JPG-Joint Photographic Experts Group or GIF - Graphics Interchange Format) to minimize the download time. For TV media, full-color TIF formatted (Tag Image File Format) graphics can be created to maximising the visual quality. All graphic products in original TIF format with all image layers must be systematically archived for future use. Tailoring graphics into various media platforms is not discussed in depth in this paper. Especially, web based data visualization and presenting methods face regular developments (Friedman, 2007; Ostrow, 2007). Therefore, the content producer must study new technological developments regularly.

Speed

Speed can be maximised at three different levels. The first is data mining, downloading, and converting into the GIS database. The second is graphic production process, which mainly deals with ArcGIS, QGIS or other GIS software, Photoshop or other graphic software, and Google Earth. Some skills in graphics software packages are necessary. The speed of the production has a link with the commercial use of the product. If the media company demands the contents without very high geographic accuracy, the content producer has to entertain such requests positively to balance the market/customer requirements. Thirdly, media contents must have the correct file size, image size, and file format to maximise the speed and support the data interoperability. Dissemination of the content through electronic media is a timeless task, but to the TV and newspapers, needs closer attention.

Cost effectiveness

The use of freely available of MODIS satellite data and Google images help to minimize the overall cost of Media GIS contents. Initial cost for ArcGIS can be a significant limitation, but QGIS (previously known as Quantum GIS - open source) can be an excellent candidate to do GIS operations. The capability of QGIS is expanding and cover vector as well as raster GIS functions. Google Earth data, functions, and a large number of supportive documents are freely available on the internet. Initial cost for Photoshop is relatively small compared to its excellent functionality in graphics. An older CS version of Photoshop is around AU $450 –

AU $600 over the web and produces excellent graphics. Also, there are free graphic software packages such as GIMP or Pixlr with cognitive capabilities.

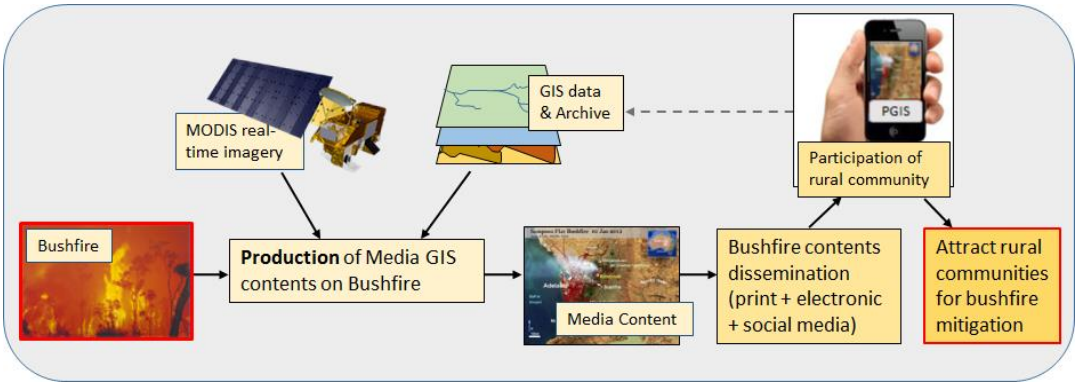
Reusability

Media GIS contents used GIS data, and imagery must be systematically archived. The final products and involved GIS data sets should be archived under the topic, geographic region, and date. Some end-products can be reused without any additional change to display historical conditions. A proper file system of contents and customer feedback will help to lower the overall production cost.

Encourage user participatory

Promote the participation of local community in bushfire mitigation is the primary target of media GIS content production in this research. Figure 5 shows the content production flow and how the Participatory GIS (PGIS) links with the flow.

Figure 5. Participation of rural community in bushfire mitigation through PGIS

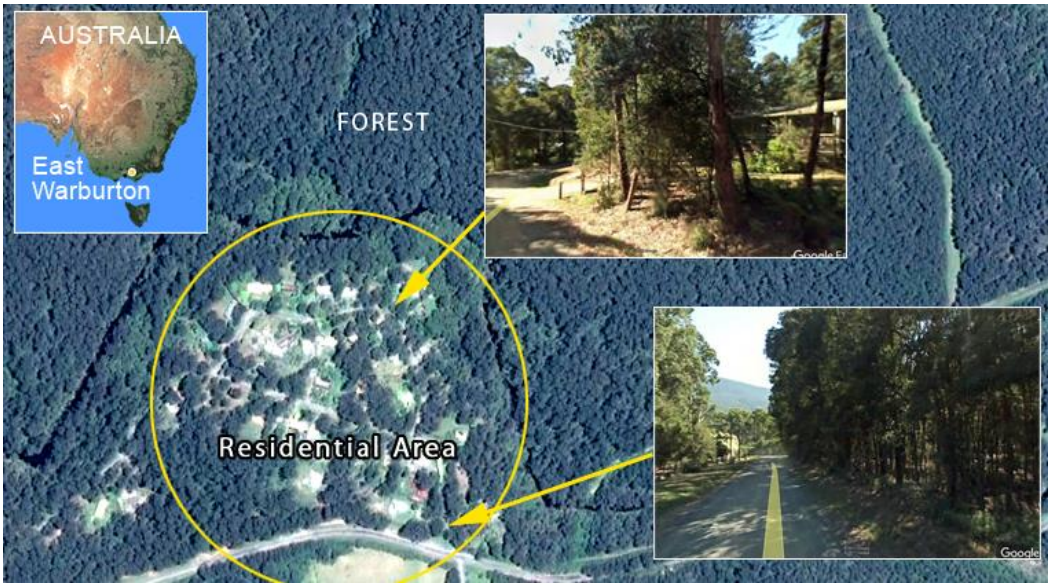


Participatory GIS (PGIS), is a collective term that described the community application of a diverse range of geographic information technologies and systems (IIED, 2015). PGIS can be used to fill the communication gaps in affected people, rescue operations, and policy makers. It uses digital maps, satellite imagery, sketch maps, and others to help involvement and awareness on a local level. (User, A. 2012). In this study, Media GIS contents aim to engage with the affected rural communities in bushfire disasters through PGIS to widen awareness on a local level. The involvement of the local community is an integral part of the research objectives since the overall aim of the study is to promote the safety of the local community from bushfire disasters. Participation of the local community is the PGIS arm of this project.

Bushfire risk in regional Australia

Bushfires in Australia often start when dry winds blow from central Australia to coastal areas where forests are located. The winds also provide ventilation for the flames. Trees such as eucalypts are especially prone to fire because their leaves have highly-flammable oil. Even though dry winds facilitate the favourable conditions, ignition of bushfire may cause by various reasons including lighting, deliberate actions, agriculture, and campfires. According to data recorded in Victoria from 1976 to 1995, only 26% of fires in 584 incidents were caused by lightning. The rest was largely caused by reasons related to human activities including deliberate actions (ABS year book, 2004). These bushfires in regional Australia have a greater danger due to the isolation of these small townships. As an example, Warburton in Victoria (about 70km northeast to Melbourne), is one such areas we randomly identified as a risk facing township (figure 6). This town within the Mountain of forest is a tourist attraction, but at the same time faces a greater risk of to bushfire by the proximity to the surrounding forest and limited road links with the other areas.

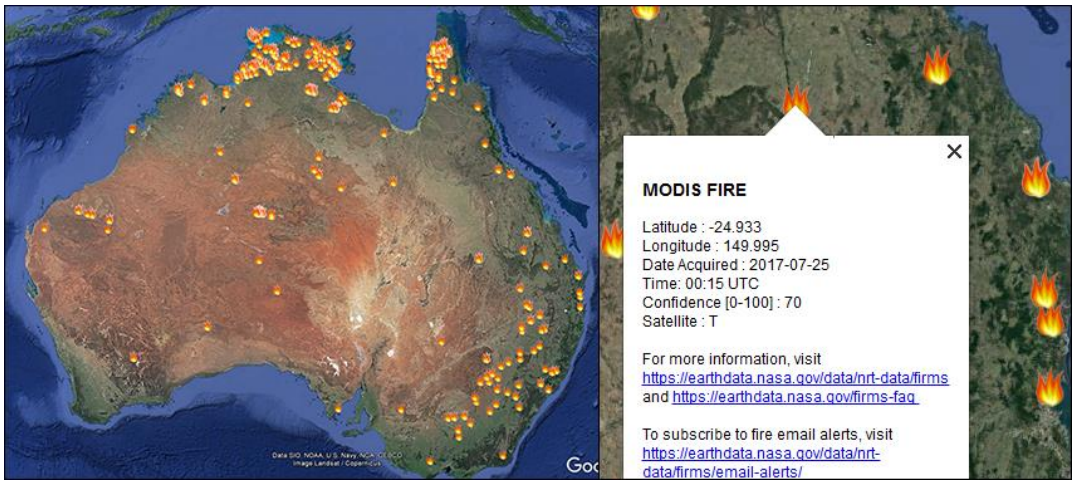
Figure 6. This image shows a section of East Warburton residential area where the forest has surrounded by nearly all sides.



Providing real-time bushfire information to people through the WWW is another promising development in bushfire disaster mitigation activities. NASA has taken the lead in this task, by facilitating a global scale real time active fire data using very useful three data formats; Shape files, KML, and Text file (FIRMS, 2017). NASA provides active fire information

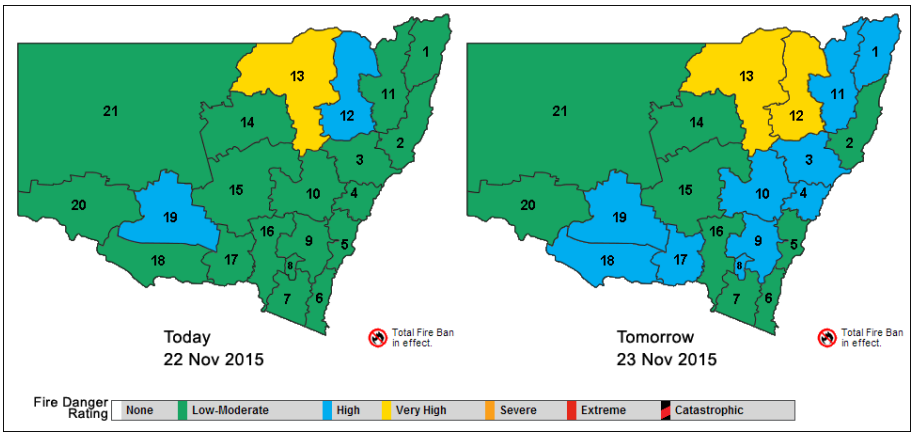
based on MODIS and VIIRS (Visible Infrared Imaging Radiometer Suite) data. This is an excellent source to identify hot-spots of fire for bushfire media content (figure 7).

Figure 7. Monitoring bushfire in real-time and updating information through the WWW (source: https://earthdata.nasa.gov/earth-observation-data/near-real-time/firms/active-fire-data).



At the national level, Australian government authorities are taking many precautionary actions to contain bushfire risk in regional Australia. All state governments have implemented own fire risk mitigation programs. Among them, NSW Rural Fire Service has a well-established approach to deal with fire related actions (NSW Rural Fire Service, 2015). The interactive map of bushfire warning for today and tomorrow is one such activity (figure 8). The QLD "Rural Fire Service" has a real time fire spot display based on ESRI products together with other useful information for people to deal with bushfire (QLD Rural Fire Service, 2017).

Figure 8. NSW government issues fire danger warnings with next day forecast in a clickable map (source: NSW Rural Fire Service, 2015, http://www.rfs.nsw.gov.au/fire-information/fdr-and-tobans).



From the other hand, altering the natural environment to reduce the fire hazard is another action consider by authorities in Australia. "*Fuel modification is a fundamental component of fire risk reduction, as discussed above and by Ellis et al. (2004). Because fuel reduction burning is the only feasible means of fuel reduction on a landscape scale, it is widely used throughout Australia*" (Whelan et. al, 2006). The knowledge about the fire resisting vegetation conditions in Australian indigenous people as well as non-indigenous research communities has widely applied for fire mitigation activities throughout the country. Media GIS can be extended to introduce this information for rural communities when PGIS groups are formed through social media.

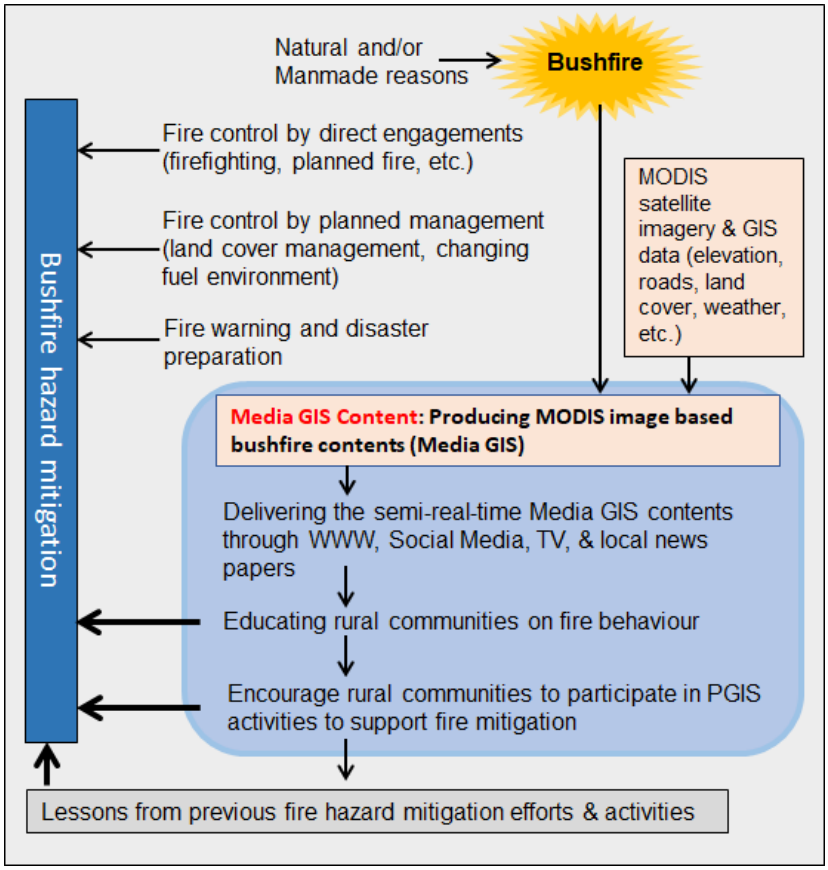
Linking Media GIS with bushfire disaster mitigation efforts

The methodology used in present study

In Australia, fire prevention related agencies work extensively to make available various data sources for public and schools. However, the flow of information to rural communities is not smooth due to various technical and social reasons, though their participation is vital. "I could see the real value of us educating the locals," said Glenn O'Rourke, Deputy Captain and Community Safety Officer at the Wollombi Rural Fire Brigade (Maddock, 2015) in NSW. This study suggests an approach to educate rural communities through Media GIS contents based on MODIS imagery. Fundamental information on Media GIS content production is discussed in previous sections.

This section focuses on linking Media GIS contents with rural communities and the attract participation in bushfire mitigation efforts, through PGIS. The participation of rural communities can be linked through already well established electronic communication facilities in Australian society. Once a method establishes to connect local communities, it is possible to assume a very positive feedback from people to support bushfire mitigation efforts. Media GIS contents will guide them to understand the developments of the fire together with other relevant information such as nearby towns, the extent of forest cover, and other high-risk areas. This GIS analysis will be based on available government information, fire warning, satellite image information, Google Earth images, and other geographic (elevation, road network, etc.) and social (rescue centres, hospitals, etc.) information. Figure 9 explains the flow of data gathering and processing as well as directions of data flow with regard to Media GIS content production for bushfire hazard mitigation.

Figure 9. Linking Media GIS with PGIS and other bushfire mitigation efforts.



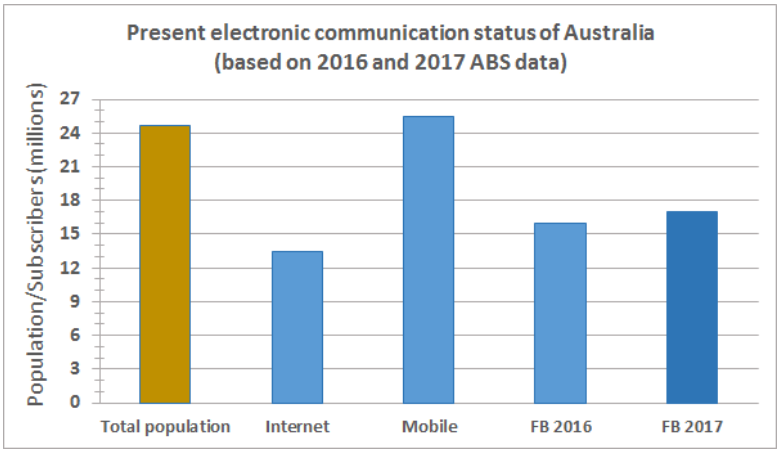
Social media, a promising too in disaster mitigation

When considering the recent developments and the flexibility in handling information technology, the Internet and social media are becoming an integral part of daily life of Australian. The internet subscription has ever increased in Australia with 4.7% increase just from December 2015 to December 2016, linking 13.5 million subscribers throughout the country (ABS, 2017). According to Australian government data, by December 2016, there were 25.4 million mobile telephone subscribers in the country, a higher number than the total population of the country. The population clock designed by the Australian Bureau of Statistics shows the latest population as 24,604,485 by 30th July 2017 (ABS, 2017), and about 10.8% of this population is from rural regions of the country.

This increasing electronic communication throughout Australia has opened new prospects for information dissemination in disaster mitigation efforts. To deliver disaster information and to attract the attention from local communities, face book is becoming a valuable social media. In Australia, about 70% of the population has face book (FB) accounts, and this is 1millon increase from 2016. In this background of high phase of electronic communication and social media (figure 10), FB can be used as a valuable tool to attract people to take part in

PGIS of bushfires. Another government document revealed, 88% of the adult population (aged over 65 years) in Australia has FB accounts. Adults who keen on FB and environmental disasters can be expected to target as the primary group of residents those who can participate in disaster mitigation efforts. In a critical bushfire disaster situation, communicating with isolated rural communities becomes difficult. Communication links will disturb or cease, including roads and telephones. When people exchange bushfire updates through FB, the new WiFi technology can be used to convert mobile phones into the WiFi hotspot, providing nearby mobiles to stay connected. Technically, this activity started with tethering or phone-as-modem, which connected PC's internet connection with other devices. When it comes to Mobile Hotspots, one mobile phone with internet access can facilitate a number of other mobiles/devices through the WiFi links, creating a mobile hotspot. In a disaster situation, people can continue to be connected through this technology and take part in PGIS to support bushfire mitigation efforts.

Figure 10. Australia has a very favourable society to use social media in disaster mitigation.

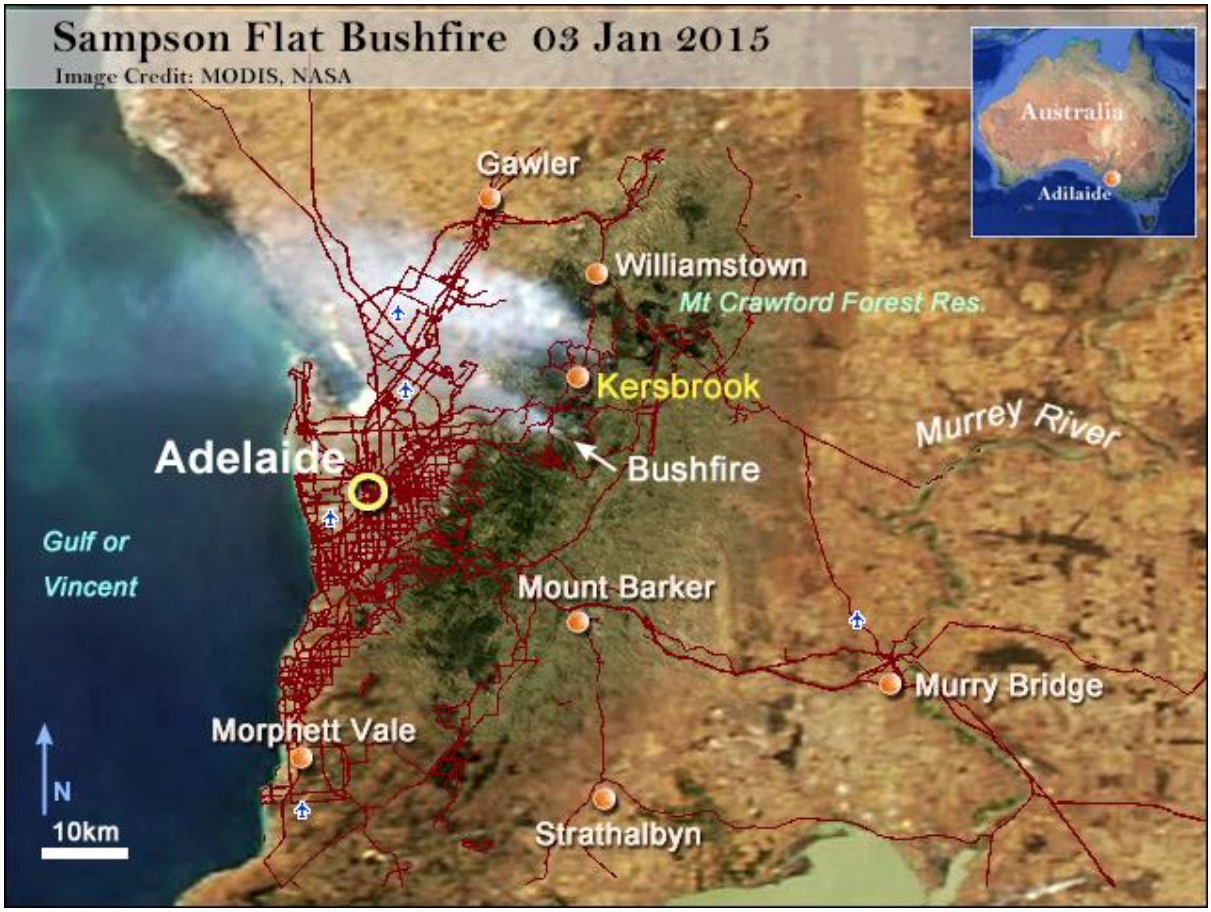


The case study: 2015 Sampson Flat bushfires

The case study in this study shows a MODIS image of the bushfire incident occurred in South Australia, in 2015. After Australia's warmest year on records in 2013, both maximum and minimum temperatures remained well above average with frequent periods of abnormally warm weather throughout 2014. In the later part of 2014, South Australia recorded a well below rainfall making the region ripe for the high potential of bushfire risk. The Simpson Flat bushfire occurred in this background on 2nd Jan 2015 in Mt Crawford Forest Reserve, which showed in the Media content in figure 11. The Media GIS graphic contains; enhanced MODIS visual band combination, Google high-resolution image portion to show the forest

cover around bushfire, road network and airports (open source maps), significant cities/townships, and labels to show major rivers. Roads and surrounding cities and towns are marked for the user to identify local area quickly. The graphic work was compiled in Photoshop to the size of 640x480 pixels. The six basic standards to follow when producing Media GIS contents explained in this paper were carefully applied throughout the process. The Simpson Flat bushfire continued for about a week and caused over AD$13 million in damage, according to media reports. Kersbrook town which is marked on the image was affected severely.

Figure 11. Media GIS content (MODIS image + Google Image + Major roads + Area information) of Sampson Flat Bushfire.



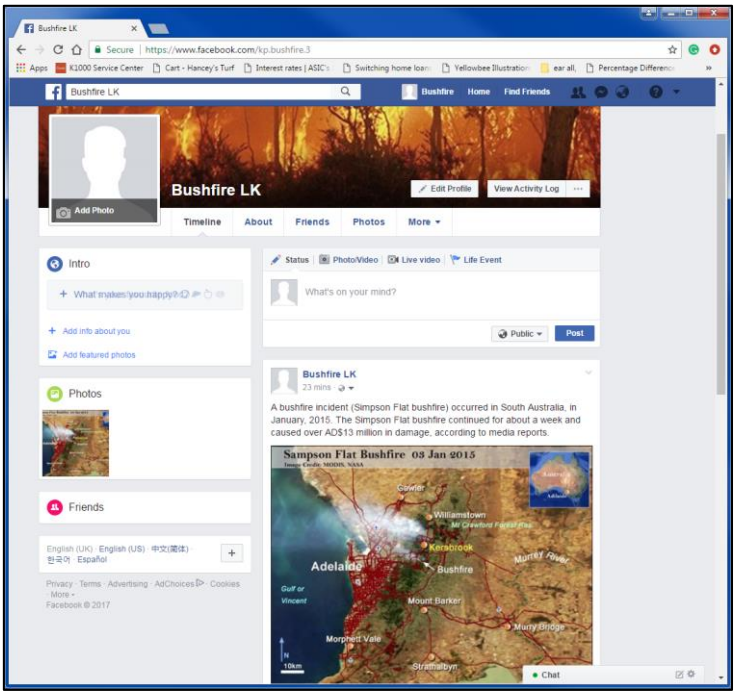
Discussion

The Media GIS contents and updates are possible to upload to local newspapers, TV, and to social media. This leads to establish a participatory user cohort and even online forums to discuss the ongoing disaster, with a focus on spatial information. Also, Google functions such as placemarks can be used in KML environment to enhance media GIS contents as

spot/image information. The role of open layers to modify maps in an open-source environment is also possible to establish, opening opportunities for interest participants to edit and input information into image maps directly.

Immediately after uploading the content to electronic media including Facebook, participatory comments on the hazard can be expected. Therefore, the content producer should establish an environment to collect response information and update the content regularly, to extend the service effectively. How to address these information coordination needs will be discussed in the next stage of this study. Collected PGIS inputs will be used to enrich the GIS database to further improve the communication process. Facebook can be counted as a very effective mean to communicate (figure 12), since smart phones are facilitating broader use of communication together with field photos and graphics. To make the Media GIS content into a genuinely useful tool; editable image maps should be available for users to add local information and share. The overall process can be used to educate rural communities those who have no familiarity with satellite images, PGIS, as well as to promote other activities to follow in non-fire seasons as precautions.

Figure 12. FB can be a very effective mean of social media in Australia to exchange natural disaster developments. This sample FB page displays the uploaded case study media GIS content.



Conclusions

Freely available MODIS satellite imagery can be successfully used to produce “semi real time” Media GIS contents to display most of the natural disasters, specially, when the disaster has an impact on a wider region and continuing for number of days (floods, forest fire, drought, etc.). The advantage of MODIS satellite imagery based Media GIS contents is the inclusion of latest conditions of ongoing bushfire monitored by the satellite on semi-real time basis. When related other GIS data blend with satellite images, a rich content of spatial information can be generated as Media GIS content. Media GIS contents must satisfy number of standards throughout the production process, such as accuracy, optimization of aesthetic quality, and production speed. In this research, Media GIS contents has produced as a tool to increase bushfire awareness among rural communities. These graphic contents can be disseminated using all possible Medias, including social media. When the content provides some useful semi-real time graphic/map based information for people to understand the status bushfire, it encourages the participation (participatory GIS) of people in bushfire affected area. The well-established electronic media environment in Australia is a vital support in this task. The case study presented in this study is showing the average quality of one Media GIS content of bushfire. It also explains how Media GIS contents can be used to present image and GIS based information about bushfire through FB. When the content is graphically attractive and geographically correct with fresh and rich information, viewers will obtain a better understanding about nature of natural disasters triggering more public involvements in disaster mitigation efforts.

Acknowledgements: Authors are thankful to CEReS, Chiba University, Japan, for funding this work (CI15-103), under CEReS Overseas Joint Research Program, 2015. Also, special gratitude is due to Professor K. MacDougal, Southern Queensland University, Australia, for providing institutional facilities and Professor Ryutaro Tateishi, CeRES, Chiba University, Japan, for valuable comments and supports for joint research works.

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