Mapping of Kangaroo Island, Australia

1. Introduction
Kangaroo Island lies in the southwest of Adelaide, is the third-largest island in Australia and is one of the popular natural destinations around the world. It has native bushland, wildlife and adventure activities (Kangaroo Island, 2020). However, the severe bushfires happened a few months ago destroyed the nature reserves and killed many wild animals.

The aim of this project is using supervised classification and indices-based approaches to analyse the changes of the burnt areas and inland water bodies of Kangaroo island on 8th December 2019 and 9th January 2020. The data was acquired from Landsat-8.

2. Methodology
The methodology for this project mainly includes three parts: colour composites and image enhancements, image classification (supervised classification and indices-based approaches) and accuracy assessment. The datasets have been processed to Surface Reflectance (Assignment instruction, 2020). ERDAS Imagine and ArcGIS Pro software were used to do the analysis and display the results.

2.1 Colour composites and image enhancements
Table 1 shows details of the Landsat 8 multispectral image, includes the band number, band name, wavelength, spatial resolution, etc. The chosen band combination in this exercise is band 7, band 5, band 3, displayed with red, green, blue respectively. The colour composites are maybe a little bit blurry. Thus, the image contrast needs to be adjusted using clip function based on the image LUT (look-up table) value.

Table 1. Bands detail of Landsat 8 image

Bands	Wavelength (µm)	Resolution (m)	What this band shows best
Band 1 Coastal Aerosol	0.433–0.453	30	Shallow water, fine dust particles
Band 2 Blue	0.450–0.515	30	Deep water, atmosphere
Band 3 Green	0.525–0.600	30	Vegetation
Band 4 Red	0.630–0.680	30	Man-made objects, soil, vegetation
Band 5 NIR	0.845–0.885	30	Shorelines, vegetation
Band 6 SWIR 1	1.560–1.660	30	Cloud penetration, soil and vegetation moisture
Band 7 SWIR 2	2.100–2.300	30	Improved cloud penetration, soil and vegetation moisture
Band 8 Pan	0.500–0.680	15	Black-and-white imagery, crisper detail
Band 9 Cirrus	1.360–1.390	30	Cirrus clouds
Band 10 TIRS 1	10.6-11.2	100	Thermal mapping, estimated soil moisture
Band 11 TIRS 2	11.5-12.5	100	Improved thermal mapping, estimated soil moisture

(Source: ESRI, 2013; ESRI, 2019; Landsat Science, 2013)

2.2 Supervised classification
Supervised classifications in this exercise were finished by using ERDAS imagine. Before doing supervised classification, a suitable training file processed by area of interest (AOI) file needs to be generated. The training file is a signature file with the document format of sig. The training samples represent some important classes in the classified image and google earth satellite imagery was chosen as the secondary source to provide ground truth and proofs when choosing the training area. In this project, the training file of Kangaroo island on 8th December 2019 has three classes: water, nature preserve, and other lands. And the training file on 9th January 2020 has four classes: burnt land, water, nature preserve, and other lands.

Supervised image classification based on maximum likelihood classifier, parallelepiped classifier and minimum distance classifier, is used for mapping and extracting burnt area. Maximum likelihood classification based on the probability that a given pixel belongs to a particular class and assumes the classified data are normally distributed (Petropoulos et al., 2012). The mean for minimum distance classifier is evaluated by using training samples and

the pixels are assigned to the nearest mean class (Sharma et al., 2018). The parallelepiped classification based on a standard deviation threshold of the mean for each selected class (Lee et al., 2018) and this classifier may cause overlap issues.

2.3 Indices-based approaches

The indices-based analyses mainly focus on the calculation of vegetation index, water index and burn ratio index, and they were finished by using "indices" function in ArcGIS Pro.

The normalized difference vegetation index (NDVI) is a standard index to assist the generation of an image which displays greenness (relative biomass) (ESRI, 2016). It also shows negative values represent clouds, water and snow, and near-zero values represent rocks and bare soil. The index is defined as:

$$NDVI = \frac{\rho_{NIR} - \rho_{Red}}{\rho_{NIR} + \rho_{Red}}$$

The modified normalized difference water index (MNDWI) uses green band and SWIR band to enhance open water features while reducing built-up areas (Du et al., 2016), which is defined as:

$$MNDWI = \frac{\rho_{Green} - \rho_{SWIR2}}{\rho_{Green} + \rho_{SWIR2}}$$

The normalized burn ratio index (NBR) uses NIR and SWIR bands to emphasize burned areas while mitigating illumination and atmospheric effects (ESRI, 2019). Images should be corrected to reflectance values beforehand. The index supports the image to be corrected to reflectance values before used. And the index is defined as:

$$NBR = \frac{\rho_{NIR} - \rho_{SWIR2}}{\rho_{NIR} + \rho_{SWIR2}}$$

2.4 Accuracy assessment

For the images processed using supervised classification, the accuracy of chosen training samples can be calculated using ERDAS imagine software. In ERDAS imagine, under "signature editor" module and under "evaluate" sub-module, the "contingency" function can provide "Error Matrix" document for the classified training file. Then we can use this file to estimate the error rate.

3. Results

Figure 1 shows the Landsat 8 acquisitions of Kangaroo island processed by colour compositing and image enhancing on 8th December 2019 and 9th January 2020. The western region of Kangaroo island in 2019 mainly distributed nature preserves and represented by green. And it occupies almost one-third of the island. However, in 2020, near half of Kangaroo island were burnt and represented by red. It is hard to show the change of the inland water area on this map.
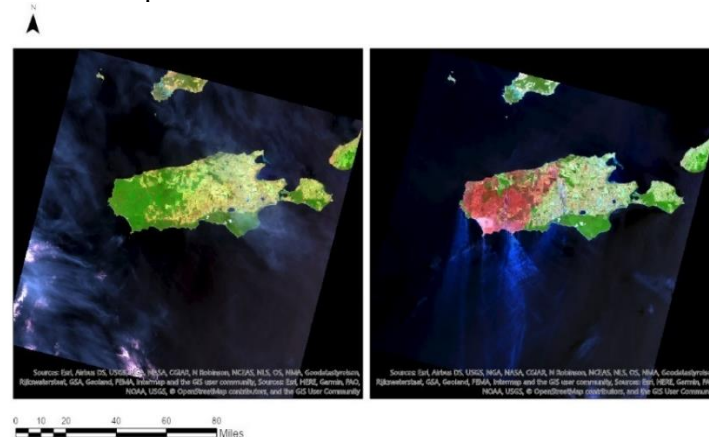

Figure 1: Landsat-8 acquisitions of Kangaroo Island from 8th December 2019 (left) and 9th January 2020 (right)

Figure 2 is an image of supervised classification result based on maximum likelihood classifier, parallelepiped classifier and minimum distance classifier of Landsat-8 data of Kangaroo Island in 9th January 2020. By comparing the classification images with google earth satellite image, best-supervised classification image was produced by minimum distance classifier. The image using maximum likelihood classified some ocean surface into inland water class. The parallelepiped classification contains many unclassified areas.
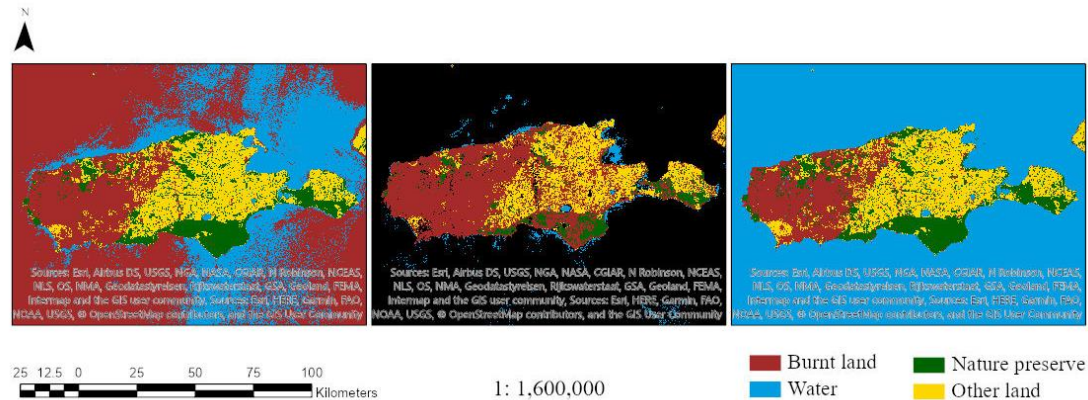

Figure 2: Maximum likelihood classification (left), Parallelepiped classification (middle) and Minimum distance classification (right) of Landsat-8 data of Kangaroo Island in 9th January 2020

Figure 3 uses minimum distance classification which is the best algorithm proved before and it shows the change of land cover of Kangaroo island between 8th December 2019 and 9th January 2020. Almost all the nature preserves in the western region changes into the burnt area within a month.
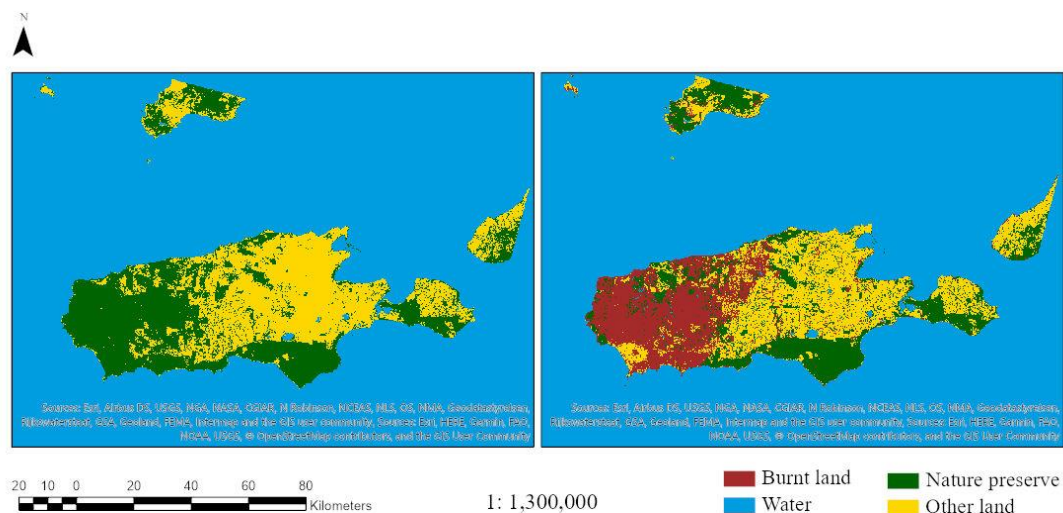

Figure 3: Minimum distance classification of Landsat-8 data of Kangaroo Island from 8th December 2019 (left) and 9th January 2020 (right)

In figure 4(a) and 4(d), brighter colour represents high reflectance and low absorption. The nature preserves which may cover with vegetation have a high reflectance in 2019, while that area after burning turned dark with low reflectance in 2020. The darkest class in the map is water, with high absorption for wavelength. Figure 4(b) and 4(e) are MNDWI images, which enhance open water features and remove the built-up land noise. The bright surfaces are water. Combined the image with google earth image, it is assumed that there is no obvious disappeared water surface. But the salty water may become shallowing and leave salt with high reflectance after the drought. In figure 4(c), the bright area represents high reflectance with healthy vegetation. And in figure 4(f), the dark area represents low reflectance with burnt areas.
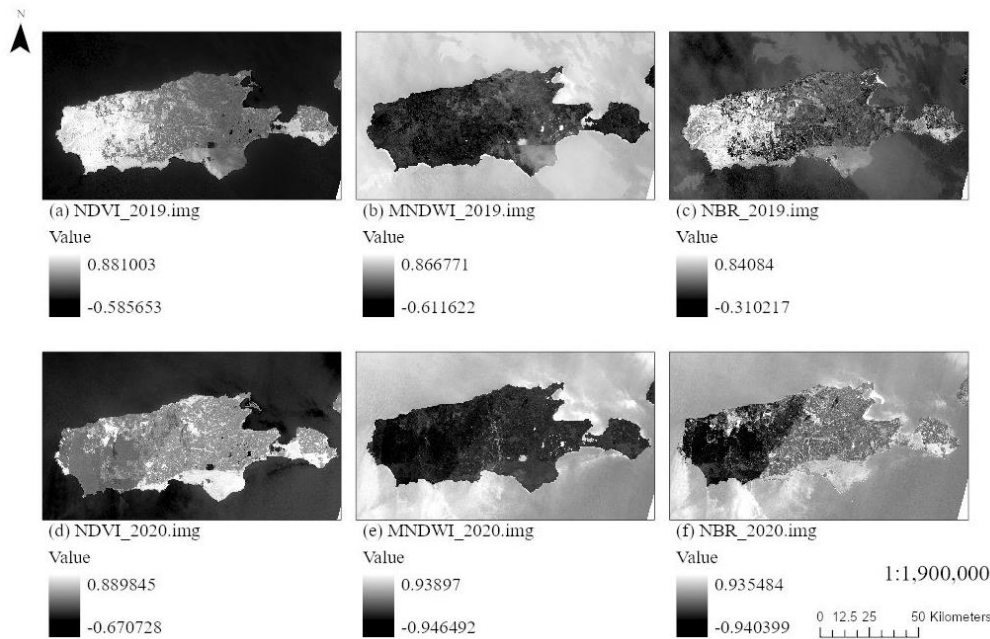
Figure 4: Classification image based on NDVI, MNDWI and NBR of Kangaroo Island
on 8th December 2019 and 9th January 2020

4. Discussion

For this project, I tried to analyse using both ERDAS imagine and ArcGIS Pro software. I found the classified images produced by the two different software are similar. Both can generate classified image with high quality.

Based on our purpose, the analysis for spectral wavelength and the expert's experience, it is easy to find that band combination of 6, 5, 4 which displayed as red, green, blue (RGB) is a common combination for vegetation analysis. However, after trying different band combinations, the band combination of 7, 5, 3, displayed as red, green, blue respectively, puts more emphasis on the fires. This band combination is more distinguishable because it shows natural with atmospheric removal (ESRI, 2013). Specifically, band 7 with the wavelength of 2.1 –2.3 nm distinguishes cloud penetration, soil and vegetation. Band 5 with the wavelength of 0.845 – 0.885 nm responses to vegetation species depends on different leaves. Band 3 with the wavelength of 0.525 – 0.6 is visible green and shows vegetation. Overall, vegetation reflects radiation well and water absorb radiation.

It is hard to distinguish smoke with burnt area clearly, so there are only four classes be classified in supervised classification in 2020. And using the evaluate module in ERDAS imagine, the accuracy of training area selection is around 97.8% for my project.

5. Conclusion

In conclusion, the band combination of band 7, 5, 3 with red, green, and blue sensors provides a good quality image for vegetation analysis and reduces the influence of clouds. Overall, the land cover change of Kangaroo island is classified using both supervised classification and unsupervised classification. The supervised classification based on maximum likelihood classifier, parallelepiped classifier and minimum distance classifier, while unsupervised classification realized by three indexes includes NDVI, MNDWI and NBR. Besides, choosing accurate training samples is important for supervised classification.

Nature preserves in western Kangaroo island almost be burnt entirely within a month. And the inland water includes lots of salty water and is assumed shallowing. UN Environment World Conservation Monitoring Centre (UNEP-WCMC) appealing everyone to protect the environment, not only on Kangaroo Island, but for all over the world.

Bibliography

Kangaroo Island Tourism Food Wine and Beverage Association, 2020. "*KANGAROO ISLAND, SOUTH AUSTRALIA … JUST ACROSS THE WATER, BUT A WORLD AWAY*". [online] Available at: https://www.tourkangarooisland.com.au/ [Accessed 16 Feb. 2020]

ESRI, 2013. "*Band Combinations for Landsat 8*". [online] Available at: https://www.esri.com/arcgis-blog/products/product/imagery/band-combinations-for-landsat-8/ [Accessed 16 Feb. 2020]

ESRI, 2016. " *NDVI function*". [online] Available at: https://desktop.arcgis.com/en/arcmap/10.3/manage-data/raster-and-images/ndvi-function.htm [Accessed 16 Feb. 2020]

Landsat Science, 2013. "Landsat 8 *Bands*". [online] Available at: https://landsat.gsfc.nasa.gov/landsat-8/landsat-8-bands/ [Accessed 16 Feb. 2020]

ESRI, 2019. "*Assess Burn Scars with Satellite Imagery*". [online] Available at: https://learn.arcgis.com/en/projects/assess-burn-scars-with-satellite-imagery/ [Accessed 16 Feb. 2020]

Petropoulos, G., Kontoes, C. & Keramitsoglou, I. 2012, "Land cover mapping with emphasis to burnt area delineation using co-orbital ALI and Landsat TM imagery", *INTERNATIONAL JOURNAL OF APPLIED EARTH OBSERVATION AND GEOINFORMATION*, vol. 18, pp. 344-355.

Du, Y., Zhang, Y., Ling, F., Wang, Q., Li, W. & Li, X. 2016, "Water Bodies' Mapping from Sentinel-2 Imagery with Modified Normalized Difference Water Index at 10-m Spatial Resolution Produced by Sharpening the SWIR Band", *REMOTE SENSING*, vol. 8, no. 4, pp. 354.

Sharma, J., Prasad, R., Mishra, V.N., Yadav, V.P. & Bala, R. 2018, "LAND USE AND LAND COVER CLASSIFICATION OF MULTISPECTRAL LANDSAT-8 SATELLITE IMAGERY USING DISCRETE WAVELET TRANSFORM", *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLII-5, pp. 703-706.

Lee, J., Acharya, T. & Lee, D. 2018, "Exploring Land Cover Classification Accuracy of Landsat 8 Image Using Spectral Index Layer Stacking in Hilly Region of South Korea", *SENSORS AND MATERIALS*, vol. 30, no. 12, pp. 2927-2941.