A STUDY ON EVALUATING RECOVERY FROM FOREST FIRE IN MONGOLIA USING NDVI AND NBR DERIVED FROM LANDSAT OLI DATA

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ABSTRACT: Mongolia is a country with a harsh natural climate, and as a result, the number of forest and steppe fires has been increasing in recent years. Therefore, forest and steppe fires are a serious problem in Mongolia. For example, statistics show that the number of fires is the highest in the last 10 years, especially in 2015. The purpose of this study is to investigate the possibility of evaluating the forest fire damages and recovery in Mongolia using data acquired by the optical sensor OLI onboard Landsat-8 satellite. The authors have utilized two indices, Normalized Burn Ratio (NBR), and Normalized Difference Vegetation Index (NDVI) derived from the OLI data for the analysis. NBR was used for detecting burnt areas. The color composite of NDVI of the year 2015 and 2018 was quite useful for evaluating the forest recovery. The analysis results suggested that a small difference of NDVI observed just after the forest fire could make a big difference in vegetation recovery.

1. INTRODUCTION

1.1 History of forest and steppe fire in Mongolia

Mongolia is located in Central Asia, bordering Russia's Siberia in the north, China's Inner Mongolia in the east and south, and China's Xinjiang in the west. It stretches about 1200 km from north to south and extends about 2400 km from west to east. The average altitude of Mongolia is 1580 m above sea level and 80% of the area is above 1000 m. Forests play an important role in maintaining ecosystem balance and mitigating climate change. Mongolia's forests are defined as mountain forests that grow in the harsh climate of Central Asia, have limited natural regenerative capacity, and are vulnerable to fire, pests, and human activities. Forests cover 8.1% or 12.7 million hectares of Mongolia's land area, and forest resources are declining due to human activities, and forest quality is deteriorating. The number of forest and steppe fires in Mongolia has been increasing in recent years. In Mongolia, the most active period for forest and steppe fires is April and May, when more than 80 percent of all annual fires occur [1,2]. Monitoring the damages of forest fire and evaluating the land recovery from the forest fire are urgent issues in Mongolia. Satellite remote sensing is one of the powerful tools for monitoring the damages of forest fire. The objective of this study is to assess the surface changes and post-fire conditions caused by forest and steppe fires using NBR (normalized burnt ratio) and NDVI (Normalized Difference Vegetation Index) derived from multi-spectral data of optical sensor OLI onboard Landsat satellite.

2. STUDY AREA

The study area is located in the eastern part of Mongolia, which covers the large area of forest and steppe fires occured in the spring of April and May 2015[1]. Figure 1 shows the map of the study area. The study area include Khentii Province and Dornod aimags Province.

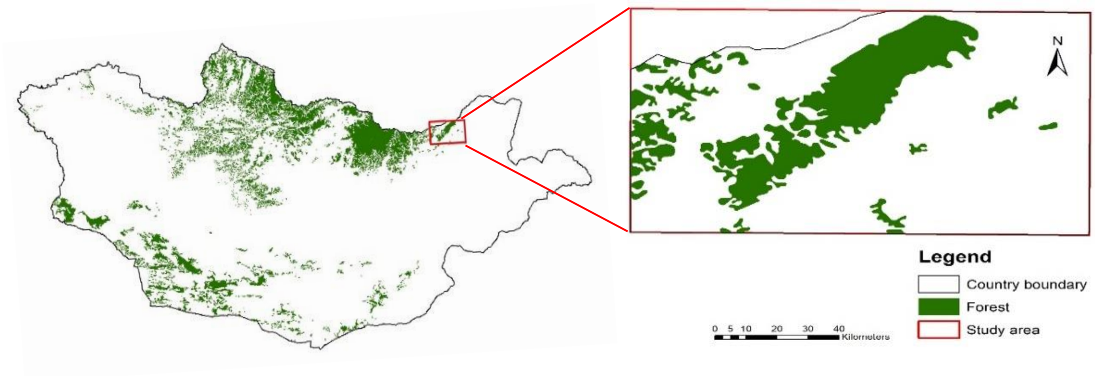


Fig 1. Study area (Environmental database [3])

3. USED DATA

3.1 Landsat 8 / Operational Land Imager (OLI)

In this study the multi-spectral data derived from the optical sensor Operational Land Imager (OLI) onboard Landsat 8 satellite was analyzed. Landsat 8 (formally the Landsat Data Continuity Mission, LDCM) was launched on an Atlas-V rocket from Vandenberg Air Force Base, California on February 11, 2013. OLI Sensor consist of nine spectral bands with a spatial resolution of 30 m for Bands 1 to 7 and 9. The resolution for Band 8 (panchromatic) is 15 m. The Specification of OLI is shown on Table 1.

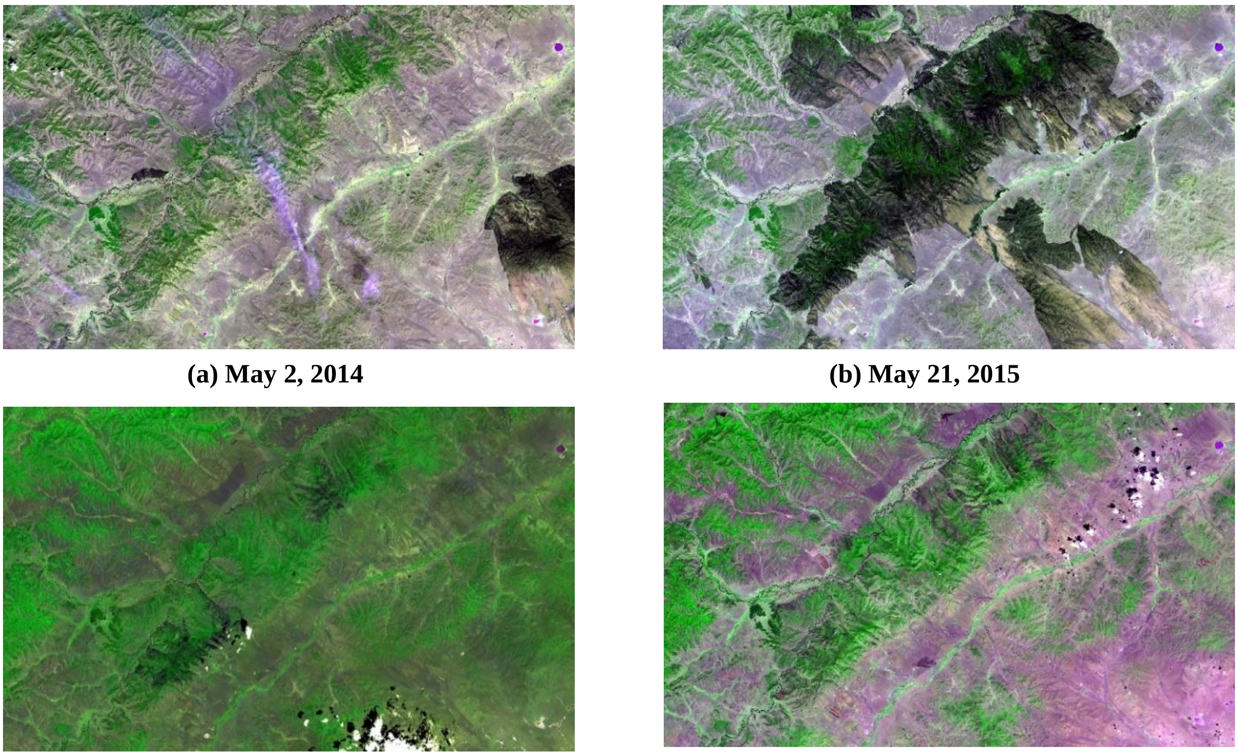
Table 1. Specifications of Landsat 8/OLI

Band No.	Wavelength(μm)	IFOV(m)	Color
1	0.43 - 0.45	30	Ultra-blue
2	0.45 - 0.51	30	Blue
3	0.53 - 0.59	30	Green
4	0.64 - 0.67	30	Red
5	0.85 - 0.88	30	NIR
6	1.57 - 1.65	30	SWIR-1
7	2.11 - 2.29	30	SWIR-2
8(PAN)	0.50 - 0.68	15	Green to Near IR
9	1.36 - 1.38	30	Middle IR

The observation dates of the OLI data used in this study are:

1. Pre fire: May 2, 2014
2. Post fire: May 21, 2015
3. Post fire: two years after the fire: May 26, 2017
4. Three years after the fire: May 29, 2018

Fig. 2 show the natural color composite images of OLI observed in 2014, 2015, 2017 and 2018. Since the near infrared band is assigned as green in this color composite, the vegetation looks in bright green in these images. A big forest fire occurred in April and May 2015. The burnt areas are appearing in dark color in Figure 2(b).



(a) May 2, 2014 **(b) May 21, 2015**

(c) May 26, 2017 **(d) May 29, 2018**

Figure 2. Natural Color Composite images of Landsat – 8/OLI
R - Band 4, G - band 5, B - Band 2

4. METHOD

In this study, the authors have calculated the Normalized Burnt Ratio (NBR) and the Normalized difference Vegetation Index (NDVI) using OLI data to extract burnt areas and evaluate the recovery of the vegetation of the burnt areas.

4.1 Normalized Burnt Ratio (NBR)

NBR is a commonly used index in remote sensing to detect burnt area and some special cases burn severity [5, 6, 7]. NBR formula is shown below.

NBR = (NIR-SWIR)/(NIR+SWIR) (1)

Where NIR: Near infrared band

SWIR: short wave infrared band

In case of Landsat 8/OLI, the NBR formular (1) is described as the following.

NBR=(Band5 - Band7)/(Band5 + Band7) (1)'

Fig.3 shows the spectral reflectance curve of burnt area and healthy vegetation. When the vegetation of an area is healthy, the reflectance of the near infrared band (NIR) is high and the reflectance of the short wave infrared band (SWIR) is low. On the other hand, as for the burnt area, the reflectance of NIR is low and the reflectance of SWIR is high. Accordingly, the NBR becomes high for healthy vegetation and becomes low for burnt area.

4.2 Normalized Difference Vegetation Index (NDVI)

NDVI is another index which quantifies vegetation by measuring the difference between near infrared and red bands [8, 9]. NDVI formula is shown below.

NDVI=(NIR-RED)/(NIR+RED) (2)

Where NIR: near infrared band

RED: red band

In case of Landsat/OLI, the NDVI formular (2) is described as the following.

NDVI= (Band 5 - Band 4)/ (Band 5 + Band 4) (2)'

Fig. 4 shows the Spectral reflectance curve of healthy and unhealthy vegetation. When vegetation is healthy, the reflectance of the red band (RED) is low and the reflectance of the near infrared band (NIR) is high. However, when the vegetation becomes unhealthy, the reflectance of RED becomes higher while the reflectance of NIR becomes lower. As a result, NDVI becomes high for healthy vegetation and becomes low for unhealthy vegetation.

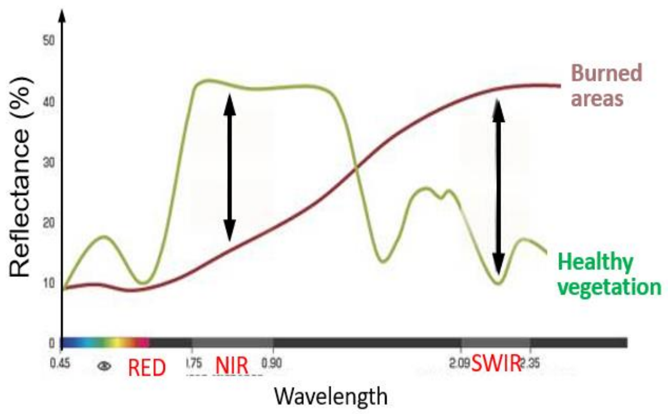


Fig 3. Physical background of NBR (After: US Forest Service)

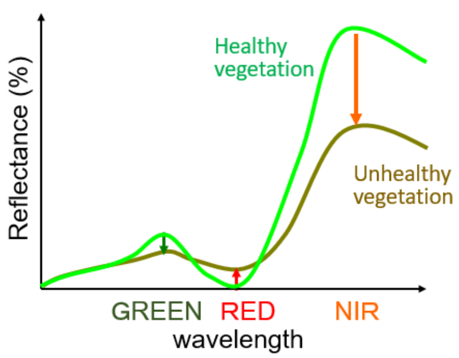
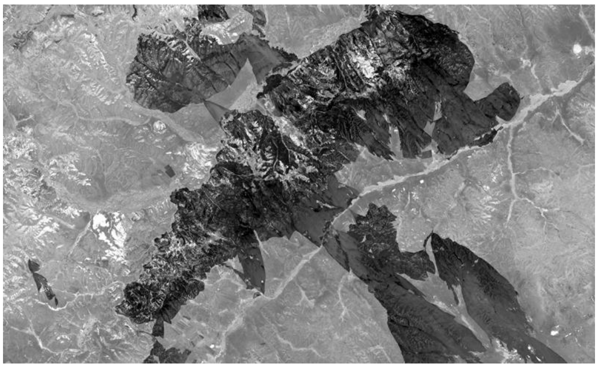


Figure 4. Physical background of NDVI

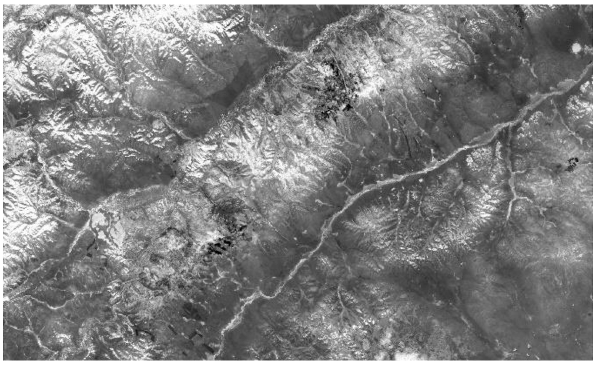
4.3 Comparison of NBR images and NDVI images

Figure 5 show the NBR images of 2014, 2015, 2017, and 2018. A The dark areas in Figure 5(b) show the burnt areas. Figure 6 show the NDVI images of the same dates. The burnt areas can not be recognized so clearly in Figure 6(b).

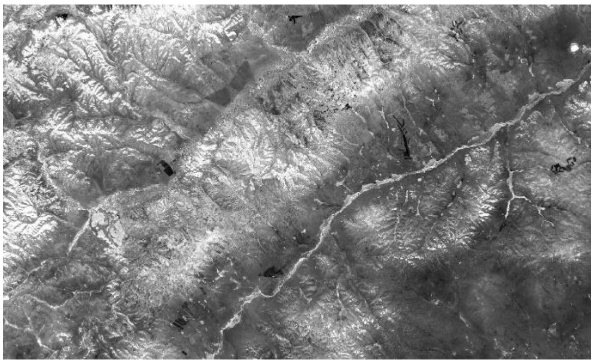
(a) May 2, 2014



(b) May 21,2015

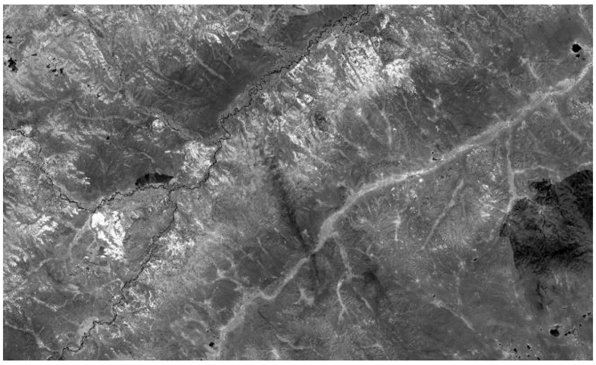


(c) May 26, 2017

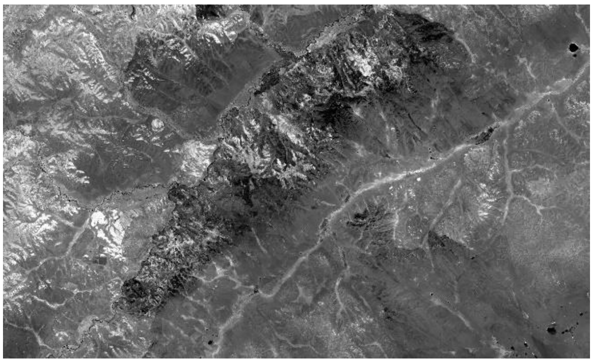


(d) May 29, 2018

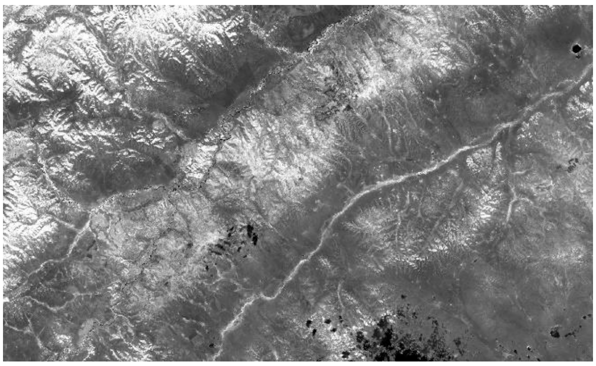
Figure 5. Comparison of multi temporal NBR images of the test area.



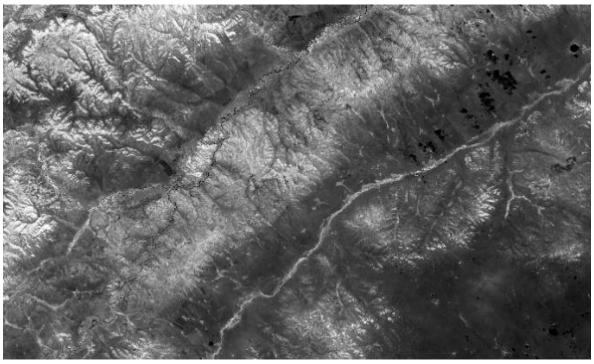
(a) May 2, 2014



(b) May 21, 2015



(c) May 26, 2017



(d) May 29, 2018

Figure 6. Comparison of multi temporal NDVI images of the test area.

4.4 Burnt area extraction using NBR

Figure 7 shows the histogram of NBR calculated from OLI data acquired on May 21, 2015. There are two peaks in the histogram reflecting the burnt areas and un-burnt areas. By evaluating the histogram, NBR=-0.075 was used as the threshold level for binarizing the NBR image to extract the burnt areas. Figure 8(a) shows the NBR image of 2015 and Figure 8(b) shows the extracted burnt areas by the binarization. This image was used as a mask data to extract only the burnt areas from NBR and NDVI images of each year.

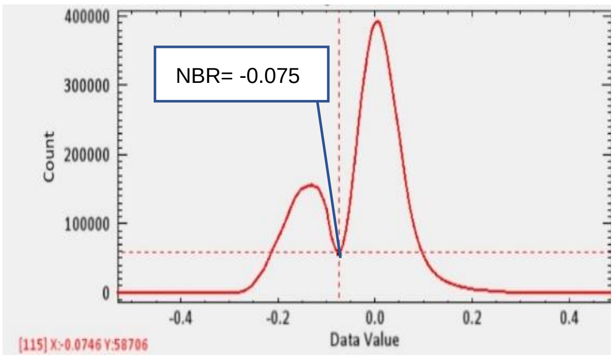
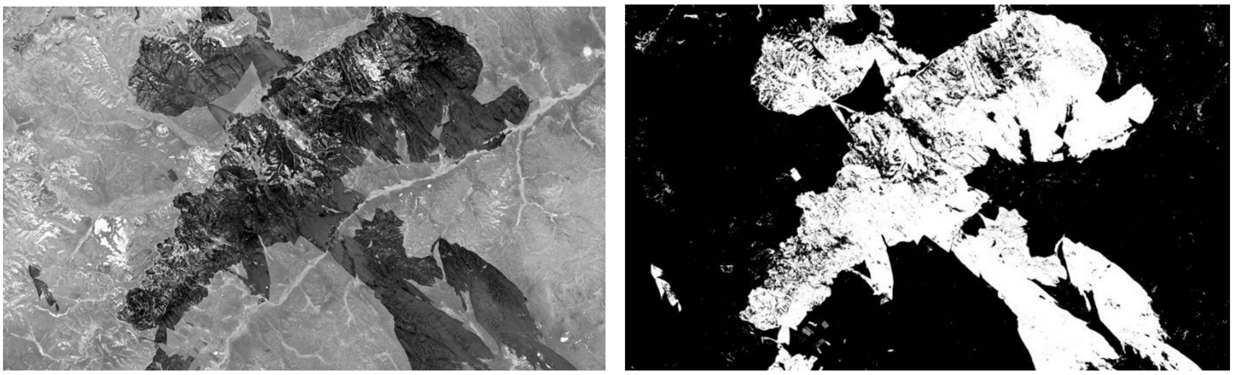


Figure 7. Histogram of NBR (May 21, 2015)

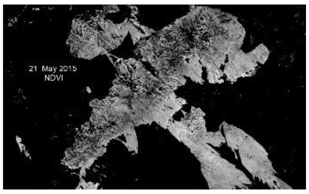


(a) NBR image **(b) Extracted burnt areas**

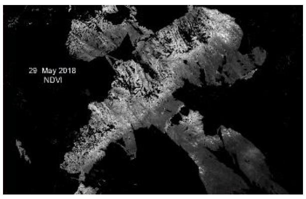
Figure 8. Extraction of burnt areas from NBR image derive from OLI data (May 21, 2015)

4.5 Production of NDVI color composite image

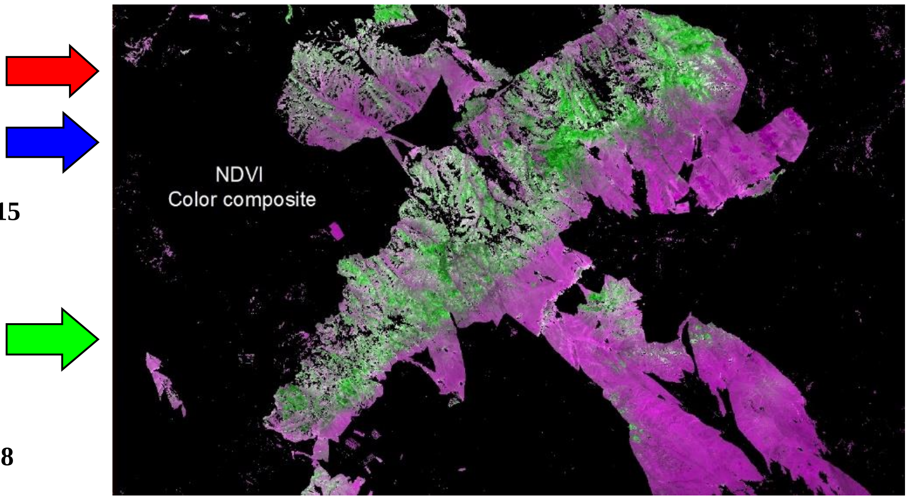
In this study the authors have applied a color composite method to clarify the vegetation recovery after the forest fire. We have assigned Red and Blue to the NDVI image of 2015 taken just after the fire and Green to the NDVI image of 2018 taken three years after the fire as shown on Figure 9. Since Green is assigned to the NDVI image of 2018, the light green areas reflect the areas where the vegetation became much active from 2015 to 2018. On the other hand, the dark green areas reflect the areas where the vegetation did not become so active from 2015 to 2018. The gray and white areas show no change of vegetation.



NDVI image of May 21, 2015



NDVI image of May 29, 2018



NDVI color composite image

Figure 9. NDVI false color compsoite
(R, B: May 21, 2015, G: May 29, 2018)

4.6 Sample points selection and comparison

By visually evaluating the NDVI color composite image of 2015 and 2018, the authors have picked up sample points of light green areas and dark green areas as shown on Figure 10. The light green areas are the areas where the vegetation became much active after 3 years, and the dark green areas are the areas where the vegetation did not become so active after 3 years. Red dots are the sample points selected from the light green areas and yellow dots are the sample points selected from the dark green areas. The time series of NBR and NDVI value of the sample points were compared to evaluate the reason of recovery difference between the light green areas and the dark green areas.

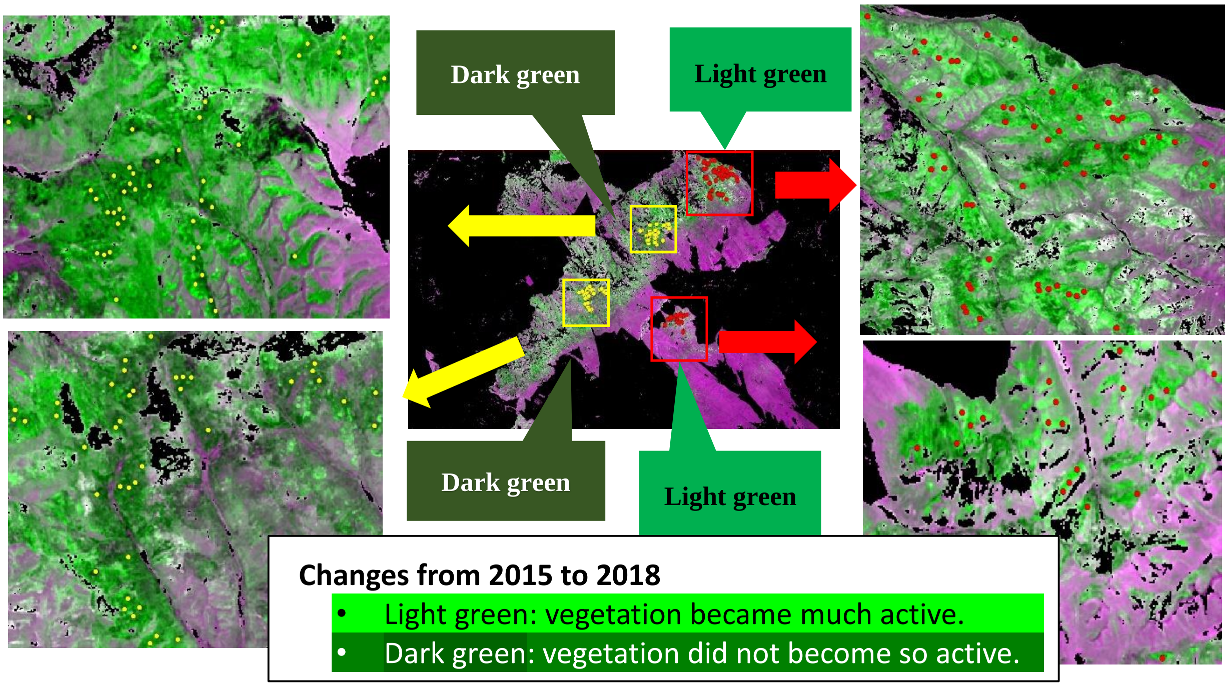
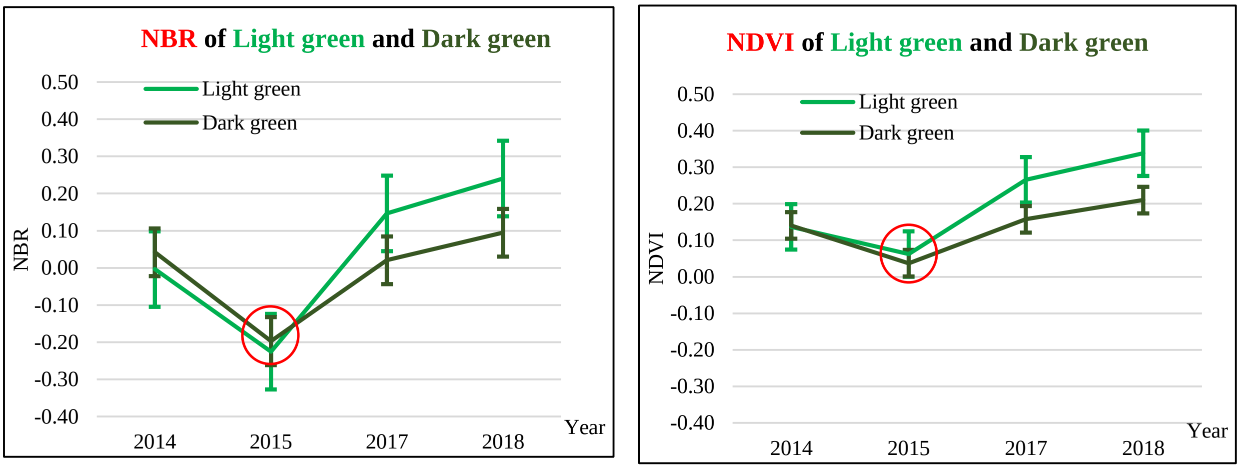


Figure 10. Selection of sample points of the light green areas and the dark green areas from the NDVI color composite image. (R, B: May 21, 2015, G: May 29, 2018)

5. ANALYZED RESULT

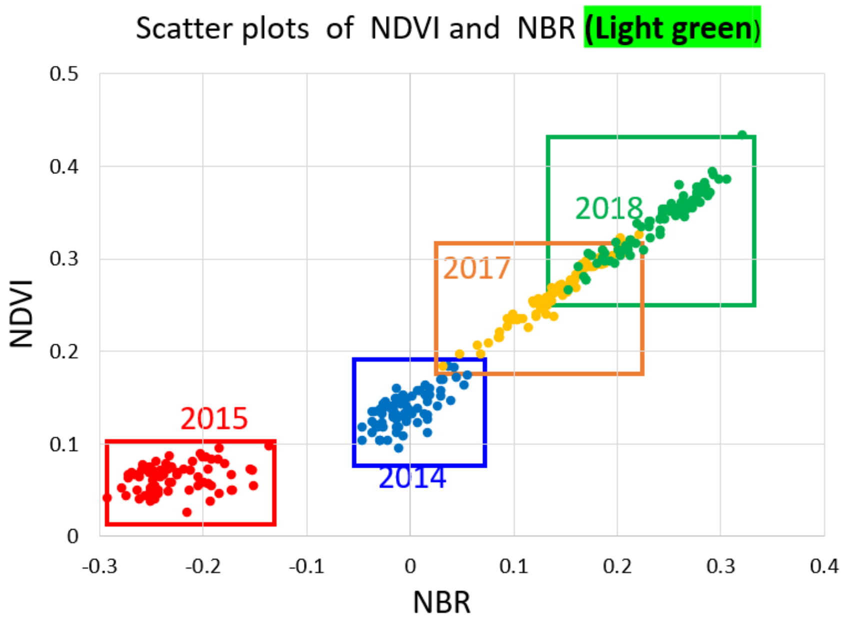
Figure 11 show the simple multi temporal comparison of NBR and NDVI for the light green areas and the dark green areas. Though both NBR and NDVI of the light green areas are higher than the dark green areas in 2017 and 2018, the NBR and NDVI of the light green areas and the dark green areas show similar values in 2014 and 2015. It is difficult to explain the reason of the difference of the light green areas and dark green areas. As a result, the authors have decided to introduce the scatter plots of NDVI and NBR for futher analysis.



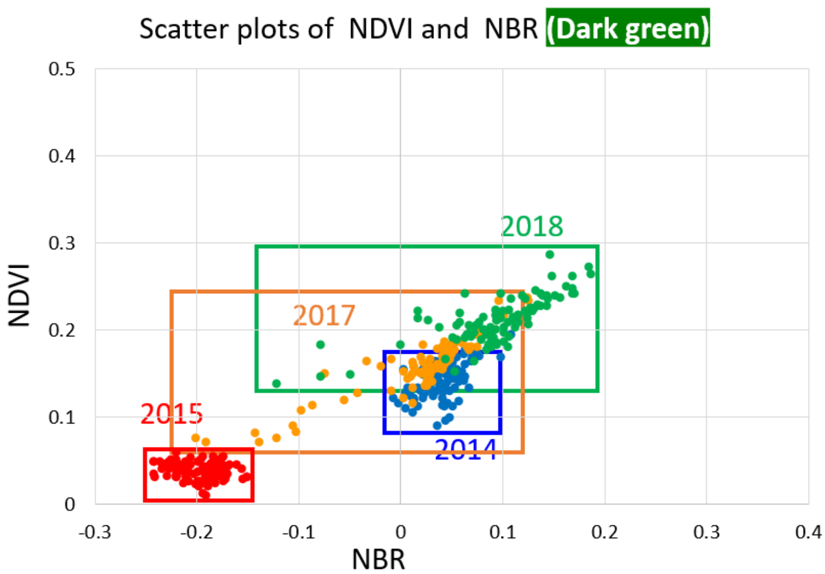
(a) NBR **(b) NDVI**

Figure 11. Multi temporal comparison of NBR and NDVI for the light green areas and the dark green areas.

Figure 12(a) shows the scatter plots of NDVI vs NBR for the light green areas, and Figure 12(b) shows the scatter plots of NDVI vs NBR for the dark green areas. It is clear that the NDVI of the light green areas are much higher than that of the dark green areas in 2018. However, the NDVI of the light green areas and the dark green areas were similar in 2014. This means that vegetation condition of both areas were similar in 2014. As for NBR, the values of the light green areas are similar or even lower than that of the dark green areas for 2015. This means that NBR does not explain the reason why NDVI of the light green areas became much higher than that of the dark green areas. In 2017, both NBR and NDVI became higher. However, the grade was rather higher for the light green areas than the dark green areas. The recovery of the Light green areas are clear compared with the Dark green areas.
The only difference we could recognize from the scatter plots is the NDVI value difference in 2015. The NDVI of the dark green areas were rather lower compared with the light green areas. The small NDVI difference observed just after the forest fire could result in a big recovery difference. This result suggests that monitoring the NDVI just after the forest fire could help the esimation of the forest fire recovery.



(a) The areas where the vegetation became very active from 2015 to 2018 (Light green areas)



(b) The areas where the vegetation became a little active from 2015 to 2018 (dark green areas)
Figure 12. Scatter plots of NDVI vs NBR

6. CONCLUSION

In this study, NBR and NDVI derived from Landsat-8 OLI data were alnalyzed for evaluating the fire damages and recovery of the forest in Mongolia. The advantage of NBR for detecting the burnt areas was clear. In order to evaluated the forest recovery difference after three years of the forest fire, the authors have introduced the NDVI color composite assigning red and blue to the NDVI image of just after the fire and assigning green to the NDVI image of the several years later from the fire. The image clearly showed the vegetation recovery difference of the burnt areas. The authors have selected sample points for the areas where the vegetation became very active and the areas where the vegetation became a little active from 2015 to 2018. The NBR of 2015 did not show any clear difference of the two areas. Then, the NBR vs NDVI scatter plots of before, just after and three years after the fire were compared for detailed analysis. The result suggested that a small difference of NDVI observed just after the fire could result in a big difference in vegetation recovery. This result suggests that monitoring the NDVI just after the forest fire could help the esimation of the forest fire recovery.

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