TRACING OF THE VEGETATION RECOVERY BY MODIS AND HIMAWARI8 AFTER THE FOREST FIRE IN NORTHERN MONGOLIA

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ABSTRACT: In recent years, large-scale forest fires occur frequently. So not only the detection of forest fire but also the recovery of vegetation after forest fire becomes the important problem. In this study, we traced the vegetation recovery of the southern limit of taiga, in northern Mongolia by using the satellite data. At first we got the ground truth data of forest fire damaged area, and checked the period of forest fire by using Landsat data. From Landsat data, we found that the area was damaged twice, 1998 and 2009, by fire. Then we calculated the three indices, NDVI, NDSI, and NDWI by using MODIS data, to corresponding to the damaged area from 2000 to 2017. We compared the value of three indices before and after the forest fire of 2009 and confirmed the change of these indices. Also we calculated these indices from AHI data and compared these indices.

1. INTRODUCTION

In recent years, large-scale fires have been frequent. For example, according to the report of National Interagency Fire Center, the 40217km2 of forest in United States were burnt in 2015. So not only the detection of forest fire but also the recovery of forest after fire become the important environmental problem. In order to obtain the information about the recovery of fire-damaged forest, a long term observation is necessary. So there are many papers that observed the recovery of fire damaged forest by using satellite data.

These papers are classifiable at least by three items; remote sensed data, analysis technique, and study field. For the observation of vegetation recovery, it is suitable satellite data that data are accumulated for long term. So as the satellite data using in these papers, MODIS (e.g. Gabriele Caccamo et al. (2014), Cuevas-González et al. (2008), Leon et al. (2012)), AVHRR (e.g. Goetz et al. (2006), Takeuchi et al. (2007)), TM, ETM (e.g. Bissom et al. (2008), Hope et al. (2007)) are mainstream. For analysis techniques in those papers, NDVI (e.g. Hope et al. (2007)) and NDVI and other indices (e.g. Takeuchi et al. (2007)) are used well. Study field are included various places, because the effect of different environmental conditions gave the difference in recovery process. Hence, for example, a tropical peat swamp forest in Indonesia (Segah et al. (2010)), boreal forest in Canada (Goetz et al. (2006)), taiga forest in Central Siberian region (Cuevas-González et al. (2008)), mediterranean coast of Spain (Belda and Melia (2000)) are included.

The objective in this study is tracing the vegetation recovery after forest fire. So we selected north Mongolia as study area because fire damaged area are increased in Mongolia in recent years. We selected NDVI, NDSI, and NDWI as the analysis technique, the major method to investigate the recovery of burnt forest so it is easy to compare the previous studies, and MODIS and AHI, as the remote sensed data, because MODIS was already used for tracing the forest recovery and AHI is the payload of new satellite, Himawari8. The space resolution of AHI is not so high compared with existing satellite data, but the time resolution of AHI is 10minutes and so high. So we used AHI, and investigated the change of NDVI just after the fire, and compared AHI and MODIS.

2. METHODOLOGY

2.1 Study Area and Ground Truth Data

We selected 2 study area. Study area 1 is for MODIS data and belongs to the north part of Mongolia, the southern limit of the taiga zone, and belongs to the semiarid region. In this area, the azimuth of slope is one of the important condition for formation of forest area. In this area trees are so precious that sometimes trees are cut after forest fire. Hence we selected 2 area A and B from the area without the effect of cutting, and made 4 study plots for each area that size is 20×20m in Khyalganat village, Bulgan prefecture which is the area of 49.6 degrees N, 104.2 degrees E (Fig. 1). The mean altitude of these plots is 1119m, mean temperature in January is -20 degree, and mean temperature in July is 16.8 degree.

The field survey was carried out over from July 8 to June 29 in 2016. For getting the ground truth data of burnt forest area, we investigated all tree in plots and calculated the percentage of vegetational cover of study plots (Table1). We found that there is no tall and subtall tree in plotA-1toA-4, on the other hand, there are some tall and subtall trees in plotB1to B4. But in all of these plots, the cover degree of herbaceous were bigger than that of tree (Fig. 2). We investigated not only survival tree but also burnt dead tree, and classified these trees to 3 categories; death tree by forest fire, tree that survived from fire, and tree which grew after the forest fire. And we estimated the disappeared biomass by forest fire from the size of death tree. Then we found that 1) the composition of trees are changed before and after fire 2) the biomass greatly decreased after fire, and the recovery of the tree is greatly late.

From the field survey, we couldn’t find when the fire occurred around these study plots. So we detected the time that the forest fire was occurred by using Landsat data. Then we found that the fire occurred twice, 1998 and 2009.

From the Landsat data, fire damaged area were able to interpret only when the forest burns, but only after 2or 3 months, damaged area became difficult to find.

Table 1: Vegetation cover degree in 8 study plot

		plotA-1	plotA-2	plotA-3	plotA-4	plotB-1	plotB-2	plotB-3	plotB-4
cover degree (%)	tall tree	0	0	0	0	0	0	45	15
	subtall tree	0	2	0	0	0	3	2	0
	shrub	<1	15	3	0	1	40	3	5
	herbaceous	60	70	75	75	45	75	80	25

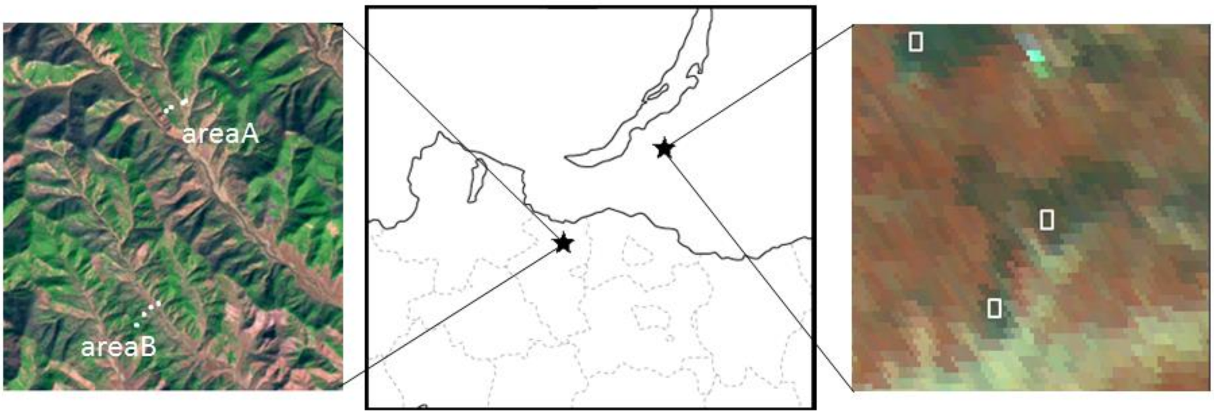

Fig. 1: Study area and study area: Left: study area1 (Landsat TM 2004/10/06), Right: study area 2 (AHI

Fig. 2: Ground truth data of study plot. Right: plotA-2, Left: plotB-3.

For study area 2, we selected the area that can observe the scar of forest fire from both AHI and MODIS, so we selected the forest fire area from forest that belongs to the same taiga area, which is the area of 52.8 degrees N, 110.6 degrees E (Fig.1). From Landsat data in May 21, 2016, after the fully operated of AHI, we found the forest fire area and named the area as study area 2. We prepared AHI data from May 21 to June 6 and MODIS data that

May 24 and June 9.

2.2 Indices of MODIS

For the observation of recovery of burnt forest, we used MODIS data, at first, and calculated 3 indices, NDVI, NDSI, and NDWI. Then we traced the change of the indices of pixel that overlapped on study plot. From Takeuchi and Yasuoka (2005), definition of 3 indices are as follows.

$$NDVI = \frac{band2\text{-}band1}{band2+band1} \quad NDSI = \frac{band7\text{-}band2}{band7+band2} \quad NDWI = \frac{band1\text{-}band7}{band1+band7}$$

MODIS data were stated to observe after 2000 year, so we couldn't know about the fire in 1998. Then we tried to detect the change of indices before and after the fire that broke out around May 30, 2009.

But in field survey, we couldn't separate the influence of 2009 fire and 1998 fire, so we selected 2 pixels that damaged by forest fire for first time in 2009, by using Landsat data. And also we selected the pixel that received fire damage only in 1998.

The resolution of MODIS is 1km, so plotA-1 to plotA-4 and plotB-1 to plotB-4 are included in each 1 pixel, so we traced indices of 2 pixels. We used 16 day composite data from 49th day of 2000 to 33th day of 2017.

2.3 Indices of AHI

Himawari-8 is a Japanese weather satellite that was launched in October 2014 and became fully operational in July 2015. The satellite has a new payload called the Advanced Himawari Imager (AHI), a sixteen-channel multispectral imager. From the AHI, data are received every 10 minutes. Then using this high-time resolution data, we aimed to investigate the change of NDVI just after the fire and to compare the indices of MODIS. We selected 3 pixels of AHI and calculated 3 indices of AHI from May 21 to 6 June in 2016 and traced the change of indices. We had to visually adjust the positions of these two datasets because there was displacement between the Landsat8 and AHI data. The definition of 3 indices of AHI are follows;

$$NDVI = \frac{band4\text{-}band3}{band4+band3} \quad NDSI = \frac{band6\text{-}band4}{band6+band4} \quad NDWI = \frac{band3\text{-}band6}{band3+band6}$$

The resolution of band3, band4, and band6 is 500m, 1km, and 2km for each band. So we calculated the average of band3 and band4 to match the resolution of 2km.

Band3 and band4 are not available from sunset to dawn, then we calculated the 1 day average in the time range that data are available (1-day average value), and compared these values and 3 indices of MODIS in May 24 and June 9 in 2016.

3. RESULT AND DISCUSSION

3.1 Change of MODIS 3 indices

We calculated the 3 indices of 2 pixels of study plots, and traced the change of values before and after fire (Fig 3).

From these graphs, we found that NDVI decreased on the 145th day (May 24) in 2009, but was restored only in 32 to 64 days. The period that NDSI deviated from that of average year was longer than that of NDVI, but the period is under 3 months. NDWI of plot A at the time of forest fire is increased, because of the influence of cloud. We want to confirm the difference of NDVI before and after forest fire, so we calculated the mean value and SD of NDVI between 2000 to 2008 and 2010 to 2016, and compared NDVI of 193th day (July 12) corresponding to the period that herbaceous influence is the highest. Difference of mean NDVI between 2000 to 2008 and 2010 to 2016 is 0.032 in plot A and 0.030 in plot B, and these values are about the same value of SD of same period. Then we found that the difference of NDVI before and after forest fire is small.

But from the field survey, we found that the forest is not recover after 7 years from forest fire. So we thought that the recovery of NDVI value is by the influence of herbaceous, but not the influence of tree. We guessed the reason why NDVI does not have a big difference before and after fire is the influence of 1998 forest fire. If fire damage of 1998 was so heavy and the part of the tree were already burnt, there were not so much trees before forest fire in 2009.

Hence next, we selected 2 pixels (P1, P2) that overlapped the area that there were dense forest before the 2009 fire in order to decrease the possibility that there was already fire damage. And we calculated 3 indices and traced the change of these indices (Fig4), also calculated difference of mean NDVI between 2000 to 2008 and 2010 to 2016. The difference of mean NDVI between 2000 to 2008 and 2010 to 2016 is 0.059 in P1 and 0.183 in P2 and these value are 2 times to 3 times of SD value. So we found that the influence of the forest fire in 2009 is continued more than several years. Especially the graph of fig. 4 of P2, the maximum value of the mean NDVI before the fire is nearly 0.8, but after the fire the value became 0.6.

And also we traced the change of indices of area that there were forest before 1998 fire. And traced the change of these indices. From these graphs, we found that the influence of 1998 fire is still remain and NDVI become under 0.6.

And comparing 2 mean value, 2000 to 2008 and 2010 to2017, we found that NDVI is increased slowly as time passes. Then we assumed that NDVI of the area that there were forest before the fire changed before and after forest fire.

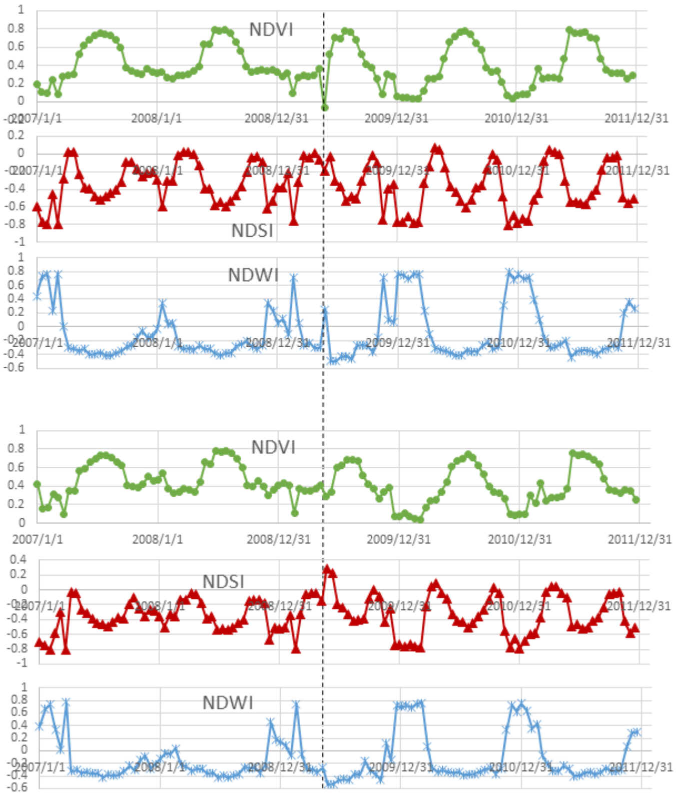

Fig. 3: Annual variation of 3 indices of study plots from 2007 to 2012. Upper 3 graphs is the graphs of plot A. Downward 3 graphs are the graphs of plot B. Black dotted line shows the forest fire period.

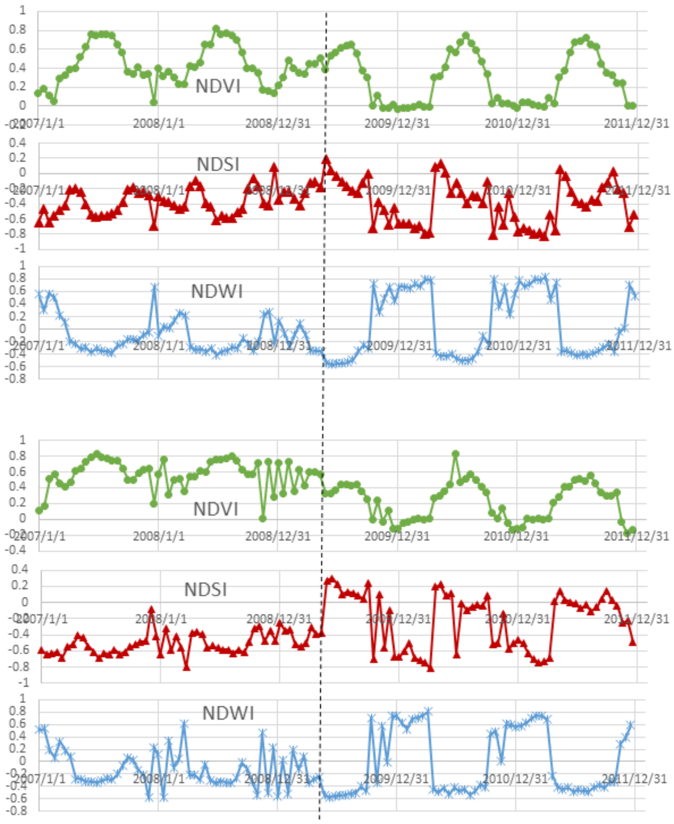

Fig. 4: Annual variation of 3 indices of study plots from 2007 to 2012. Upper 3 graphs is the graphs of P1. Downward 3 graphs are the graphs of P2. Black dotted line shows the forest fire period.

But these 3 pixels belong to the area more than 1600 asl, then we could assume that the influence of herbaceous is not so high in these area. Hence from this study, we couldn't know about the change of NDVI in the burnt forest area in low altitude area that the influence of herbaceous is higher.

And also, NDWI of winter are increased after forest fire, especially inP1 and P2. It is the result that the bare field were increased after the forest fire, and snow piled up on the bare field.

3.2 AHI 3 indices

We calculated 3 indices from AHI, and calculated the1-day average in the time range that data are available, selected the result of 2 pixels, and compared the same 3 indices from MODIS (Fig.5). X axis is the number of days from 21 May.

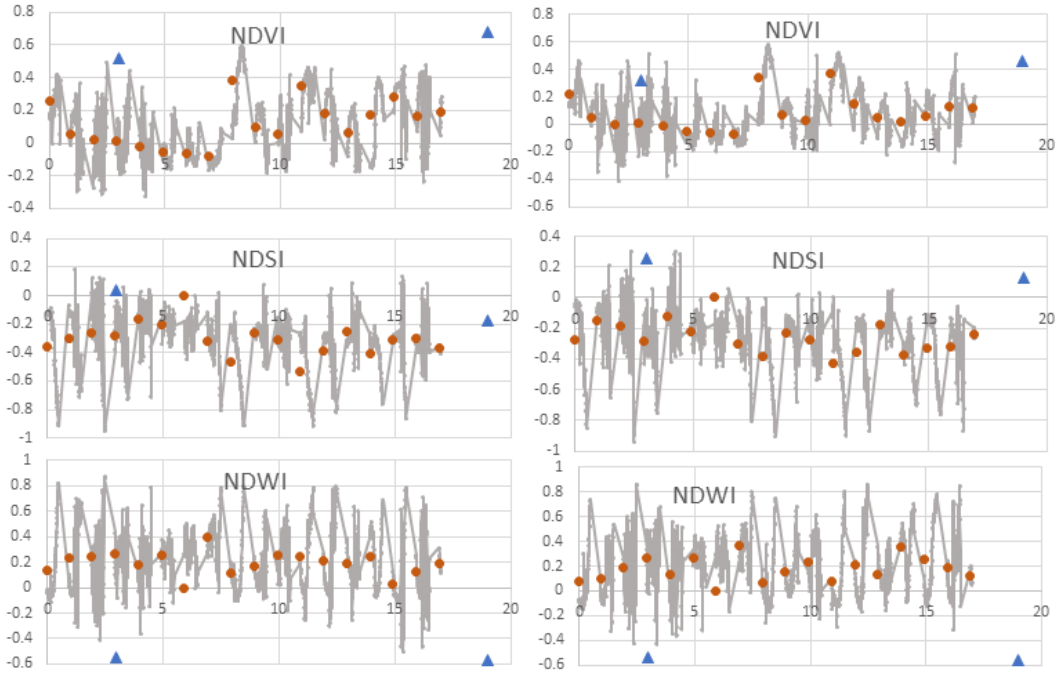

Fig. 5: Trace graphs of 3 indices.

Gray line: indices of every 10 minutes, Red circle: indices of 1-day average,

Blue trigone: indices of MODIS

From these graphs we found that there are different between 1-day average NDVI and NDWI of AHI and NDVI and NDWI of MODIS, but max of NDVI of this day is nearly to NDVI of MODIS. NDWI are much different between MODIS and AHI, even if the range of the daily fluctuations was taken into account. NDSI is not so much different between MODIS and AHI.

And we found that the range of daily fluctuations were big. So it is more suitable to use 1-day average indices to trace the change of indices. Both of 2 pixels, NDVI was decreased nearly linier from 1st day to 7th day from 21 May. After 8th day, NDVI was increased with big dispersion. NDSI and NDWI are not so changed between these 16 days. So we could assume that influence of cloud is not so different between before 7th day and after 8th day, because of the little different of NDWI, and the condition of fire area was changed in 7th day to 8th day.

4. CONCLUSIONS AND NEXT STEP

From this study we traced the recovery of vegetation by using NDVI, NDSI, and NDWI. Then we found that the recovery of NDVI does not mean the recovery of trees, but means the recovery of herbaceous. Then from the area that there were forest before fire and high attitude, we found the influence of burnt trees from change of NDVI.

And also we traced the change of 3 indices of AHI, and found that the range of the daily fluctuations were big, so 1-day average NDVI is more suitable to detect the change of the indices.

So next step, we want to make the map of time width to recover NDVI, and to investigate the conditions to estimate the time width. And also, we want to collect the ground truth data for the AHI data. We found the turning point of NDVI, but without the ground truth data at that day we couldn't understand the exact meaning.

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