ASSESSMENT OF DROUGHT IMPACT ON RICE PADDY FIELD IN NORTH KOREA FROM 2007 TO 2019

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ABSTRACT: North Korea said that this year become worst drought and serious food shortages will occur this year. They said they has received only 53mm rain from January to center of May, that lowest level since 1982. However, usually in North Korea, there has little rainfall from winter to spring, so it is whether the dry condition in this period will be caused the drought or not.
Then in this study we assessed the drought impact of North Korea in 2000's in order to decide whether drought is occurring in 2019. We used Keetch–Byram drought index, KBDI for index of drought. Then we selected indicators of drought impact, i.e. the water area of the paddy field, and investigated how this indicator changed under the influence of drought by using SAR and Landsat data. As a result, we confirmed whether North Korea in 2019 is under the influence of the drought.

1. INTRODUCTION

Around May of this year, news was reported that “the drought has occurred in North Korea and there is a risk of a food crisis”. Three months have passed since then, and there is no next news, and it is unclear whether a drought has occurred or not. Therefore, we investigated whether drought actually occur this year and how it can be perceived by satellites when drought occurs.

We used The Keetch-Byram Drought Index (KBDI) as a drought indicator. This is a continuous reference scale for estimating the dryness of the soil and duff layers, and the scale ranges from 0 (no moisture deficit) to 800 (extreme drought). KBDI calculated based on MODIS data can be referenced and extracted from Google Earth Engine from 2007 to the present.

We thought about the changes that can be observed from satellite data when droughts occur and decided to follow the changes of the paddy field area that would be directly linked to the food shortages. We selected Landsat data for observing the changes. There have already been many papers for mapping paddy field with various analysis methods, for example, supervised classification by bands and NDVI (Genc, et al. 2014), using the change of NDVI, EVI and LSWI (Jin, et al., 2016), using NDVI and Tasseled Cap Transformation (Riadi, et al., 2017), object-based image analysis (Su. 2017). In this study, we selected supervised classification using only Landsat bands.

However, the period of paddy field is not so long and the opportunity for data acquisition is about twice a year. And the period of paddy field is overlapped with rainy period and sometimes the influence of clouds was so severe that we could not estimate the paddy field area. Therefore, we used to estimate the paddy field area by using SAR data.

Ishituka and Ouchi (2017) reported that for estimation of cropland, C and X band are more suitable than L band. In SAR data, paddy fields at the time of rice planting are usually observed dark, and after rice grows, it is usually observed brightly due to strong backscattering by rice. Some paper reported that these temporal change of SAR data is useful to detect paddy fields (Takeuchi, et al. 2000, Kimura, et al. 2015). Then we decided to use this method in this study.

2. METHODOLOGY

2.1. Study area and data

The study area was selected from the area near Sariwon City, about 60 km south of Pyongyang (Fig. 1). From Landsat data, we can see that paddy fields are concentrated in this area. The cropland area inside the study area was identified by using the crops-coverfraction layer from Copernicus Global Land Cover Viewer. In the layer data, 0 is for non-agricultural land and 1-100 are for agricultural land. Therefore, pixels that value is more than 1 were regarded as the cropland, and the total number of pixels estimated as paddy fields in these areas were defined as the paddy field areas.

For drought index, we selected KBDI. We extracted KBDI of the paddy field from Google Earth Engine. KBDI is calculated from 20070101 to today almost daily. Then we calculated the annual average of KBDI in every year to investigate the relationship with paddy field area.

For identification of paddy field area, we selected 2 types of data, optical and SAR. Based on the interpretation of Landsat image's annual change, we determined that water drawing to paddy field is completed from the end of May to the beginning of June. Then we selected 8 images with the least cloud effect from images at that period (Table 1).

However, the period suitable for this purpose is short, and data cannot be acquired when there is an influence of clouds. Therefore, we considered extracting paddy fields from SAR data without cloud effects. We selected 14 images of Sentinel1 (Table 1).

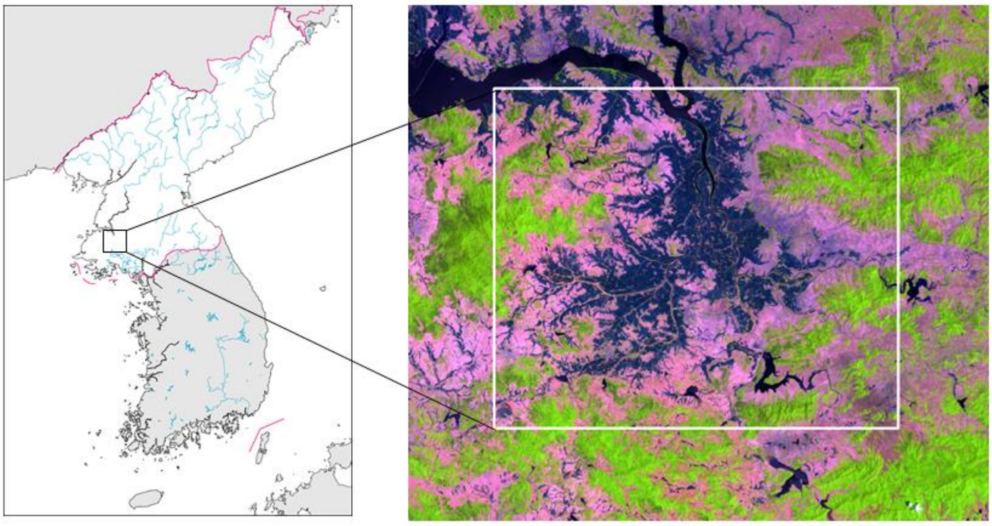

Fig.1. Study area. Right image: Landsat8 20170614 band6,5 and4.

Table.1. Acquisition dates of satellite data

Landsat	Sentinel 1
Landsat5	16 June 2015
3 June 2007	28 June 2015
20 May 2008	15 August 2015
24 June 2009	10 June 2016
14 June 2011	21 August 2016
Landsat 8	30 May 2017
14 June 2014	11 June 2017
9 June 2015	22 August 2017
14 June 2017	6 June 2018
1 June 2018	18 June 2018
	17 August 2018
	1 June 2019
	13 June 2019
	12 August 2019

2.2 Supervised classification using Landsat images

For paddy field area classification, we used band1-5 and 7 of Landsat 5 and band1-7 of Landsat 8. Classification model is Maximum likelihood method. We selected the training data while checking with Google Earth Pro. The data resolution is 30m.

2.3 Paddy field identification using Sentinel 1

For paddy field identification by Sentinel 1, we used at least 2 data for each 1 year. We calibrated, reduced speckle noise by using Lee filter, and did terrain correction by using SNAP. We compared VV and VH data by visually and decided to use VH data in this study. To estimate the area, we did coordinate conversion and the data resolution is 10m. Then we made the paddy field polygons and calculated average and std value of June and August Sentinel VH data that corresponding to each polygon. From these values we decided the threshold to separate paddy field.

3 RESULT AND DISCUSSTION

3.1 Relationship between KBDI and paddy field area from Landsat images

We estimated 8 years paddy field areas by using Landsat and supervised classification and compared annual average of KBDI (Fig.2). We couldn't estimate in 2010 and 2016 year because of cloud effect, and in 2012 and 2013 years we could get only injured Landsat 7 data.

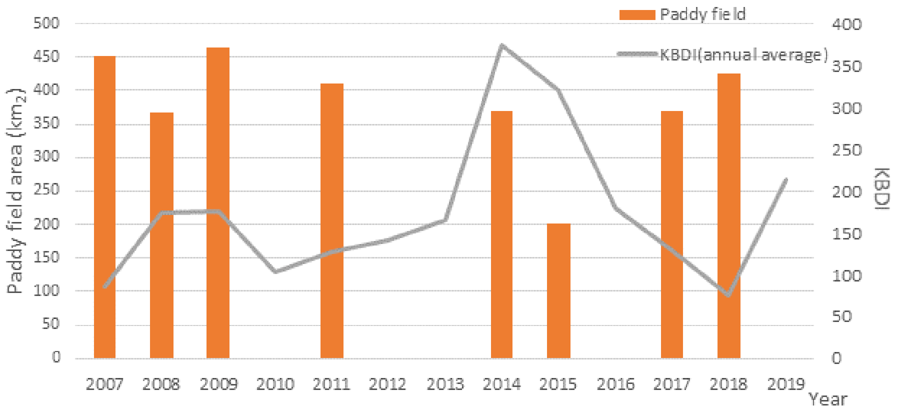

Fig.2. Estimated paddy field area from Landsat (Bar graph) and annual mean KBDI (Line graph) from 2007 to 2019.

From this graph, we found that KBDI of 2014 and 2015 are quite high. In fact, it has been reported that drought has occurred in North Korea in these years under the influence of the El Nino phenomenon. However, in spite of the higher value of KBDI in 2014, the paddy field area has not yet shown a significant decrease. We found that the water of reservoirs that exist in the surrounding area were decreased between 2014 to 2015 and used water was not refilled. So, in 2015, after the water of reservoirs were used, the paddy field area was greatly reduced under the condition of high KBDI.

The paddy field area in 2008 is smaller than that in 2007 and 2009, even though KBDI values are comparable. One of the reasons for this is suggested that we used the data of 2008 that acquired about 2 weeks earlier than other years and therefore, it is considered that the paddy field area was underestimated.

3.2 Relationship between KBDI and paddy field area from Sentinel1 images

From backscatter coefficients of plural sample paddy fields, we tried to decide the threshold value to separate paddy field area. However, we found that SAR value is low in June and high in August not only paddy field area but also cropped area that distributed around paddy fields in 2015, 2017 and 2019.For example, in Fig.3, we found that the range of backscatter coefficient of paddy field area and cropped area are overlapped in 20170611. As the result, we couldn't separate the paddy field area and cropped area from 2 data. But from Fit.3, we found that the gap between paddy field area and cropped area in 20170530 is a slightly larger than that of June's. Then we selected 2 data, from end of May to beginning to June and 1 August data and estimated 3 threshold values.

We, at first, used 2 data for identification of 2016 and 2018 year, and 3 data for 2015, 2017, and 2019 year.

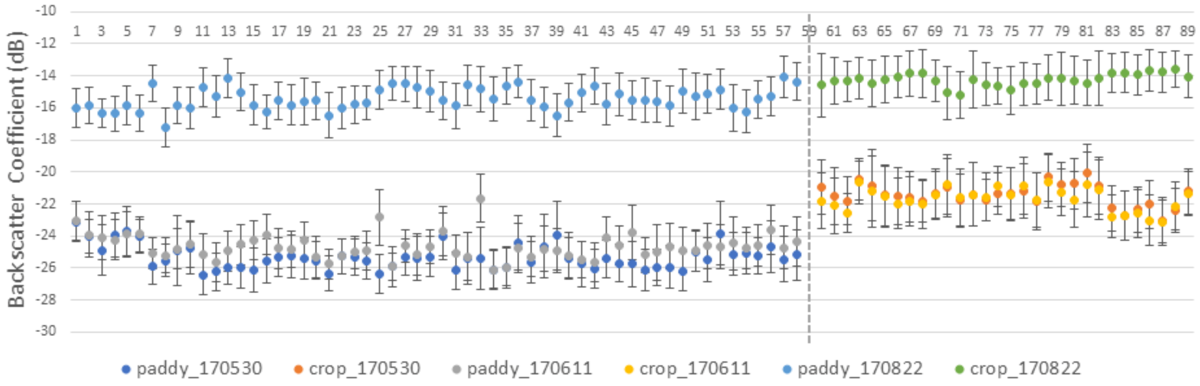

Fig.3. Backscatter coefficients of sample paddy fields (No.1 to 58 of X axis, left side of gray dotted line) and sample crop fields (No. 61 to 89 of X axis, right side of gray dotted line). We decided the threshold to separate the paddy field area from this graph. For example, from this graph, we decided

BC (1 June) ≦-23, BC (13 June) ≦-22, and BC (22 Aug.) ≧-19,

is paddy field area. (BC (date): Backscatter Coefficient of in that date)

Then we estimated 5 years paddy field areas by using Sentinel 1 data and compared annual average of KBDI (Fig.4). KBDI of 2019 is the average until August 20.

We, at first, compared the paddy field area in 2015 and 2017 to that of estimated from Landsat, and found that those 2 estimated areas by Sentinel 1 are 70 km_2 less than those estimated by Landsat data, respectively.

One possible cause is misclassification of water area. We removed some extent of water area by using crop-cover layer from Landsat estimated area. But it is difficult to separate the thin river and shallow area of reservoirs by supervised classification of only 1 period image. However, from the area of Sentinel 1, which was estimated using 2 thresholds of 2 different period, it was found that such thin rivers were also removed.

But 70km_2 is too big as misclassification. We compared the estimated images and found that water was drained from part of the paddy field that once filled with water only 12 days ago, from estimated area by using 3 SAR data.

In japan, water was drained from paddy field after about 1 month from the rice planting period, and paddy field was filled with water about 1 week before the rice planting period. Then we thought that it is not so usual to drain water about 2 weeks after filling.

Next, we wanted to know how much area is treated like that. We couldn't use the 2017 data because the error in crop land is too large of the estimated area by using only 2 different period data. Then we confirmed the area by using 2018 data and found that the area was decreased about 100 km_2 (Fig. 5).

Paddy field area of 2019 is bigger than that of 2019, even though KBDI of 2019 is higher than that of 2018. Then it seems that there will be no drought effect on North Korea in this year. But we found that some of the reservoirs around the paddy field were depleted.

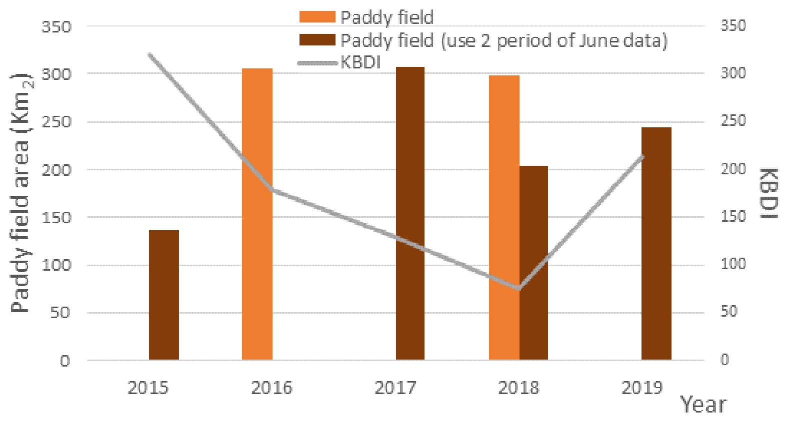

Fig.4. Paddy field area (Bar graph) and annual mean KBDI (Line graph) from 20015 to 2019. Orange bar means that the paddy field area was estimated from 2 data, June and August. On the other side, dark brown bar means that the area was estimated from 3 data, 2 June and 1 August.

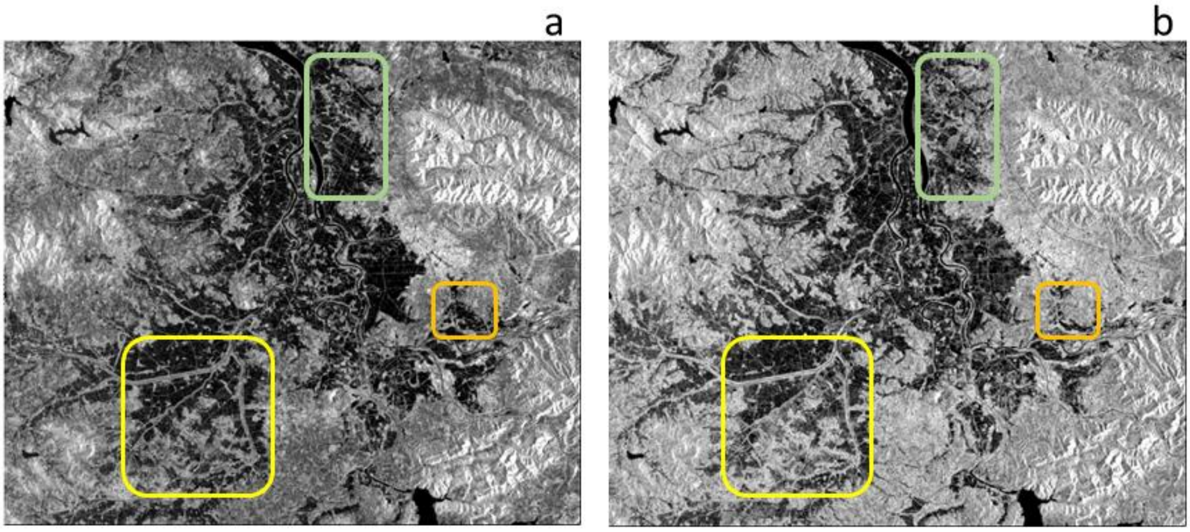

Fig.5. Sentinel1 VH data. a: 20180606, b: 20180618.
Black color area corresponds to paddy field area and water area.
The areas surrounded by three colored lines are was filled at 6 June and drained away between 6 June to 18 June.

4 CONCLUTION

We investigated the relationship between KBDI and paddy field area in North Korea from 2007 to 2019. We used Landsat data to estimate the paddy field area from 2007 to 2018 and used SAR data from 2015 to 2019. And we found that annual average of KBDI was abnormally high in both 2014 and 2015 due to the influence of El Nino, whereas the paddy field area decreased only in 2015 because of the surrounding reservoirs. Then we found that the paddy field area drastically decreased when drought condition continued for more than 1 year.

On the other hand, paddy field area estimated by Landsat are considerably higher than that estimated by Sentinel1. One reason for this result is that found that water was drained from part of the paddy field that once filled with water only 12 days ago. We confirmed with Sentinel1data from 2017 to 2019 and found that the tendency was particularly remarkable in 2018, and as a result, the paddy field area in 2018 was considerably smaller than that in 2017.

The paddy field area in 2019 is larger than that in 2018 and the impact of drought is not so clear. However, we found that water decreased in some reservoirs from June to August. KBDI value in 2019 is also not as high as 2014 and 2015, but higher than other years. North Korea's rainy season is Jury to August and the precipitations of these 2 months in 2019 are less than average. Precipitation tend to decrease after October in North Korea. Therefore, if there will not rain in September, there are possibility that the paddy field area will decrease in next June.

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