Evaluation of fire severity in Japan's evergreen needleleaf forests concerning dryness

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1. INTRODUCTION

The global mean temperature is projected to rise due to climate change. With this increase, precipitation and annual surface evaporation, including dryness, are expected to increase. The risk of wildfire occurrences is higher during dry condition because fuel moisture content influences the wildfire inception and spread. Extended drought period can lead to fuels with very low moisture content. Changes in moisture could significantly alter the moisture content of fuels, including foliar moisture content.

Extreme fire behaviour is often associated with crown fire, whereby forest damage is indicated by crown scorch (Scott *et al.*, 2013). Therefore, it is imperative to understand the changes in fire severity pattern due to dryness conditions. This study evaluates the fire severity changes in Japan's evergreen needleleaf forests (ENF), characterised by crown scorch detected by Normalised Difference Vegetation Index (NDVI), with dryness condition indicated by the Keetch-Byram Drought Index (KBDI).

2. STUDY AREA

From 1995 to 2017, more than 14% of Japan wildfires with a burnt area greater than 10 ha occurred in Tohoku, the second-highest number of wildfires after Kyushu but with the most extensive burnt area (Fig.1).

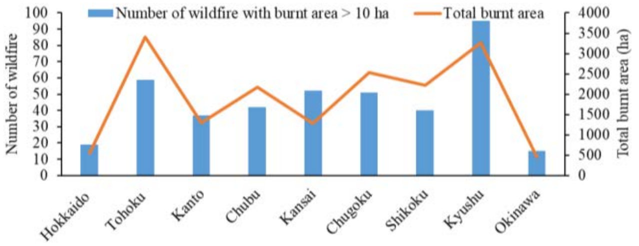

Fig. 1. Distribution of wildfires in Japan (1995 – 2017).

The study is limited to high severity to overcome the lack of fire severity ground truth. High fire severity is defined by more than 80% crown scorch, which is the highest probability of tree mortality (Ryan, 1982).

Additionally, only wildfires occurring in ENF were considered due to minimal seasonality in NDVI phenology. These wildfires were isolated using two High-Resolution Land Use Land Cover (HRLULC) maps provided by the Japan Aerospace Exploration Agency (JAXA, 2016). The 10 m spatial resolution HRLULC map was resampled to 30 m to match Landsat NDVI spatial resolution.

3. METHODOLOGY

Observation of needleleaf crown scorch from the largest wildfire in Japan for the same period that broke out in Kamaishi, Iwate on 8 May 2017 (Emang *et al.*, 2019) was used to isolate wildfires with high fire severity in ENF. Least square regression analysis was used to fit the crown scorch observations and Landsat 8 differenced pre and post-fire NDVI (dNDVI). All NDVI were from Landsat Surface Reflectance-derived spectral index product (Vermote *et al.*, 2016).

The determined high fire severity threshold for Landsat 8 was dNDVI > 0.24 and dNDVI > 0.23 for Landsat 7 calculated using Eq. (1) (Roy *et al.*, 2016)

$$ETM+ = 0.0029 + 0.9589\ \mathrm{dNDVI} \qquad (1)$$

where *ETM+* is the equivalent high fire severity threshold for Landsat 5 and 7, due to the similarity of NDVI Landsat 5 and 7 (Vogelmann *et al.*, 2001) so Landsat 5 utilised dNDVI> 0.23 for high fire severity threshold. A High Fire Severity Index (HFSI) was created using Eq. (2) to analyse the high fire severity

$$HFSI = \frac{Area_{dNDVI}}{TBA} \qquad (2)$$

where $Area_{dNDVI}$ is the area of a wildfire that has dNDVI > 0.24 (Landsat 8) or 0.23 (Landsat 5 and 7), and TBA is the total burnt area reported for that wildfire. Five wildfires in Tohoku's ENF with HFSI were identified. KBDI was calculated based on Keetch & Byram, 1968 and in the metric system (Crane, 1982). Average annual precipitation, maximum daily air temperature and daily precipitation used in the calculation for KBDI were from Automated Meteorological Data Acquisition System (AMeDAS)

4. RESULTS

KBDI computed ranged from 0 to 150 mm (Fig. 3). In most prefectures, KBDI increased as spring began and reached its peak in the middle of summer. Several peaks occurred in a year usually in the middle of spring and summer and occasionally in autumn depending on daily precipitation. Then, KBDI decreased when winter began. All the wildfires occurred in early spring when KBDI increased. It was expected a wildfire with high HFSI to appear at the highest peak of KBDI (driest day), but the temporal evolution of KBDI and wildfires did not portray this.

Keywords: Wildfire, remote sensing, fire severity, dryness hazard
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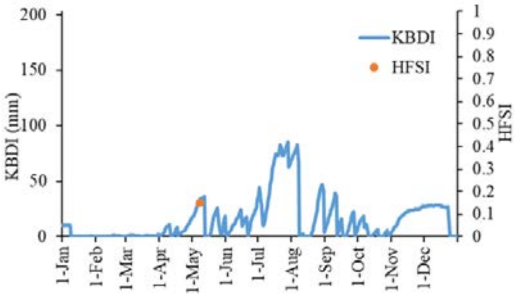
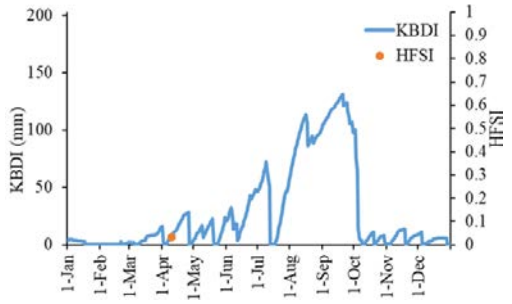
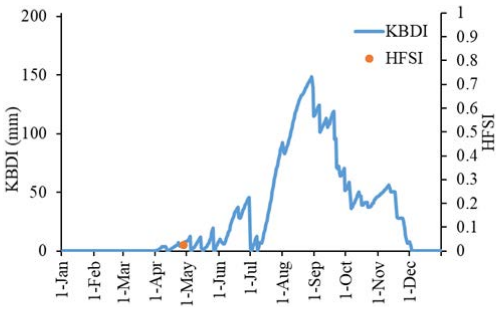


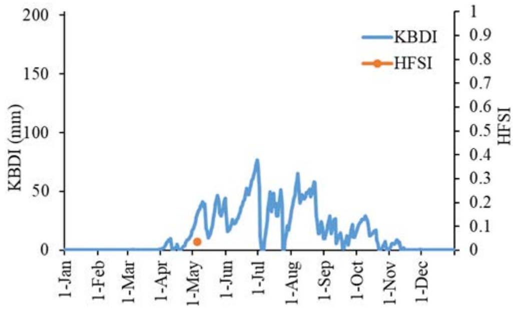
(a) Wildfire with 0.15 HFSI in 2017 (Iwate).



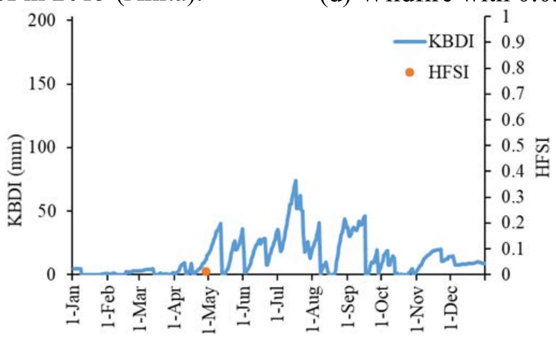
(b) Wildfire with 0.03 HFSI in 2009 (Miyagi).



(c) Wildfire with 0.02 HFSI in 2015 (Akita).



(d) Wildfire with 0.03 HFSI in 2017 (Yamagata).



(e) Wildfire with 0.01 HFSI in 2017 (Fukushima)

Fig. 3 Temporal evolution of KBDI and HFSI. The orange circle indicates the start of wildfires.

5. CONCLUSIONS

The utilisation of drought index such as KBDI is common in predicting wildfire danger. However, results showed that KBDI is not a predictor of dryness and wildfire danger because of no apparent relation between KBDI and wildfire with high fire severity. High fire severity wildfires were found in lower KBDI values where the soil and fuel were moist. KBDI low performance concerning wildfire with HFSI, clearly shows that using KBDI as a reliable predictor of dryness condition and danger of wildfire in Tohoku is not advisable

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