IMPACT ASSESSMENT OF SURFACE DRYNESS AND SNOW COVER ON WILDFIRES IN FAR EAST RUSSIA

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ABSTRACT: Forest ecosystem in cool to cold climate plays a role of major carbon absorber. In Russia, there are fire events continuously along with recent economic development. Against the limitation of lack of in-situ observation data, this study aimed to generate a system for estimating land surface dryness using satellite-based Keetch-Byram drought index (KBDI). The KBDI is calculated by land surface temperature (LST) of Himawari, and precipitation of Global Rainfall Watch (GSMaP). The empirical method of KBDI considers vegetation status as a proxy of evapotranspiration. Especially, fire events were detected by MOD14 hotspot data and the carbon emission was calculated with reference to the modeled biomass from the Vegetation Integrative Simulator for Trace gases (VISIT). Since this region has large amount of snow during winter, daily snow cover area of AMSR-2 was used for the comparison between KBDI and snow covers. As a result, the land surface is dry in summer because of the high LST and this related to the increase of the fire occurrence. While the KBDI is low or not available with low LST in winter, the fire occurrences were also low. Fire occurrences have rapidly increased in spring, however, KBDI is not estimated during the season when some snow coverages still remained. It implied if KBDI is used as an index of fire control in this region, we need to consider snow accumulation and melting algorithms which let provide the moisture into the soil layer especially in spring season, and it might affect to prevent the fire occurrence in high latitudinal regions.

1. INTRODUCTION

The carbon storage of those ecosystems is known as about twice of tropical forests (Pimm et al., 2009). Positive feedbacks of the disturbances of forests to the global warming are reported many previous studies recently (Bradshaw et al., 2009). The effects of global warming to high latitudinal region are more severe than the other ecosystems which is formed under the low temperature. However, wide area and low accessibility of forest in Russia are main limitations for obtaining regularly taken ground-truth data. Wildfire events are common and regularly detected in forests in Far East Russia (Mollicone et al., 2006, Loboda and Csiszar, 2007). Accordingly, protecting the forest ecosystem in Russia is urgent issue for the global society. The global warming and the human activity are major reasons for disturbing those carbon reservoirs. For the mitigation of wildfire in this region, the reason and influence of the fire should be clarified. As an influential factor to the fire emission, the dry condition would be considered. Keetch-Byram drought index (KBDI) had been proposed for monitoring wildfires in US (Keetch-Byram, 1968). In previous study, fire occurrences and KBDI showed positive relationships (Park and Takeuchi, 2019). The relationship was confirmed only in natural vegetation of land cover. Artificially generated or operated croplands showed negative relationships between both of indices. From the paper, we found needs of improvements in high latitudinal regions because of the lack of process regarding snow and snow melting effect to the surface dryness. Hence, the objective of this study is to reveal the relationship between FE and KBDI under the snow or non-snow coverages.

2. METHODOLOGY

The study area is Far East Russia (40-55N, 120-145E). For the detection of wildfire, MODIS hotspot (MOD14) data was used. Fire radiative power (FRP) was calculated from MOD14 and the location of fire, as well. Both of the fire emissions of AGB and SOM were used for counting fire occurrences. If there is above 0 of fire emission (FE), the fire occurrence (FO) was counted from each pixel. The counting was conducted in each landcover (LC) types separately. Totally, 16 kinds of LC types from the IGBP scheme in MCD12Q1 were used. The Keetch-Byram Drought Index (KBDI) (4km) was resampled to 1km to have same pixel location with FO. For the next step, the KBDI was counted when the FO was counted. Finally, the monthly counts of FO and averages of KBDI were computed in each LC type. However, the ranges of FO and KBDI varied among LC covers. For that, the results were normalized using max-min range of data of whole LC types. This study used modified KBDI, which is modified from a typical KBDI and calculated by Eq. 1.

$$mKBDI = \times\ 100r + \frac{0.968(800 - mKBDI0)\exp\ (0.486T)}{1.0 + 10.88\exp\ (-0.441R)} \qquad \text{(Eq. 1)}$$

For snow (SN) coverage, AMSR-2, a passive sensor data was used. The snow water equivalent (m) is strongly related with passive microwave sensor (Armstrong et al., 1993). Basically, snow covers are detected using the difference between TbV18 and TbV36 when it is greater than 0. TbV18 and TbV36 are the vertically-polarized brightness temperature at 18GHz and 36 GHz, respectively (Kelly, 2009). Notably, since monthly data of FE were used and daily data of KBDI and SN were used from 2013 to 2017 (since the existence of AMSR-2). For a daily regional investigation, Ussuriysk (43.77N, 131.85E) was chosen. A flowchart of this study is shown in Figure 1.

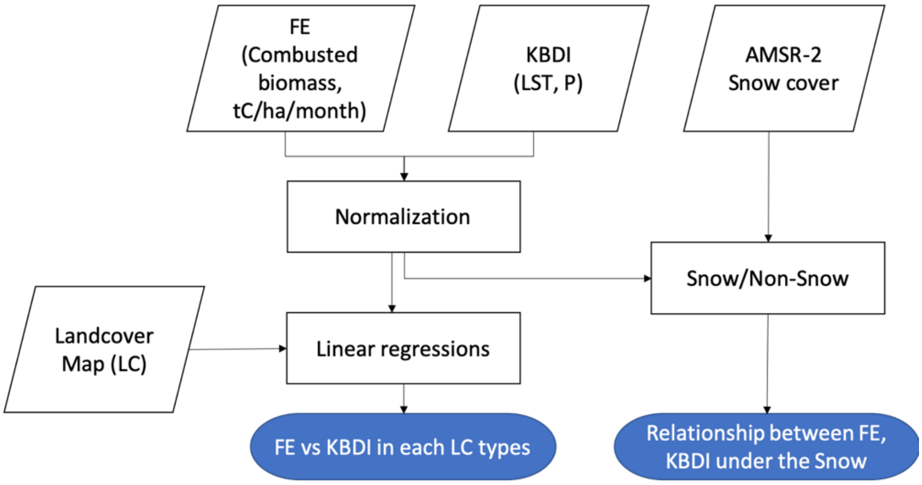

Figure 1. Flow of this study

3. RESULTS

The fire emissions in Far East Russia were high in summer season. Within LC types, Savannas, Evergreen Needleleaf Forest, and Grasslands showed positive relationships between FE and KBDI. Notably, the Savannas class will be mentioned as sparse forest because the definition is 10-60% tree coverage and higher than 2m above ground, however, Savannas are not suitable to use in high latitudinal regions. The fire in sparse forests (e.g., Savannas and Woody Savannas) showed dominant in Far East Russia in terms of fire occurrences when it was compared with dense forests (e.g., ENF, EBF, DNF, DBF, MF classes which refer to IGBP scheme). However, in artificially vegetated area (e.g., Croplands) results clear negative relationship between FE and KBDI. Especially, in winter season, KBDI is not sensitive under the low land surface temperature. In this study, KBDI and FE under the snowy season were investigated cold climate conditions. As the result of monthly spatial averages of FE and KBDI in Far East Russia (Figure 3), FE in snow area (SN) and non-snow area (nSN) showed small and large number of fire emissions, respectively. However, KBDI under SN showed unexpected patterns which were rapid changes during summer season. On the other hands, KBDI under nSN the increasing pattern during summer is stable. FE agreed with KBDI under the nSN condition. FE does not always match with KBDI well (for examples in August of nSN), however, slightly increasing patterns were also found. KBDI and FE under the SN were shown unstable and it would represent higher uncertainties than that of nSN.

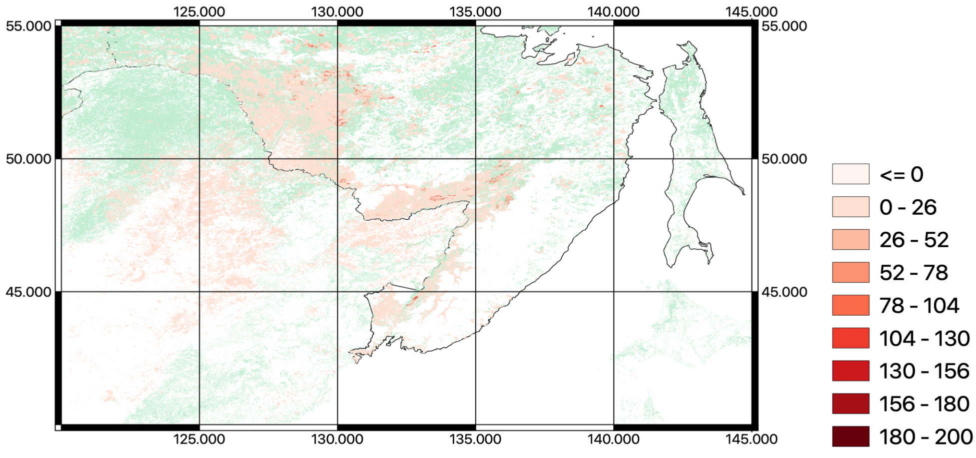

Figure 2. Total fire emissions on the sparse forest landcover map (Unit: tC/ha)

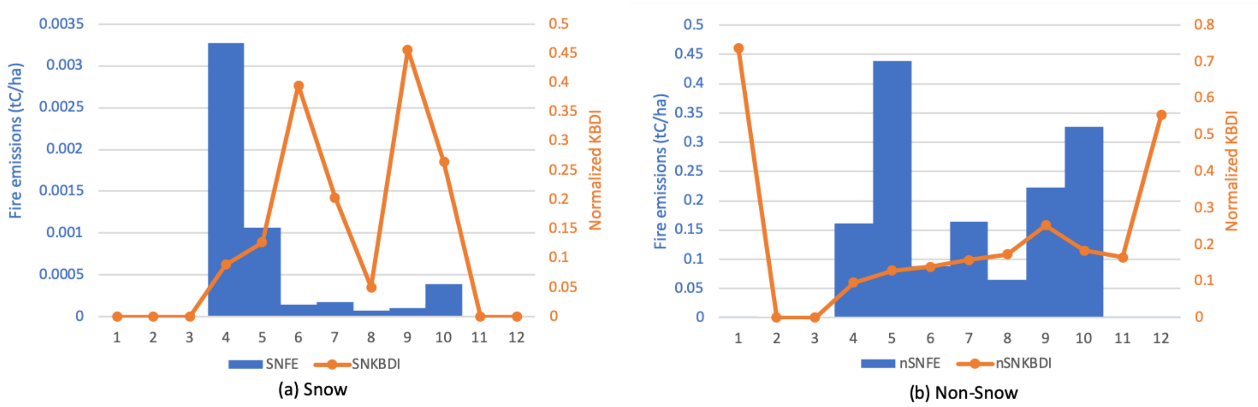

Figure 3. Averages of normalized Fire Emissions (FE) and Keetch-Byram Drought Index (KBDI) in (a) snow, (b)non-snow coverage based on AMSR2. X-axis shows month from January to December.

As an example of regional value, Ussuriysk was chosen and the burnt biomass (FE), KBDI, snow coverage (%) (Figure 4). KBDI and snow coverage, and FE are daily, and monthly, respectively. As the result, snow coverage has increased during winter and the KBDI has oppositely decreased. From spring (Apr), the KBDI is drastically increased and the FE also appears in spring. Usually, the temperature in spring is increased and the snow might be melted rapidly. The reason for agricultural fires are usually known as land clearance. If it is happened by human activities, fires are dominant in spring when before the seeding. For making fire warning and control system, the dryness of land surface could be an index. Especially, the KBDI during winter to spring would be helpful to grasp land surface dry conditions accurately.

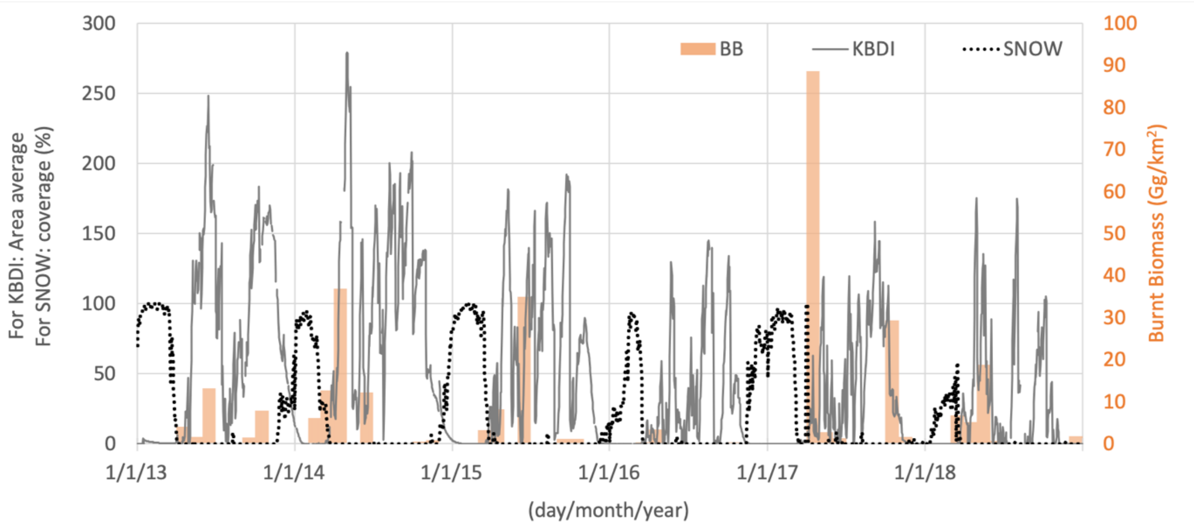

Figure 4. Regional comparison among KBDI, Snow coverage, Burnt Biomass (BB or FE) in Ussuriysk in Far East Russia.

3. CONCLUSIONS

The temporal changes of fire emissions (FE), land surface dryness (KBDI), and snow coverage (SN) were investigated to know what kind of improvement could be conducted for the next generation of KBDI in high latitudinal regions. First of all, natural and sparsely distributed forests were vulnerable to wildfires in terms of dryness. Current version of KBDI showed more positive relationship with FE during summer season. However, in terms of KBDI under the snow coverage, KBDI showed different pattern during summer when the time-series was compared with non-Snow (nSN) conditions. It might be affected by low temperatures which was caused by snow. Although total amount of FE under the SN was less than nSN, KBDI showed clearly an opposite pattern between SN and nSN. The result in regional time-series in Ussuriysk also showed KBDI could not be estimated under the snow conditions. The most controversial period was in spring because there are high FE, but low or no KBDI, and snow also still existed. This study concluded the priority of period to improve KBDI was found in spring season, and it might be solved by adjustments of KBDI adding LST-Snow melting formula into the current algorithm of KBDI. If the KBDI under the snow could be estimated correctly, the land surface dryness including snow melting will be a key source for supporting the protection activity of wildfires in Far East Russia.

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