Using NDVI to estimate forest fire effect between tree types in the 2017 Kamaishi forest fire

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INTRODUCTION

In May 2017, several fire broke out in three prefectures in Tohoku region due to dry weather especially in eastern coast of Japan and strong wind in Tohoku region. This dry weather was because of 60% lower precipitation in winter compared to normal year and strong wind from western blowing into Tohoku region (Touge *et al.*, 2018) One of these fire broke out in Kamaishi, Iwate Prefecture on 8 May 2017. The burnt out area (Fig. 1) was larger than the total burnt area for the whole of Japan in 2016. The extensive fire was due to strong presence of wind and low accessibility of vehicle into the burnt area.

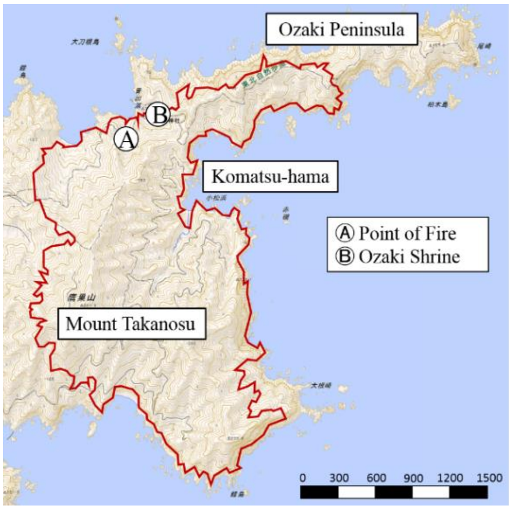

Fig. 1. Area affected by fire drawn based on information from Kamaishi Forestry Association

Forest fire causes deterioration of environment quality such decreasing numbers of arboreal fruit eating primates and birds (Barlow and Peres, 2004) and increase in greenhouse gas (Watson *et al.*, 2000), sedimentation yield (Silins *et al.*, 2009) and effects the tree mortality (Dale, 2001).

Satellites are used worldwide to detect forest fire and as a tool in fire management. Landsat 8 launched in 2013 offers spatial resolution up to 30 meter with more than 650 scenes a day. This study aims to statistical analyses the fire effects in tree types using difference of post and pre NDVI of Landsat 8 and ground truth by using paired samples t-test.

GROUND TRUTH

A field investigation in Kamaishi was made to collect ground truth such as location, diameter, height and type of tree, height of stem-bark char and scorch crown. In this study, information on tree type and its location were used and 650 observation points were collected (Fig. 2).

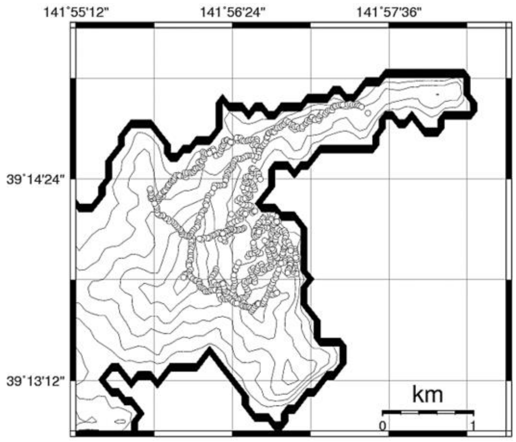

Fig. 2. Distribution of 650 observation points

The tree types observed in Kamaishi were needleleaf, and broadleaf. 28 trees which were not recorded of its tree type were excluded in Fig. 3 and the term " Mix" in Fig. 3 consists both types of tree.

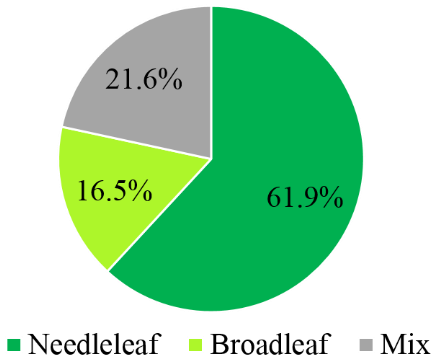

Fig. 3 Tree types observed in Kamaishi forest

STATISTICAL ANALYSIS

Paired sample t-test was used in the statistical analysis to determine the significant difference between the mean of post (M_{post}) and pre fire (M_{pre}) images from NDVI based on tree type which are interpreted to be related to the 2017 Kamaishi forest fire effect. T-test was chosen because only two variables were analyse which M_{post} and M_{pre} were of NDVI. Table 1 describe the type of t-test, null hypothesis, H_0 and alternative hypothesis, H_1 used. All statistical analysis use the alpha level of 0.05 and NDVI were assumed to be normally distributed.

Keywords: Forest fire effect, tree type, NDVI, Landsat-8, paired samples t-test
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Table 1 Framework of statistical analysis using t-test

Type of tree	Type of test		Hypothesis	$NDVI_{ave}$
Needle-leaf	One-tailed	Lower-tail	H_0	$M_d = M_{post}$-$M_{pre} = 0$ No difference in M_d
Broad-leaf			H_1	$M_d = M_{post}$-$M_{pre} < 0$ A decrease in M_d
Mix				

RESULTS

Table 2 showed the detailed results from the statistical analysis which indicates all tree types had significant difference with needleleaf trees having the greatest reduction in NDVI with post fire (M= 0.374, SD=0.183) and pre fire (M= 0.487, SD=0.104) conditions; t (374) = -11.51, p <0.001, followed by mix tree types and broadleaf trees.

Needleleaf trees showed greatest reduction in NDVI compares to broadleaf trees suggesting that changes in crown for needleleaf trees was greater than changes in crown for broadleaf trees. This finding is also supported when comparing the distribution of fire severity levels with distribution of tree types (Fig.4). Needleleaf trees were found to be 76% in very high fire severity level and 85% high fire severity level compared to broadleaf trees which were 8% and 0% for the respective severity levels. This fire severity levels were based on rate of scorch crown over total crown height for each tree observed. “Undefined” in Fig. 4 (right) refers to no observation of tree type was recorded.

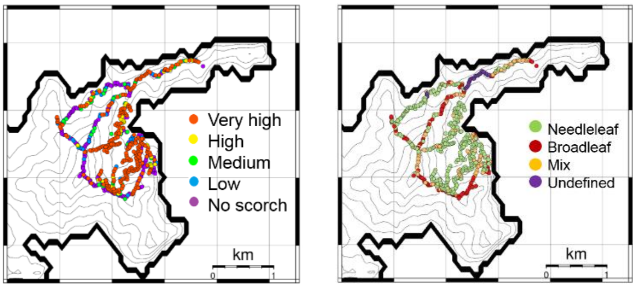

Fig. 4 Distribution fire severity levels (left) and tree types (right)

CONCLUSIONS

Both statistical analysis and comparison with distribution of severity levels and tree types indicate NDVI is capable to assess the changes in crown of tree due to the 2017 Kamaishi forest fire. This suggest that NDVI is reliable in accurately sensing the changes related to the health (greenness) of a tree’s crown especially for needleleaf tree whose crown are more dense than broadleaf tree. Based on NDVI changes post fire, it can be concluded that needleleaf trees types were the most damaged in the 2017 Kamaishi Forest Fire.

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Table 2 Statistical analysis for post and pre fire (t-test) over tree type

Tree Type	**Post NDVI**		**Pre NDVI**		**Difference**		**df**	**T**	**p**
	$\mathbf{M_{post}}$	**SD**	$\mathbf{M_{pre}}$	**SD**	$\mathbf{M_d}$	**SD**			
Needleleaf	0.374	0.183	0.488	0.104	-0.113	0.189	367	-11.49	< 0.001
Broadleaf	0.414	0.201	0.505	0.095	-0.091	0.211	98	-4.28	< 0.001
Mix	0.366	0.202	0.473	0.108	-0.107	0.191	125	-6.27	< 0.001