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Monitoring leaf-out day of forests in Gifu, Japan using Terra/MODIS data

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Carbon dioxide concentration in the atmosphere would accelerate global warming. Therefore climate change would have strong effects on terrestrial ecosystems, and analyzing the impacts on terrestrial ecosystems is required. Growth stages of vegetation are controlled by air temperature in the humid temperate zone. The seasons from spring to autumn under high air temperature are growth period by photosynthesis. Winter under cold air temperature is dormant season. Global warming would make the growth period longer. If photosynthesis becomes possible through a year due to air temperature rise, deciduous trees are left out of their own habitat. Monitoring phenology would be important to evaluate effects by global warming. However, observing phenology is difficult in large forests on the ground.

MODIS sensors on Terra and Aqua satellites observe the same point on the earth every day, although their ground resolution is coarse. MODISs observe red and near infrared bands, which are effective for vegetation analysis, with 250m resolution, and their reflectance images after atmospheric and geometric corrections are open to public. Even MODISs observe the same point every day, MODISs cannot observe the ground quite often due to cloud over Japan in the humid temperate with frequent cloud covers. Therefore cloud free images are produces by mosaicking 8 days' or 32 days' images, and phenology is analyzed by curve fittings using the normalized difference vegetation index (NDVI) images with smoothing. The smoothing and curve fittings would reduce accuracy of analysis, since they change seasonal trends of NDVI slightly.

We produced a leaf-out day analysis method using a linear regression model which showed a trend of NDVI change at each pixel. We applied the linear model to daily MODIS NDVI of each year in the leafing period and estimated leaf-out days over forests in Gifu prefecture. The process is as follows. 1) Moving averages of NDVI during 3 days in some years and their moving median during 7 days were computed on each pixel according to the day of year (DOY) from the New Year's day. 2) A linear regression line was estimated selecting DOY as an independent and NDVI as the dependent variables in each pixel during the leafing period. 3) A threshold value at the time of leafing start was determined by searching NDVI after dropping leaves in autumn. 4) The leaf-out date was estimated using the linear regression line and the threshold value in each pixel using daily NDVI data.

Advantages of this method are as follows. 1) Leaf-out day can be determined daily basis in each pixel. 2) Since any smoothing and curve fittings are not applied, the method analyzes NDVI change trends in detail. 3) Mixed pixels with different forest types can be analyzed by the same method. Although the method is not suffered by noises by clouds, noises of increasing NDVI by atmospheric correction errors reduce accuracy.

The method estimated leaf-out days quite accurately in deciduous forests with great seasonal NDVI changes in snowy areas. On the other hand, leaf-out day was not estimated in evergreen forest, since coefficients of determination were not high enough in the regression analysis due to small seasonal changes and the linear equations were not reliable. Inter-annual changes in pixels of evergreen forests where leaf-out day was estimated appeared greater than those in deciduous forests. It suggested that additive noises on NDVI reduced accuracy. Accurate leaf-out day estimation was also difficult in mixed pixels with urban areas, farm lands and forests. We concluded that mapping of inter-annual changes of leaf-out days was possible in deciduous forest, however, effects of global warming were not validated yet due to the short period of MODIS images available.

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Keywords: phenology, leaf-out day, MODIS, NDVI