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Identification of agricultural drought extent based on vegetation health indices of Landsat data: case of Subang and Karawang, Indonesia

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Abstract

Agricultural drought monitoring is paramount in order to maintain food security in Indonesia, particularly in Subang and Karawang as the national rice production centers. In this paper, satellite-borne remote sensing data are tested for monitoring drought extent in about 184.486 ha of both regencies. Vegetation Health Index (VHI), a vegetative drought indices based on remote sensing data, is studied in this case using long term sequence of 2000, 2005, 2010, and 2015 dry season Landsat data. VHI collates overall vegetation health, which in turn suitable to indicate agricultural drought extent. It measures either moisture vegetation/vegetation condition (VCI) or thermal condition of vegetation (TCI). Both indices were derived from Normalized Difference Vegetation Index (NDVI) and land surface temperature (LST) data respectively. The results revealed that VHI decreased more than 50 percent, from 30.86 in 2000 to 14.66 in 2015. This figure indicated drought extent intensified in research area, from mild drought to severe drought. The severity was mainly triggered by the rising LST from 27°C in 2000 to 40°C in 2015. In addition, there was a decreasing tendency of NDVI values in recent years, leading agricultural fields more susceptible to drought.

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Keywords: agriculture; drought; Landsat; LST; NDVI; VHI

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1. Introduction

Drought is a crucial natural hazard causing significant loss to crop production, water supply, and livestock [1]. Its impacts on agriculture are tremendous. In recent years, droughts have been occurring frequently because of El Nino phenomenon. This phenomenon increasingly triggers several threat to the Indonesian agriculture, particularly in Subang and Karawang district as the national rice production center. Identification of drought extent at administrative levels, is therefore an important program to evaluate the probability of drought occurrence and its severity in order to increase food security [1]. Impacts due to drought can be mitigated, if they are detected in advance through measures and monitor.

Drought can be monitored effectively over large areas using remote sensing technology. Satellite-borne remote sensing data provides a synoptic view of Earth surface, and therefore can be used to evaluate drought occurrence spatially [2]. Several remotely-sensed drought indices have been developed and applied, which include duration, intensity, severity, and spatial extent [3]. Among those indices, the Normalized Difference Vegetation Index (NDVI) as a probe for vegetation health has been one of most commonly used approaches to drought events monitoring [4, 5]. To improve the approach, it has been advisable to combine vegetation index and temperature. A combined NDVI and land surface temperature (LST) provides strong correlation and gives useful information to identification of agricultural drought as an early warning system [6].

While many vegetative drought indices based on remote sensing data have been introduced, Vegetation Health Index (VHI) has demonstrated a greater capability and has presented a better suitability in detecting drought [7, 8]. It considers both vegetation condition (termed VCI) and thermal condition of vegetation (TCI) within a period of observation. Therefore, VHI subsequently evaluates vegetation drought stressed by temperature [8, 9]. Both parameters can be derived from Normalized Difference Vegetation Index (NDVI) and land surface temperature (LST) data. Owing availability of relatively clear high resolution data, in this research VHI was derived using long term sequence of 2000, 2005, 2010, and 2015 dry season Landsat data. Landsat is considered in this paper due to its open-access policy while has relatively fine temporal and spatial resolution for drought monitoring [10, 11]. The purpose of this paper is to seek drought extent in rice production center of Subang and Karawang based on remote sensing data. In addition, an inter-comparison of the drought for long term sequence of 2000, 2005, 2010, and 2015, is conducted to determine various condition of drought extent in both regencies during these periods.

2. Study Area

Subang and Karawang were chosen as the study areas (Fig. 1). Subang and Karawang regencies are situated in the north part of West Java, which are geographically situated between 5°56’-6°34’S and 107°02’-107°40’E for Karawang and 6°11’-6°49’S and 107°31’-107°54’E for Subang. Administratively, both of regencies bounded by Java Sea in the North, Indramayu and Sumedang regencies in the East, while Purwakarta and Bandung are in the South border, and emerging industrial regency of Bekasi lies in the West. Landforms in the research areas are dominated by flat terrain between 0-50 m above sea level. Almost 50 percent of land utilization in the research areas are rice fields, about 184,486 ha of 397,104 ha total land area in both regencies. These regions serve as the national rice production centers in Indonesia. The 2015 long drought causes loss to crop production and severe water supply shortage at some agricultural areas including Subang and Karawang.

3. Methodology

In this research, droughts were identified from long term sequence of 2000, 2005, 2010, and 2015 dry season Landsat data. Multispectral and thermal data from Landsat were used to construct Normalized Difference Vegetation Index (NDVI) and land surface temperature (LST) data. Prior biophysical analysis, all data were converted to sensor spectral-radiance through radiometric calibration developed by Chander *et al.* [12]. This research also applied atmospheric correction [13] to remove mild atmospheric effects in processing thermal band for absolute temperature study. In this research, we employed atmospheric correction developed by Coll *et al.* [14]. Then, using atmospherically-corrected thermal band, at-sensor brightness temperature was derived using equation provided by Chander *et al.* [12].