Satellite Remote Sensing and GIS-based Land Suitability Assessment: A Machine Learning Approach for Yield Prediction of Maize

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Abstract

Maize is more susceptible to climate change and vulnerable in droughts with lower production of yield in Indonesia. To face this climate change, land suitability assessment and yield prediction is highly required in the drought prone areas. Therefore, the purpose of this research is to develop a new methodology to determine suitable lands for maize production using multicriteria decision support system and machine learning system in the drought prone regions of Indonesia.

First, the suitability analysis was performed for maize production at the district level. The ground reference data were collected through a field survey by interviewing the farmers and government. The criteria for suitability assessment of maize production were the distance from roads, distance from rivers, slope, land use land cover (LULC), elevation, soil type, normalized difference vegetation index (NDVI), soil adjusted vegetation index (SAVI), rainfall and land surface temperature (LST). These criteria were reclassified into 4 categories according to the land suitability evaluation refer by the United Nations of Food and Agriculture Organization (FAO). Furthermore, a yield prediction model was developed for maize using NDVI (R2=77.81%) and SAVI (R2=72.8%) with 5 years (2013-2018) satellite remote sensing datasets. These results can be used to predict the yield for inventory planning of maize production.

Second, the land suitability analysis was scaled up to drought prone regional level for the Central East Java of Indonesia. The site-specific classifier of maize in the drought-prone areas were distance from roads, distance from rivers, slope, elevation, soil type, soil pH, Standard Precipitation Index (SPI), LULC, NDVI and Land Surface Temperature (LST). The suitability analysis was made using multi-criteria and AHP methods to find the drought-prone areas. The land suitability analysis using the Analytical Hierarchy Process (AHP) showed that 40.26% of

lands were highly suitable, 30.82% of lands were moderately suitable, and 21.89% of lands were marginally suitable for maize production in the drought-prone areas of central East Java.

Third, land suitability analysis was extended further for validation based on random forest machine learning approach to develop site-specific micro-level classifiers in highly, moderately, marginally and not suitable from 5 years (2013-2018) normalized yield data collected from regencies. It was significant to report that there were 3 villages in Gresik regency, 52 villages in Malang, 4 districts in Mojokerto and 3 villages in Sidoarjo were not suitable for maize production. It was also evident that the production of maize decreased due to drought. The machine learning approach is used to classify the site-specific areas based on the normalized yield from time-series datasets which is beneficial for farmers to know maize production that has impact on drought.

Fourth, machine learning approach was integrated with YOLO V3 deep learning system for clarification of drought severity at the different growing stages based on the Normalized Difference Vegetation Index (NDWI) from Sentinel II datasets of 10 m resolution. The NDWI were used to classify the water stress with three classifiers as extreme, moderate, and marginal droughts for maize growth. The models were generated using Convolution Neural Network (CNN) and YOLO to build the sets of training and testing datasets for the deep learning approach. These results of deep learning can be used for validation drought prone areas for yield assessment of maize.

The integrated model of remote sensing, machine learning and deep learning was used to understand the water stress of maize and impact of drought conditions. The developed land suitability model could be applied for the regional level for land suitability assessment to maximize maize production to ensure food security in Indonesia.

Keywords: land suitability analysis, GIS, Remote Sensing, drought, machine learning