Relating soil moisture variations to land-use types using time-series MODIS data for early warning of agrodrought in the Vietnamese Mekong Delta

N.T.Son[1], C. F. Chen[1,2]

[1]*Department of Civil Engineering, National Central University, Jhongli City, Taoyuan, Taiwan*
[2]*Center for Space and Remote Sensing Research, National Central University, Jhongli City, Taoyuan, Taiwan*

Agrodrought refers to a short period of abnormal precipitation which impacts crop production through insufficient soil moisture (Adamson, 2005). In the Vietnamese Mekong Delta, more droughts have recently occurred (ACB, 2009), especially in the winter-spring and early winter-autumn rice crops, which impacted on rice production, forests, and local people's livelihoods. Leading world agriculturalists have also warned that rice production in this delta needs to be reduced as the region is likely to face water shortage over the next decade (Oryza, 2009). This document presents some initial findings regarding soil moisture variations in relation to land-use types in the Vietnamese Mekong Delta for the year 2007 were discussed using time-series Moderate Resolution Imaging Spectroradiometer (MODIS) data.

The methodology used for land-use type classification and soil moisture index computation included four main steps. These were as follows:

1) The time-series normalized difference vegetation index (NDVI) data derived from MODIS (MOD09Q1) for the year 2007 was filtered with the empirical mode decomposition (EMD)-based low-pass filter (Huang et al., 1998). The principle components analysis (PCA) method was then applied to the filtered data to reduce the dimensionality;
2) The retained principle components (PCs) were used in the maximum likelihood-based supervised classification (MLC) to create land-use classes;
3) The temperature dryness vegetation index (TDVI) (Sandholt et al., 2002), widely applied for drought monitoring, was computed by linear least squares regression analysis between land surface temperature (LST) derived from MOD11A2 and NDVI space; and
4) The classification result and TDVI were compared with ground truth (land-use map 2006) and cumulative eight-day rainfall data, respectively.

The initial findings indicated that PCA was a good method to reduce the dimensionality of the time-series MODIS data. The application of MLC to the first seven PCs, which explained 99.7% of variances, showed overall accuracy (76.0%) and Kappa (0.6). The spatial distribution of land-use types was shown in Figure 1. Generally, the triple rice cropping occupied the central (between the Mekong and Bassac rivers) and southeast parts of the region while double rice cropping concentrated on the upper part. The single and double rainfed-rice cropping systems were more common along the coastal zones. The annual crops were rare, scattered in a small part of the region. Much of forest (melaleuca) were distributed in the northwest and northeast parts.

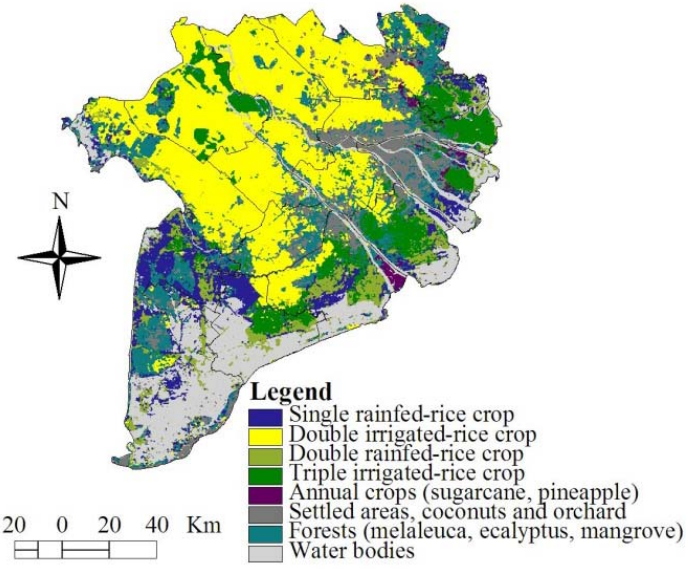

Figure1. Distribution of land-use types in the Vietnamese Mekong Delta.

The TDVI calculated from the linear regression analysis between LST-NDVI space was reclassified into five categories: very wet ($0.0 < TVDI \leq 0.2$), wet ($0.2 < TVDI \leq 0.4$), balanced ($0.4 < TVDI \leq 0.6$), dry ($0.6 < TVDI \leq 0.8$), and very dry ($0.8 < TVDI \leq 1.0$). Distribution of land surface soil moisture during February to mid April was shown in Figure 2. There was a large variation in soil moisture condition over the region in both space and time. The areas suffering from agrodrought were distributed in the northeast part of the region and the coastal zones. The soil moisture condition became dry to very dry especially from mid February [day of year (DOY) 49] to early April (DOY 97) because of the poor drainage.

It was noticed that the impact of agrodrought coupled with salt-water intrusion into the mainland might create severe impact on rice production since this period corresponds to the reproductive phase (flowering/ripening) of spring-winter rice crops which are sensitive to thermal stress. In addition, poor soil moisture and fresh water deficiency in early April (DOY 97) could also adversely affect the upcoming summer-autumn crop when rice is in the vegetative phase (after sowing/transplanting). Moreover, water shortage and drier soil moisture that last for more than one month [from February 26 (DOY 57) to April 07 (DOY 97)] could lead to forest fires. As such, forests in the provinces of Kien Giang, Ca Mau, Dong Thap, and Long An may be at risk. Local authorities should prioritize areas vulnerable to fires due to deficit soil moisture to save both rice crops and forests which occupy thousands and hundreds of hectares, respectively.

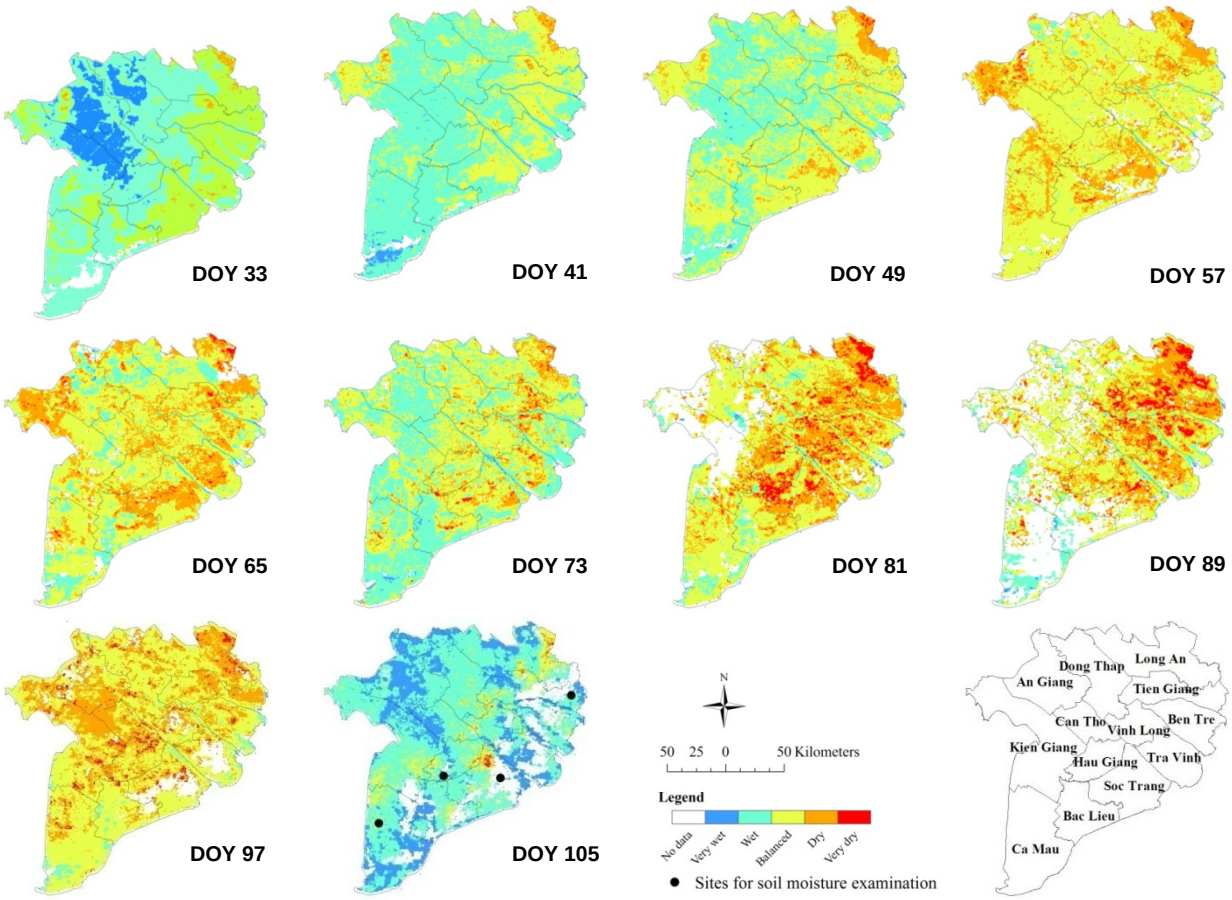

Figure 2. Distribution of land surface soil moisture.

The temporal soil moisture variations were also examined in relation to the four land-use types namely 1) double irrigated-rice crop in Hau Giang, 2) rice crops (including single, double rainfed and triple rice cropping) in Soc Trang, 3) melaleuca forest in Ca Mau, and 4) triple rice cropping in Tien Giang. Using 5x5 moving window size, the magnitude of temporal TDVI values at these sites was smaller than that shown in the maps because these TDVI values were calculated based upon a large area which probably included mixed pixels (Figure 3). In general, the TDVI trend was increasingly positive from DOY 41 and showed a reverse trend for DOY 73. The trend after this Julian day continued to increase and reached a value higher than 0.6 until DOY 97.

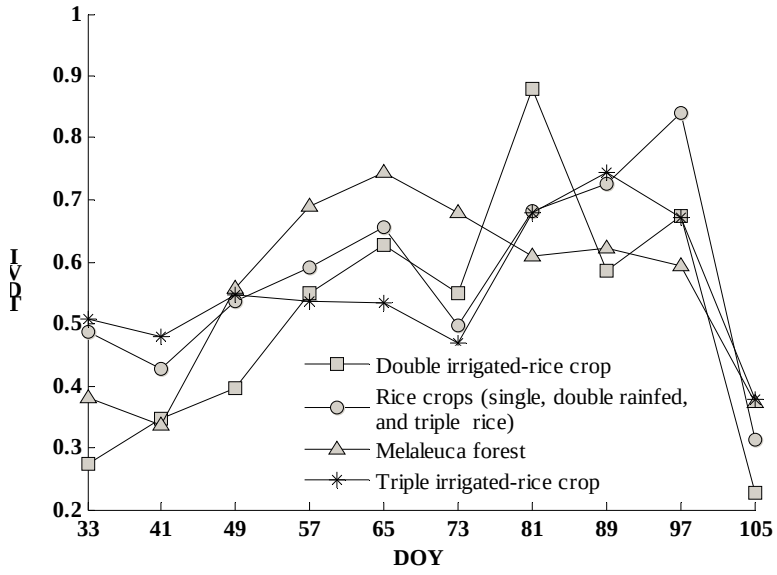

Figure 3. TDVI variations in relation to land-use types.

The soil moisture was dry to very dry at DOY 65 and from DOY 81 to 97 for rice pixels in provinces of Hau Giang, Soc Trang, and Tien Giang. The melaleuca forest in Ca Mau province suffered drought from DOY 57 to 97. Based on this information, one can obtain early information on drought levels to minimize its negative impact.

The relationship between TDVI and the cumulative eight-day interval rainfall for pixels at five rain gauge stations across the Mekong Delta was also compared (Figure 4). The trend of TDVI was generally declining after rain events because the rainfall increases the moisture content in the soils. The TDVI would increase after certain dry days as moisture content in the soils decrease.

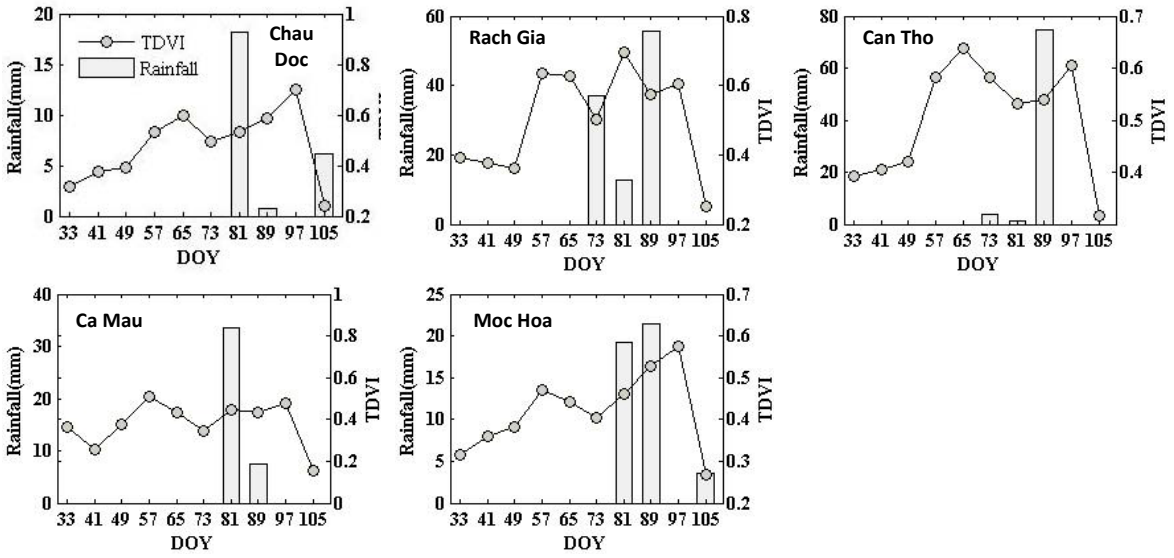

Figure 4. TDVI and cumulative eight-day rainfall at five rain gauge stations.

From the findings, it can be concluded that the EMD-based low-pass filter method is efficient at filtering out noise from time-series MODIS NDVI data. The PCA was useful to reduce the dimensionality of the filtered time-series data. The application of MLC to the first seven PCs, which explained 99.7% of variances, indicated its validity for mapping land-use types in the study area. The overall accuracy and Kappa coefficient were 76.0% and 0.6, respectively. It was found that the northeast and coastal regions suffered from agrodrought. The poor soil moisture could be observed from mid February (DOY 49) to early April (DOY 97). Soil moisture was dry to very dry at DOY 65 and from DOY 81 to 97 for rice pixels in Can Tho, Soc Trang, and Tien Giang provinces while very dry from DOY 57 to 97 for melaleuca forest pixels in Ca Mau. There was a good agreement between TDVI and the cumulative eight-day rainfall data. From early information of agrodrought levels, local authorities would have measures to protect rice crops and forest from the negative impacts of droughts. More field investigations and validations of soil moisture estimation with climatic data are needed to increase the classification accuracy and to confirm validity of the methods for early drought warning in the Mekong Delta.

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