CROP WATER STRESS INDEX (CWSI) ESTIMATION USING MODIS DATA

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Abstract

Crop Water Stress Index (CWSI) is an index which is used to explain the amount of crop water defisiency based on canopy surface temperature. Many researches of CWSI have been done for arranging irigation water system in several crops at different areas. Beside its application in irigation system, CWSI is also known as one of parameters that can influence crop productivity. Regarding the above explanation. It is implied that CWSI is important for monitoring crop drought, arranging irigation water, and estimating crop productivity. This research is proposed to estimate CWSI using MODIS (Moderate resolution Imaging Spectroradiometer) data which is related to Normalized Difference Vegetation Index (NDVI) and Soil Moisture Storage (ST) in paddy field. The interest area is in East Java which is the driest area in Java Island. MODIS land surface temperature is used to estimate CWSI, while MODIS reflectance 500 m is used to estimate NDVI. They were downloaded from NASA website. Data period was from June 15th to June 30th, 2004. Based on the correllation between NDVI and CWSI, we can estimate NDVI value when paddy water stress occurred. The result showed that the largest paddy area in East Java which has high water stress is located in Bojonegoro District. The water stress area in Bojonegoro Distric increased from June 15th to June 30th, 2004. The high to medium water stress level in East Java were predicted as bare land. The CWSI has negative correlation with NDVI and ST. The CWSI > 0.6 are obtained in NDVI < 0.5 with ST less than 50%. This showed that the paddy water stress began at NDVI < 0.5 and ST < 50%. Coefficient of correlation between CWSI and NDVI is -0.58, while CWSI and ST is -0.71. The correlation model between CWSI, NDVI and ST is statistically significant

Keywords : CWSI, NDVI, ST. MODIS Land Surface Temperature. Water Stress.

I. Introduction

Crop Water Stress Index (CWSI) is an index which is used to explain the amount of crop water defisiency based on canopy surface temperature (Yuan et al., 2004). Many researches on CWSI have been done for arranging irigation water system in several crops in any different area. Irmak, et al (2000) confirmed that CWSI is potential tool to determine irigation system schedulle in agricultural land. Beside its application in irigation system, CWSI is also known as one of parameters that can influence crop productivity such as com (Gardner et al., 1986). Regarding the above research. It is implied that CWSI is important for monitoring crop drought, arranging irigation water, and estimating crop productivity.

The CWSI can be obtained by calculating the difference value between canopy surface temperature (Tc) and **air** temperature (Ta), and by calculating the different values between surface vapor pressure and air pressure (Vapor Pressure Defisit, VPD). The CWSI formulas was

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found by Idso et al. (1981) dan Jackson et al. (1981). Infrared Thermometer (IRT) measure canopy surface temperature (Tc). However, this instrument can not efficiently measure Tc in a large area. The remote sensing technology can go through this limited capability to obtain Tc in a large area.

Many of remote sensing sattellite data such as NOAA AVHRR, LANDSAT TM, ASTER, MODIS, etc. have a specification to detect thermal infrared spectrum which determine surface temperature. For example, if the surface object is vegetation, then the detected temperature is canopy surface temperature, and if the surface object is bare land, then the detected temperature is bare land temperature. Based on this specification, remote sensing technology can be used to estimate CWSI.

MODIS (Moderate Resolution Imaging Spectroradiometer) instrument that aboard the satellites TERRAA.QUA with temporal resolution 1-2 days and three kinds of spatial resolution, i.e., 250 meters, 500 meters, and 1000 meters has 36 channels. From the 36th channel, the most precise thermal infrared channels which are used to estimate surface temperature are the 31st and 32nd channels. NASA has published MODIS land surface temperature 1 km which can be downloaded from its website. However, we can not obtained the surface temperature if there are clouds cover in the remote sensing data. The advantage of using sattellites remote sensing data is their capability to cover a large area in one acquisition. According to the above explanation, this research is proposed to determine CWSI by using MODIS data, especially in paddy field in East Java and to determine the correlation between CWSI, NDVI and soil moisture storage (ST).

II. Material and Methods

MODIS land surface temperature and •MODIS reflectance 500 m were used in this research. Data is from June 15 until June 30, 2004. MODIS land surface temperatur is used to estimate CWSI, while MODIS reflectance 500 m is used to estimate NDVI. They were downloaded from NASA website. Correllation analysis between CWSI and NDVI is used to obtain NDVI value when paddy water stress occurred.

Sun et al. (2004) has defined CWSI as follows:

$$CWSI = 1 - \frac{LE}{Rn - G}$$

Where,
LE = Latent heat for evaporation (W m^{-2})
Rn = Net Radiation
G = Soil Heat Flux

We assume linear equation model to explain the relationship between CWSI and surface temperature as follows (Morse et al., 2000)

Tshot ⟶ LE ? 0 CWSI= 1
Tscold ⟶ H ? 0 CWSI= 0

Figure 1 illustrates the equation to estimate CWSI. In its application, the highest LST (Tshot) and the lowest LST (Tscold) from each MODIS data are extracted to get the regression equation.

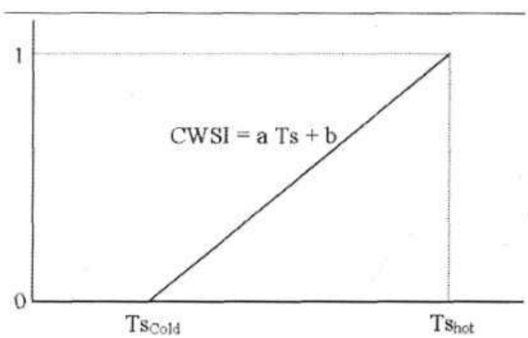

Figure 1. CWSI illustration in its relation to Ts.

Table 1 is examples of linear equation to estimate CWSI by using MODIS Land Surface Temperature.

TEible 1. Examples CWSI equation from MODIS land surface temperature

No.	Date	CWSI
1.	June 16th, 2004	0.0323 Ts-9.1935
2.	June 18th, 2004	0.0341 Ts-9.8621
3.	June 25th, 2004	0.0357 Ts-10.214
4.	June 30th, 2004	0.0345 Ts-9.8276

The CWSI estimation used in this research is the simplest method of CWSI methods. There are many things need to complete this CWSI estimation, so the result can be better for detecting crop water stress level, especially paddy.

III. Results and Discussion

a. CWSI in paddy field

The result of CWSI estimation from MODIS data that acquisitated on June 16l 18 th, 25 th, and 30 th, 2004 are shown in

Table 2 ding to Irmak *et al.* (2000), water s pens in a crop if the CWSI is greati i.6. Table 2 also explain the interval v. /SI in determinating paddy water stress.

Table 2. Paddy water stress level based on CWSI.

No.	CWSI	Water Stress Level
1.	<0.6	No Water Stress
2.	0.6-0.7	Low Water Stress
3.	0.7-0.8	Medium Water Stress
4.	>0.8	High Water Stress

Figure 2 shows that the largest paddy areas in East Java which has high water stress are located in Bojonegoro District. The high water stress area in in this Distric increased from June 15th to June 30th, 2004. In the figure, the high water stress is shown in red area, while the medium water stress is shown in pink area. The high to medium water stress level in Figure 2 were predicted as bare land.

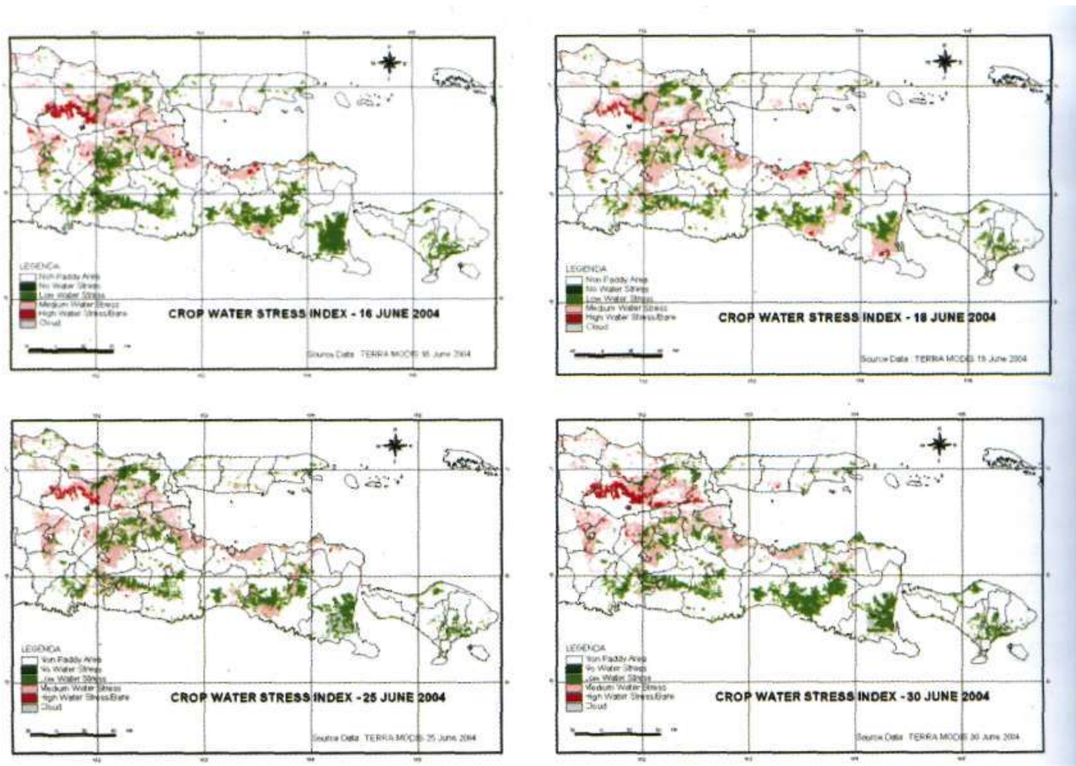

Figure 2. The change of water stress level in East Java paddy field based on MODIS CWSI

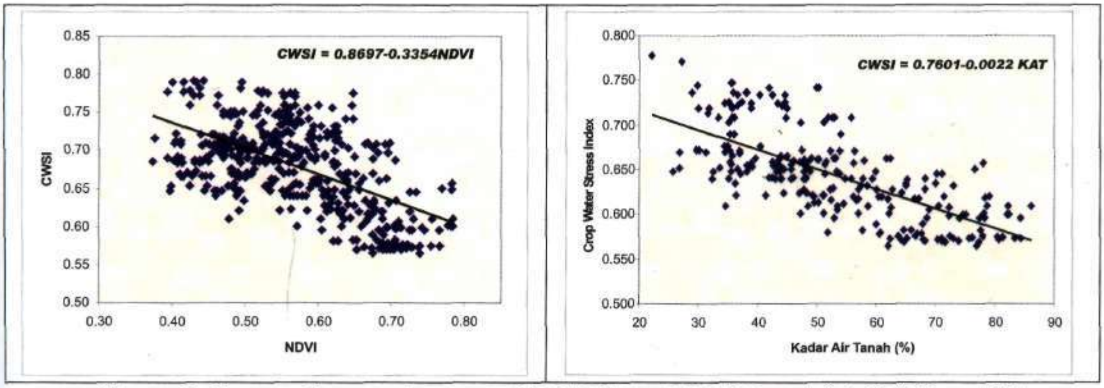

Figure 3. Scatter diagram between (a) CWSI and NDVI, and (b) CWSI and ST

b. Correlation Between CWSI, NDVI, and ST.

Figure 3 shows the relation between CWSI, NDVI, and ST. It is showed that CWSI has negative correlation with NDVI and ST. The CWSI > 0.6 are obtained in NDVI < 0.5 with ST less than 50 %. This shows that the paddy water stress began occurring at NDVI < 0.5 and ST < 50 %.

The correllation coefficient between CWSI and NDVI is -0.58, and its determination coefficient (R2) is 0.34. These value are not too high, but, the F-value as a result from regression analysis between CWSI and NDVI is significant. Like F-value, the P-value of gain and intercept model is less than 0.05. It means that the relation between CWSI and NDVI is statistically significant. According to that results, the paddy CWSI can be obtained from its NDVI.

Negative correllation is also found between CWSI and Soil Moisture Storage (ST). The correllation coefficient is -0.71, while the determination coefficient (R2) is 0.52. These value are again not too high. However, the F-value as a result from regression analysis between CWSI and ST is significant. Like F-value, the P-value of gain and intercept model is less than 0.05. Thats mean that relation between CWSI and ST is statistically significant.

According to that results, the paddy CWSI can be obtained from its ST.

Conclusions

The largest paddy area in East Java during June I5th - 30th, 2004 which has high water stress located in Bojonegoro District. The high water stress area in Bojonegoro Distric increased from June I5th to June 30th, 2004. The high to medium water stress level in East Java were predicted as bare land. The paddy CWSI has negative correllation with NDVI and Soil Moisture Storage. The CWSI > 0.6 are obtained at NDVI < 0.5 with ST less than 50 %. This showed that the paddy water stress began occurring at NDVI < 0.5 and ST < 50 %. Coefficient of correlation between CWSI and NDVI is -0.58, while for CWSI and ST are -0.71. The correlation model between CWSI, NDVI and ST is statistically significant.

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