Vegetation Health Index (VHI) analysis during drought season in Brantas Watershed

F Masitoh¹ and A N Rusydi²

¹ Department of Geography, Faculty of Social Science, State University of Malang, 5 Semarang Road. Malang City, 65145 East Java, Indonesia
² Department of Information System, Faculty of Computer Science, University of Brawijaya, 8 Veteran Road, Malang City, 65145 East Java, Indonesia

Abstract. The Brantas Watershed located in East Java has the vulnerability of drought as one of hydrometeorological disasters. The Vegetation Health Index (VHI) as one of remote sensing index was used to analyse drought. VHI can be derived based on both the Land Temperature Surface (LST) and Normalized Differenced Vegetation Index (NDVI). This research aimed to determine the influence of LST and NDVI, respectively, to VHI, especially in dry season of 2008 - 2017. The data used were MODIS Vegetation Indices (MOD13A1) and MODIS Land Surface Temperature (MOD11B1). The influence of LST and NDVI to VHI in the Brantas Watershed was analysed using correlation and regression testing. The LST - NDVI correlation of Brantas Watershed was negative (-0.73). The high temperature distribution was dominantly located in the low-density vegetation areas. The LST - VHI correlation was 0.35, and NDVI - VHI correlation was 0.63. This illustrated that the influence of land surface temperature to the vegetation drought was weak. Drought indicated by VHI was more likely to be influenced by internal conditions of vegetation and other environmental elements.

1. Introduction
Drought is one of the most common hydrometeorological disasters in Indonesia. The area that often occurs drought is the Brantas Watershed. The main river of it is the Brantas River crossing 15 districts / cities in East Java. The Meteorology and Geophysics Agency claimed that drought occurred in the Brantas Watershed usually began in July to October. As the second largest watershed on Java Island, the Brantas Watershed covers about ± 25% of East Java Province or ± 9% of Java. The Brantas Watershed consists four basins which are the Brantas Basin, the Central Basin and the Ringin Bandulan Basin and the Kondang Merak Basin [1]. Drought can affect the people activities, especially agriculture activities. Therefore, drought management focusing on agricultural activities or vegetation condition become to be important in regional and watershed scale context. [2].

Drought is generally characterized by poor rainfall intensity and warm air temperatures. Drought assessment can be analyzed using remote sensing satellite imagery. Remote sensing is one of quick effective assessment method of drought using wide spatial indices distribution by sequential times. The indices that can be applied are: Normalized Differenced Vegetation Index (NDVI) [3], and Land Surface Temperature (LST) [4]. The composite indices of NDVI and LST which can also be applied are:
Vegetation Condition Index (VCI) [5], Vegetation Health Index (VHI) [6], and Vegetation Temperature Condition Index (VTCCI) [7].

Figure 1. Study area.

The aim of this research is to determine the influence of LST and NDVI, respectively to VHI, especially in drought period of 2008 - 2017. Generally, NDVI-LST relationship of drought was going to be significantly negative relationship. That relationship intensely depended on both location and time conditions. The location conditions included topography and latitudes, whereas the time conditions included seasons and day/night [4]. NDVI was going to be influence to LST variation as land cover consequences [8]. LST became to be important variable in drought assessment. Drought influenced by surface temperature could impact the heat-related stress of vegetation [9]. Topography condition like mountainous area was not going to influence significantly to surface temperature [10]. Spatial distribution of NDVI and LST had contrary patterns depending on spatial combination for each land use type [11]. VHI was composite index of NDVI and LST that could assess drought based on vegetation stress. VHI was used to monitor vegetation status. VHI mapped continually could reveal a plot assisting vegetation management, so any environment disruptions could be prevented [12]. VHI was not accidentally determined by NDVI and LST. NDVI was used to determine Vegetation Condition Index (VCI), whereas LST was used to determine Temperature Condition Index (TCI). VHI could identify vegetation canopy stress, so it could be used as drought assessment indicator index [13]. Understanding vegetation status condition and its response to environment changes was quite important to ensure natural resources safe [14].

2. Research Method
MODIS Vegetation Indices (MOD13A1) and MODIS Land Surface Temperature (MOD11B1) satellite imagery between 2008 – 2017, had been used in this research. In July, severe to extremely droughts often occurred in the Brantas Watershed. Drought assessment applied vegetation indices approach using the spectral reflection of vegetation leaves represented as NDVI. Surface temperature variable was also used to assess drought using spectral reflections of the ground surface represented as LST. The vegetation indices were obtained based on the spectral reflection energy coming from photosynthesis vegetation leaves. It was obtained by identification of appropriate wavelengths including blue channels.
(470 nm) and red (670 nm). The use of those canals would help reduce the atmosphere effects on vegetation [15].

This research used MODI13A1 satellite imagery data which had 16-day / 500m resolution, int16 data type, valid range at -2000, 10000; and scale factor at 0.0001 [15]. NDVI was one of vegetation indices that commonly applied to assess drought [4]. In this research, NDVI was obtained using MODI13A1 satellite imagery. That data was then used to obtain the Vegetation Condition Index (VCI). The VCI formula is shown as below:

\[
VCI = \frac{NDVI' - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \times 100
\]  

NDVI’ is NDVI mean value of related month, whereas NDVI_{max} and NDVI_{min} is the highest value of NDVI and the lowest value of NDVI, respectively, of each observation period. Individually, VCI could be used to assess drought. VCI had high accuracy to assess drought based on duration and its impact to vegetation [6]. VCI could be used with other indices to predict vegetation status/condition. Khan [7] used VCI together with LST to obtain vegetation status in Pakistan by representing as Vegetation Temperature Condition Index.

MODI11B1 LST satellite imagery is one of MODIS Level 3 product. It has Nominal Data Array Dimensions 200 rows by 200 columns, spatial resolution of 6 kilometers (actual 5.56 kilometers), daily temporal resolution, and sinusoidal map projection. LST was obtained by Terra-MODIS satellite with data number types of 16 units, temperature units of Kelvin, valid range of 7500-65535, scale factor of 0.02 [16]. This satellite provided LST information that could be used to assess and to map surface temperature condition by wide scale perspective. LST was used to assess surface heat, so it could mitigate the environment impacts [9].

LST was used to acquire Temperature Condition Index (TCI) value. TCI used together with VCI would provide better representation of drought condition [6]. TCI determination was done by Brightness Temperature (BT) of LST. TCI formula is shown as below:

\[
TCI = \frac{BT_{max} - BT'}{BT_{max} - BT_{min}} \times 100
\]  

BT’ is mean of composite temperature value for each certain observation period. BT_{max} and BT_{min} are maximum temperature and minimum temperature, respectively, identified compositely by maximum pixel value and minimum pixel value in similar observation period. TCI provided better representation of vegetation stress since of temperature [6]. MODI13A1 satellite imagery had different resolution to MODI11B1 satellite imagery. Therefore, resampling process on MODI13A1 was applied using Nearest Neighborhood to make the same spatial resolution of MODI11B1.

The advanced data processing was correlation testing of LST-NDVI. Strong LST-NDVI correlation was become to be the basis for determining VHI values. Meanwhile, weak LST-NDVI correlation could not be used as the basis for VHI determination, so not all area was able to be applied by VHI for drought assessment [4]. VCI and TCI combination was used to represent vegetation condition by Vegetation Health Index (VHI) [13]. VHI formula is shown as below:

\[
VHI = \alpha \cdot VCI + (1 - \alpha) TCI
\]  

VHI formula is combination of VCI and TCI that has a constant \( \alpha \) of 0.5. VHI values was tested using correlation testing using LST and NDVI as influencing factors. VHI values were classified into 4 classes: Extreme drought (<10), Severe Drought (10-20), Moderate Drought (20-30), Mild drought (30 – 40), dan No Drought (>40) [6].

3. Result and Discussion

3.1. NDVI-LST Relationship
NDVI-LST correlation testing is important for analysis of how influence factor of vegetation cover to surface temperature distribution. NDVI-LST correlation of -0.64 had strong negative relationship occurred in Mashad, Iran. The researcher found that high LST value occurred in urban area with less or not vegetation cover at all [17]. LST value was influenced by built-up area, forest, vegetation greenness, and water bodies. Built-up area contributed about 53% to surface temperature. The difference of built-up area and water bodies was up to 4.4°C, whereas that of built-up area and vegetation was about 2.5°C [18].

Figure 2 (a-k). NDVI – LST Correlation Test Result

July was peak month of dry season in Brantas Watershed. In July of 2008-2017, the mean slope of NDVI-LST is going down (see Fig 2a-j). Correlation of -0.794 to -0.732 with determination coefficient of 0.536 to 0.6307, occurred in July months of 2008, 2014, and in August of 2013 and in August of
2017. Correlation of -0.691 to -0.509 with coefficient determination of 0.478 to 0.259, occurred in July months of 2009, 2011, 2012, and 2016. Correlation of -0.805 to -0.838 with coefficient determination of 0.648 to 0.702, occurred in July months of 2010 and 2015. It was agreed with research done by Sun [19] that declared the negative NDVI-LST correlation in dry season. Strong negative correlation occurred because of seasonal changes of sun radiation energy and vegetation condition. Besides that, it occurred because of rainfall probability influencing vegetation condition and surface temperature, especially in dry season [4]. Research done by Deng [11] resulted that NDVI-LST was weak positively correlated (0.32) in woodland area, and that correlation by dry season was getting near of 0.1 in cultivated land. That research was focused on karst area presumed that desertification process occurred.

Fig 1(k) showed increasing and decreasing of NDVI-LST correlation. The weakest NDVI-LST correlation occurred in July of 2012 and the strongest that correlation occurred in July of 2010. Generally, NDVI-LST correlation was about -0.725. It showed that NDVI-LST had strong negative relationship. Research done in urban area of Berlin also resulted negative correlation of NDVI-LST. LST value depended on seasons, land cover, and daily difference of day/night [20]. NDVI-LST correlation studied in North America resulted that strong negative relationship occurred mainly in area of 25° – 30° towards north latitudes. The strong significantly correlation of NDVI-LST occurred in area of 45° – 60° towards north latitudes. But, in area located in 30° – 45° north latitudes, NDVI – LST had weak significantly correlation. It showed that not all locations had strong NDVI-LST correlation, either in positive or negative correlation. In weak NDVI-LST correlation, use of vegetation factor could not be related to surface temperature [4]. Season condition was also going to influence to NDVI-LST correlation. In winter, NDVI-LST had strong positive correlation. But in summer, NDVI-LST was going to be strong negative correlation. Based on that condition, drought assessment using NDVI and LST as related variables was appropriate only in summer [19]. In general way, strong significantly negative correlation showed that the higher NDVI, the lower LST was going to be, especially in dry season.

3.2. NDVI and LST Influence To VHI

| No | Date     | NDVI     | LST       | VHI       | Class               |
|----|----------|----------|-----------|-----------|---------------------|
| 1  | Juli_2008| 0.59835484 | 26.1325852 | 10.325954 | Severe drought      |
| 2  | Juli_2009| 0.60463  | 24.5940033 | 13.386156 | Severe drought      |
| 3  | Juli_2010| 0.64185  | 30.3753388 | 15.209434 | Severe drought      |
| 4  | Juli_2011| 0.56798333 | 29.8880056 | 9.258471  | Extreme drought     |
| 5  | Juli_2012| 0.63833333 | 29.596715  | 17.399242 | Severe drought      |
| 6  | Agustus_2013| 0.64897  | 33.3120057 | 16.323064 | Severe drought      |
| 7  | Juli_2014| 0.68202  | 29.2253397 | 16.148641 | Severe drought      |
| 8  | Juli_2015| 0.59123667 | 31.2113383 | 15.03076  | Severe drought      |
| 9  | Juli_2016| 0.76313  | 27.5353404 | 16.448675 | Severe drought      |
| 10 | Agustus_2017| 0.59297  | 31.0993439 | 14.589173 | Severe drought      |

Determining VHI of 2008-2017 used NDVI and LST data. NDVI resulted from MOD13A1 VI satellite imagery was used to obtain VCI value. VCI determination used formula (1), whereas TCI determination used formula (2). TCI value was obtained based on MOD11B1 LST satellite imagery. Both VCI and TCI were obtained compositely ranging from years of 2008-2017. Those were used to determine VHI. VHI determination used formula (3). Table 1 showed NDVI-LST-VHI condition in Brantas Watershed. In July of 2011. Brantas Watershed experienced with extreme drought, whereas in that month of previous years, it experienced with severe drought. VHI value of Brantas Watershed was influenced by LST and NDVI, with stronger NDVI-VHI correlation than LST-VHI correlation.
VHI correlation was about 0.63, whereas that of LST-VHI was only about 0.35. It indicated that VHI was dominantly influenced by NDVI than LST. It was also to be assumed that vegetation health was more likely controlled by its own internal condition, which was represented as vegetation greenness, than by surface temperature changes of its location in. The vegetation of Brantas Watershed was more endure to temperature changes of dry season.
Fig 3(a-j) showed annual various spatial distribution of VHI for dry season of July in years of 2008-2017. Pei [21] classified VHI into 3 categories which are In Stress (0-40), Normal (41-60), Favorable Condition (60-100). The maximum VHI of Brantas Watershed over that period was 68, and the minimum VHI of that was 40. It indicated that in each July, most vegetation was in normal condition. In July months of 2008, 2011, and 2016, normal VHI was only identified in part of area, and the remain was In Stress. In July months of 2009, 2010, 2012, 2015 and in August months of 2013, 2017, vegetation was mostly in normal condition. Based on VHI (See Table 1), Brantas Watershed was on extremely drought in 2011. It was suited with spatial distribution of VHI (See Fig 3d) that normal vegetation was only centrally located in the center towards north west of study area. In 2002, Brantas Watershed experienced with severe drought. But, VHI showed that vegetation in almost areas was in normal, despite dry season. By considering by VHI spatial distribution, almost area which was in center towards South East of Brantas Watershed was also in normal condition.

VHI was estimation result of VCI and TCI. But, the contribution weight of VCI and TCI to VHI was not easy to be known, although each variable was determined by 50% (0,5) [22]. The weight of VCI and TCI to VHI was tested using potatoes plant as the object and it was estimated by multiple linear regression [23]. This research also used that regression to test NDVI-LST correlation to VHI. This research was based on thesis that both NDVI and LST were able to be used individually to obtain vegetation drought condition [19]. Testing result obtaining NDVI-LST correlation to VHI in Brantas Watershed was stated in regression equation shown below:
The regression equation above indicated that multiple factor of NDVI was larger than that of LST, so it was able to be taken understanding that VHI of Brantas Watershed was more dominantly influenced by NDVI.

\[ VHI = -17.837 + 0.421357LST + 31.44724NDVI \]  

The dominance of NDVI-VHI correlation compared to LST-VHI correlation was also proved using comparison of NDVI-VHI change detection for each observed year ranging from 2008-2017. The change percentage of NDVI-VHI was shown in Fig 3 dan Fig 4. In 2008-2009, increase of NDVI was about 45.303%. In this period, increase of VHI was about 11.06% over Brantas Watershed. The increase of NDVI followed by VHI also occurred in 2009-2010 which was about 41.66% and 8.93%,
respective. Different condition of those occurred in 2010-2011 which there were decrease of NDVI was about 10% followed by decrease of VHI of 2,42%. In 2011-2012, those similar phenomena occurred which were 22,27% and 4,24%, respectively. Both VHI of 2008-2009 and VHI of 2009-2010 had been changed in almost same area. In 2013-2014, all NDVI had increased of 33,03%. The increase was followed by VHI of 24,39%. The same condition occurred in 2015-2016. Increase of this period was about 21,06% since of increased NDVI by 49,39%. In 2014-2015, all NDVI had decreased, so VHI had also decreased of 25%. Decrease of NDVI causing decrease of VHI that totally occurred in 2016-2017 by NDVI and VHI changing of 27,88% and 77,33%, respectively.

| No | Year     | Indicator | NDVI  | VHI   | No | Year     | Indicator | NDVI  | VHI   |
|----|----------|-----------|-------|-------|----|----------|-----------|-------|-------|
| 1  | 2008-2009| Change (+)| 45.30 | 11.06 | 6  | 2013     | Change (+)| 33.03 | 24.39 |
|    |          | Change (-)| 7.27  | 2.58  |    |          | No change| 6.00  | 8.10  |
|    |          | No change | 47.42 | 86.36 |    |          | No change| 46.67 | 68.64 |
|    |          | Indicator | Increase| Increase | 2014|          | Indicator | Increase| Increase |
| 2  | 2009-2010| Change (+)| 41.67 | 8.94  | 7  | 2014     | Change (+)| 8.33  | 5.61  |
|    |          | Change (-)| 10.91 | 8.03  |    |          | Change (-)| 45.00 | 25.00 |
|    |          | No change | 47.42 | 83.03 |    |          | No change| 46.67 | 69.39 |
|    |          | Indicator | Increase| Increase | 2015|          | Indicator | Decrease| Decrease |
| 3  | 2010     | Change (+)| 10.00 | 2.42  | 8  | 2015     | Change (+)| 49.39 | 21.06 |
|    | - 2011   | Change (-)| 42.73 | 11.06 |    |          | Change (-)| 3.94  | 2.27  |
|    |          | No change | 47.27 | 86.52 |    |          | No change| 46.67 | 76.67 |
|    |          | Indicator | Decrease| Decrease | 2016|          | Indicator | Increase| Increase |
| 4  | 2011     | Change (+)| 22.27 | 4.24  | 9  | 2016     | Change (+)| 5.45  | 2.88  |
|    | - 2012   | Change (-)| 31.06 | 15.30 |    |          | Change (-)| 47.88 | 19.39 |
|    |          | No change | 46.67 | 80.45 |    |          | No change| 46.67 | 77.73 |
|    |          | Indicator | Decrease| Decrease | 2017|          | Indicator | Decrease| Decrease |
| 5  | 2012     | Change (+)| 41.52 | 29.70 |    |          | No change | 46.67 | 77.73 |
|    | - 2013   | Change (-)| 11.67 | 17.12 |    |          | No change | 46.82 | 53.18 |
|    |          | No change | 46.82 | 53.18 |    |          | Indicator | Increase| Increase |

VHI was able to show stress level on vegetation and was able to monitor vegetation activity. Monitored vegetation activity by VHI was going to be different in each area. Generally, VHI determination depended on surface temperature since the temperature would influence vegetation growth tenacity and it was able to raise vegetation stress [21]. The existence of water in dry season could be a constraint factor of vegetation growth, especially in low latitude areas [24]. The Brantas Watershed was in low latitude tropical area. In this research, NDVI-LST correlation testing of July resulted strong negative correlation. It also showed that influence contribution of temperature to VHI was fewer, which was 35%, than that of NDVI to VHI which was about 63%.

NDVI represented the ecosystem by vegetation biology perspective [25]. NDVI used locally to asses drought was going to represent various land cover and climate condition [24]. As shown in Table 2, the increase change of NDVI in 2008-2017 was only about 28,5% for each year and the not changed NDVI was about 47% for each year. It indicated that almost part of Brantas Watershed area was covered by vegetation. By interpreting of spatial NDVI distribution, almost part of Brantas Watershed area was covered by vegetation, especially in the centre and south east of the area. Those areas were dominated.
by forest and mountainous area. As Table 3 shown, normal vegetation areas were about 75.77%.

The vegetation would reduce their activities in dry season and would show their own more intensive biology activities in rain season [25]. The normal vegetation condition of Brantas Watershed showed that the vegetation had good resilience capacity enough, despite in dry season. Taabe [14] explained that the resilience capacity of vegetation was part of important ecosystem health factors and vegetation tenacity to face environment changes.

4. Conclusion
This research used VHI to assess vegetation status in Brantas Watershed. NDVI-LST correlation testing had been applied to analyze NDVI-LST relationship before VHI was determined. NDVI-LST correlation testing showed its strong negative relationship. Therefore, it was able to obtain VHI [4]. The result showed that VHI of Brantas Watershed had experienced severe to extremely drought along in July of 2008-2017. Generally, vegetation status showed normal activity, although it occurred in peak of dry season. The condition represented that vegetation of Brantas Watershed had good resilience capacity enough although it was in peak of dry season. VHI distribution by normal to favorable condition were mostly in forest and mountainous area. In the fact, the normal vegetation status was not influenced significantly by temperature (LST). The testing showed that influence of LST was fewer than that of NDVI. Stable NDVI trend could be interpreted by change detection of NDVI and VHI. If there was decrease of NDVI, so that VHI would also be decreased. Therefore, it was able to be concluded that VHI of Brantas Watershed in dry season tended to be influenced by vegetation internal factor and other environment factors.

5. References
[1] Pengelolaan Sumber Daya Air Wilayah Sungai Brantas Tahun 2010. Republic, Indonesia Public Works Ministry of, 2010.
[2] T. W. Biggs et al., “Remote Sensing of Evapotranspiration from Croplands,” no. December, 2015.
[3] V. Zuzulova and J. Vido, “Normalized difference vegetation index (NDVI) as a tool for the evaluation of agricultural drought,” Ecocycles, vol. 4, no. 1, pp. 83–87, 2018.
[4] A. Karnieli et al., “Use of NDVI and Land Surface Temperature for Drought Assessment: Merits and Limitations,” JOURNAL OF CLIMATE, vol. 23, pp. 618–633, 2009.
[5] C. Adede, R. Oboko, P. W. Wagacha, and C. Atzberger, A Mixed Model Approach to Vegetation Condition Prediction Using Artificial Neural Networks (ANN): Case of Kenya’s Operational Drought Monitoring, no. Figure 1. 2019.
[6] F. N. Kogan, “Application of vegetation index and brightness temperature for drought detection,” Adv. Space Res. 15, pp. 91–100, 1995.
[7] J. Khan, P. Wang, Y. I. Xie, L. E. I. Wang, and L. I. Li, “Mapping MODIS LST NDVI Imagery for Drought Monitoring in Punjab Pakistan,” IEEE Access, no. July, 2018.
[8] H. Cisneros, M. Andrea, A. Laura, and M. Cintia, “Spatial and temporal analysis of the LST-NDVI relationship for the study of land cover changes and their contribution to urban planning in Monte,” vol. 64, pp. 25–47, 2018.
[9] C. F. Agbor and E. O. Makinde, “Land Surface Temperature Mapping Using Geoinformation Techniques,” Geoinformatics FCE CTU, vol. 17, no. February, p. 1, 2018.
[10] T. D. L. Leder and N. Leder, “Land Surface Temperature Determination in the Town of Mostar Area Land Surface Temperature Determination in the Town of Mostar Area,” Tehnički vjesnik, vol. 25, no. 4, pp. 1219–1226, 2018.
[11] Y. Deng, S. Wang, X. Bai, Y. Tian, and L. Wu, “Relationship among land surface temperature and LUCC, NDVI in typical karst area,” Scientific Reports, vol. 8, no. October 2017, pp. 1–12, 2018.
[12] A. C. Sparavigna and R. Marazzato, “Recurrence Plots of Geolocated Time Series from Satellite Maps of NOAA STAR Vegetation Health Index,” International Journal of Sciences, vol. 4,
[13] F. N. Kogan, “Operational Space Technology for Global Vegetation Assessment,” in *Bulletin of the American Meteorological Society*, 2001, pp. 1949–1964.

[14] A. Ranjbar, M. Taabe, S. H. Mousavi, and M. A. D. Khosroshahi, “Quantifying The Vegetation Health Based On The Resilience In An Arid System,” *Ekológia (Bratislava)*, vol. 37, no. 1, pp. 32–41, 2018.

[15] K. Didan, A. B. Munoz, S. Ramon, and A. Huete, *MODIS Vegetation Index User’s Guide (MOD13 Series)*, vol. 2015, no. June. The University of Arizona, 2015.

[16] Z. Wan, *MODIS Land Surface Temperature Products Users’ Guide*, no. March. Santa Barbara: ICESS, University of California, 2007.

[17] S. A. Gorgani, M. Panahi, and F. Rezaie, “The Relationship between NDVI and LST in the urban area of Mashhad , Iran,” in *International Conference on Civil Engineering Architecture & Urban Sustainable Development*, 2013, no. 27&28 November 2013.

[18] I. Ibrahim and R. Fauzi, “The land surface temperature impact to land cover types,” no. June, 2016.

[19] D. Sun and M. Kafatos, “Note on the NDVI-LST Relationship and the Use of Temperature-Related Drought Indices Over North America Note on the NDVI-LST relationship and the use of temperature-related drought indices over North America,” *GEOPHYSICAL RESEARCH LETTERS*, vol. 34, no. L24406, 2007.

[20] F. Marzban, S. Sodoudi, and R. Preusker, “The influence of land-cover type on the relationship between NDVI–LST and LST–T-air,” *International Journal of Remote Sensing*, vol. 39, no. 5, pp. 1377–1398, 2018.

[21] F. Pei et al., “Monitoring the vegetation activity in China using vegetation health indices Agricultural and Forest Meteorology Monitoring the vegetation activity in China using vegetation health indices,” *Agricultural and Forest Meteorology*, vol. 248, no. 2018, pp. 215–227, 2018.

[22] V. A. Bento, I. F. Trigo, C. M. Gouveia, and C. DaCamara, “Contribution of Land Surface Temperature ( TCI ) to Vegetation Health Index : A Comparative Study Using,” *Remote Sensing*, vol. 101324, 2018.

[23] A. Rahman, “Using AVHRR-Based Vegetation Health Indices for Estimation of Potato Yield Civil & Environmental Engineering Using AVHRR-Based Vegetation Health Indices for Estimation of Potato Yield in Bangladesh,” no. March, 2019.

[24] A. Karnieli et al., “Use of NDVI and Land Surface Temperature for Drought Assessment : Merits and Limitations,” *JOURNAL OF CLIMATE*, vol. 23, no. February, 2010.

[25] G. Dall’olmo and A. Karnieli, “Monitoring phenological cycles of desert ecosystems using NDVI and LST data derived from NOAA-AVHRR imagery,” *Int. J. Remote Sensing*, vol. 23, no. 19, pp. 4055–4071, 2002.