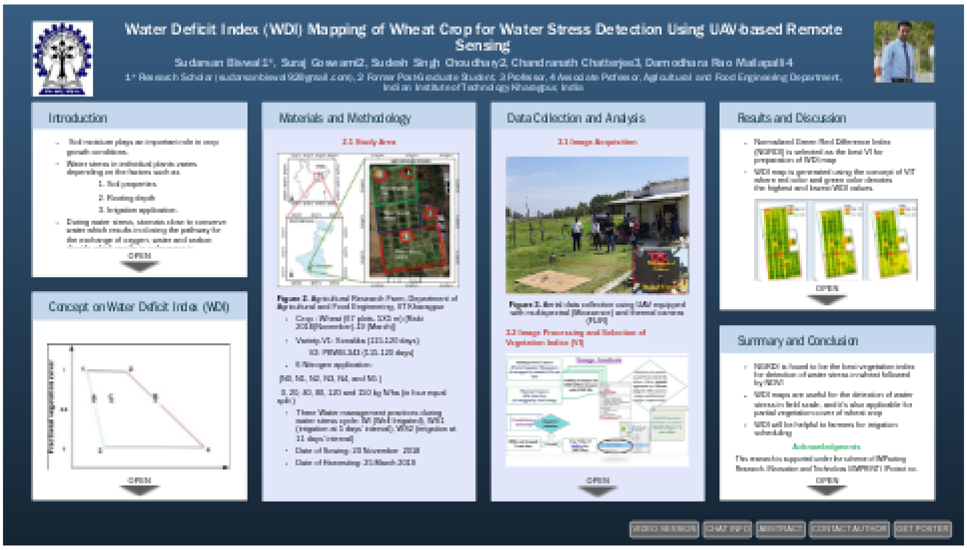
Water Deficit Index (WDI) Mapping of Wheat Crop for Water Stress Detection Using UAV-based Remote Sensing



Sudarsan Biswal1*, Suraj Goswami2, Sudesh Singh Choudhary2, Chandranath Chatterjee3, Damodhara Rao Mailapalli4

1* Research Scholar (sudarsanbiswal92@gmail.com), 2 Former Post-Graduate Student, 3 Professor, 4 Associate Professor, Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, India

PRESENTED AT:

INTRODUCTION

- Soil moisture plays an important role in crop growth conditions.

- Water stress in individual plants varies depending on the factors such as

  1. Soil properties

  2. Rooting depth

  3. Irrigation application.

- During water stress, stomata close to conserve water which results in closing the pathway for the exchange of oxygen, water and carbon dioxide which results in a decrease in photosynthesis (Porporato et al. 2001).

- Airborne practices (balloons, airplanes, and satellites) are less acceptable for timely irrigation management due to lack of spatial and temporal resolutions.

- Unmanned Aerial Vehicle (UAV) equipped with multispectral and thermal cameras with higher spectral and temporal resolutions are used as promising tools for detecting water stress under different water deficit conditions.

- Objective: To develop Water Deficit Index (WDI) maps for water stress detection in wheat crop

CONCEPT ON WATER DEFICIT INDEX (WDI)

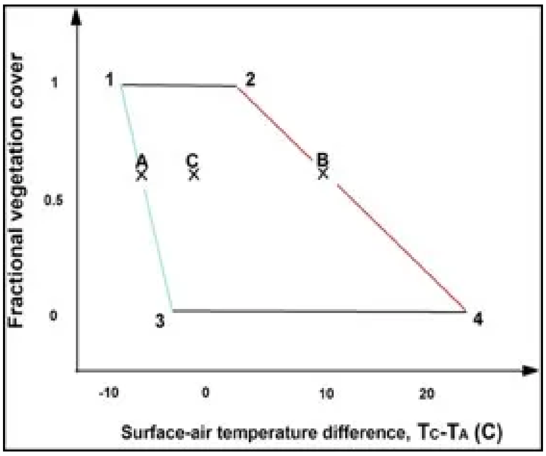


Figure 1. Vegetation Index Trapezoid to construct water deficit Index (Moran et al., 1994)

$$WDI = 1 - \frac{\lambda E_{act}}{\lambda E_{pot}} = \frac{(T_s - T_a)_{mes} - (T_s - T_a)_{min}}{(T_s - T_a)_{max} - (T_s - T_a)_{min}}$$

Where

(1) well-watered full-cover vegetation

(2) water-stressed full-cover vegetation

(3) saturated bare soil and

(4) dry bare soil.

A: minimum surface air temp. difference

B: maximum surface air temp. difference

C: measured surface air temp. difference

MATERIALS AND METHODOLOGY

2.1 Study Area

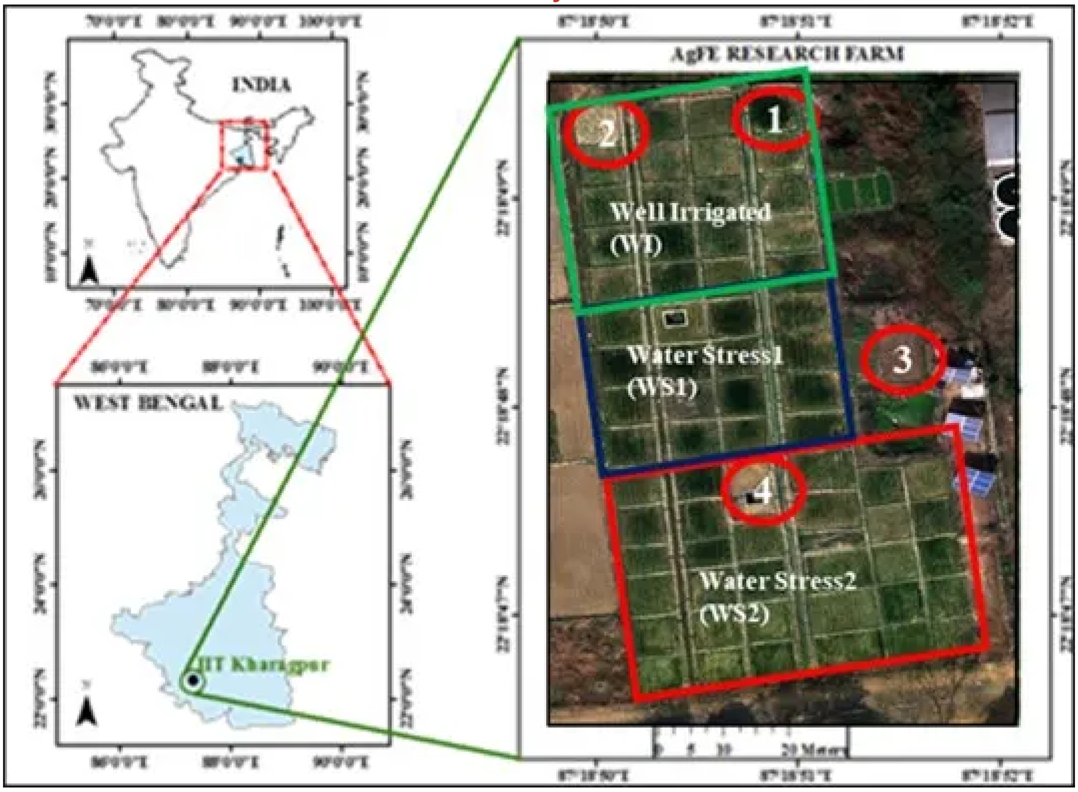


Figure 2. Agricultural Research Farm, Department of Agricultural and Food Engineering, IIT Kharagpur

- Crop : Wheat (67 plots- 5X5 m) (Rabi 2018(November)-19 (March))
- Variety-V1: Sonalika (115-120 days)

  V2: PBWB-343 (115-120 days)

- 6 Nitrogen application:

(N0, N1, N2, N3, N4, and N5)

0, 20, 40, 80, 120 and 150 kg N/ha (in four equal split)

- Three Water management practices during water stress cycle: WI (Well Irrigated), WS1 (irrigation at 5 days' interval), WS2 (irrigation at 11 days' interval)
- Date of Sowing: 20 November 2018
- Date of Harvesting: 25 March 2019

DATA COLLECTION AND ANALYSIS

3.1 Image Acquisition

Figure 3. Aerial data collection using UAV equipped with multispectral (Micasence) and thermal camera (FLIR)

3.2 Image Processing and Selection of Vegetation Indice (VI)

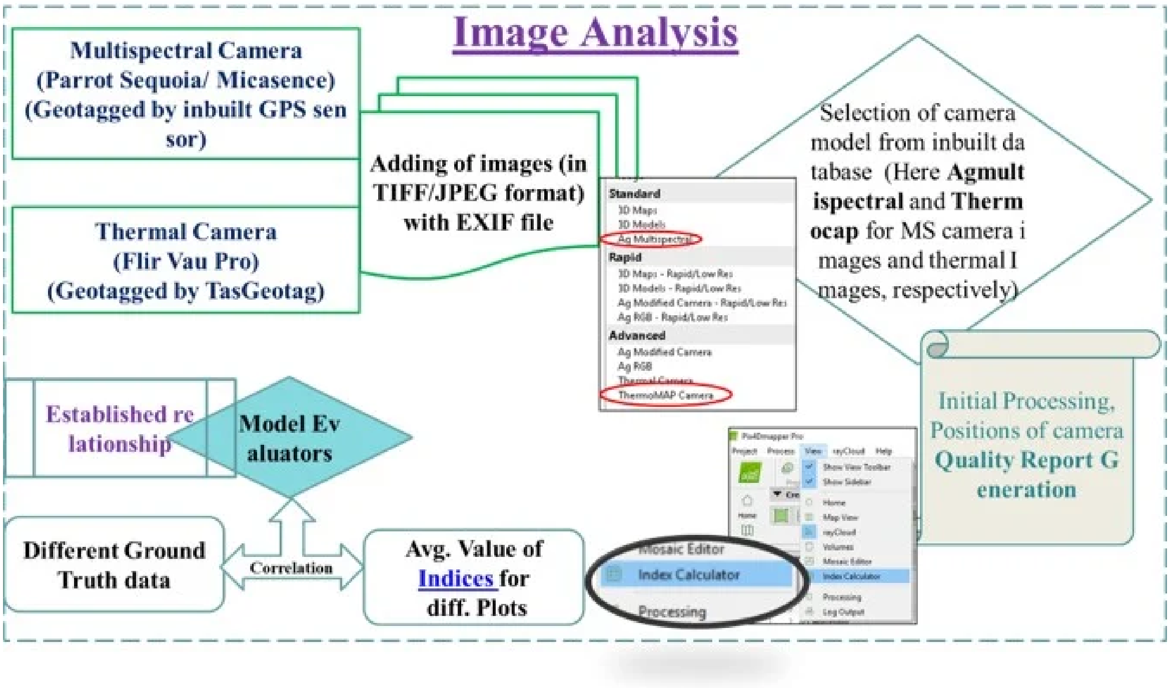


Figure 4. Flow chart for image processing and selection of VI

3.3 Ground Truth data

- Chlorophyll content of leaf by using SPAD meter
- NDVI by greenseeker.
- Soil moisture content (volumetric basis) by Frequency Domain Reflectometry (FDR)

RESULTS AND DISCUSSION

- Normalized Green Red Difference Index (NGRDI) is selected as the best VI for preparation of WDI map

- WDI map is generated using the concept of VIT where red color and green color denotes the highest and lowest WDI values.

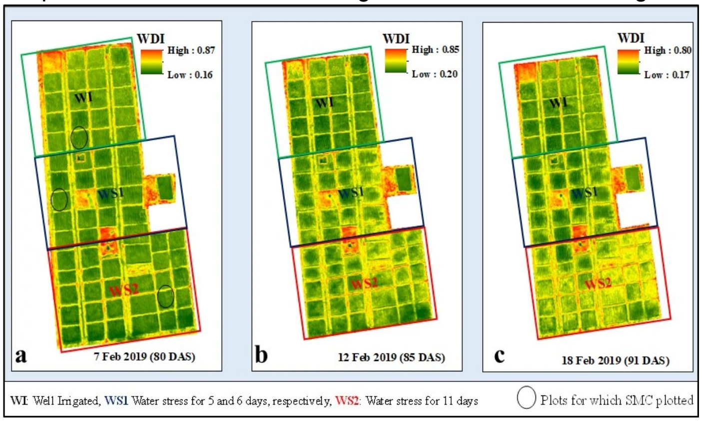


Figure 5. Water Deficit Index for different dates during the water cycle (a) 7 Feb 2019 (b) 12 Feb 2019 (c) 18 Feb 2019

SUMMARY AND CONCLUSION

- NGRDI is found to be the best vegetation index for detection of water stress in wheat followed by NDVI
- WDI maps are useful for the detection of water stress in field scale, and it's also applicable for partial vegetation cover of wheat crop
- WDI will be helpful to farmers for irrigation scheduling

Acknowledgments

This research is supported under the scheme of IMPacting Research, INnovation and Technology ((IMPRINT) (Project no. 5682) funded by the Ministry of Human Resources Development (MHRD), Government of India, New Delhi, and the Ministry of Agriculture & Farmers' Welfare (MoA&FW), Govt. of India, New Delhi.

References

Moran, M.S., Clarke, T.R., Inoue, Y., Vidal, A., (1994). Estimating crop water deficit using the relation between surface-air temperature and spectral vegetation index. Remote Sensing of Environment 49 (2), 246–263

ABSTRACT

Water stress mapping in crops and its spatial disparity study at field scale is important for precise management of irrigation. Results obtained from conventional airborne practice (balloons, airplanes, and satellites) are less acceptable for timely irrigation management due to lack in spatial and temporal resolutions. Unmanned Aerial Vehicle (UAV) equipped with multispectral (MS) and thermal cameras with higher spectral and temporal resolutions can be used as a promising tool for preparing water stress maps under different water deficit conditions. In this study, Water Deficit Index (WDI) maps are generated at different days after sowing (DAS) in wheat crops under three different water conditions (WI (well water), WS1(irrigation at 5 days' interval), and WS2 (irrigation at 11 days' interval)) using the concept of Vegetation Index Trapezoid (VIT) using UAV based thermal and MS imageries. The UAV is flown at 60m altitude during the Rabi season 2018-19. After pre-processing of images in Pix4dMapper, nine vegetation indices are calculated from MS images and one of the indices, Normalized Green Red Difference Index (NGRDI) is selected based on the higher correlation with ground truth data (R^2 greater than 0.5) and visual interpretation according to the real field condition to construct the VIT. Vegetation index and temperature values are calculated for four points of VIT by using four boundary conditions such as bare soil with (1) dry and (2) wet conditions, and full vegetation with (3) well-watered and (4) water stress conditions. By using the ArcGIS, geo-referencing of thermal images with respect to MS images is done to get the exact overlap of both images, and resampling of thermal and MS images are also carried out to get the same pixel size. WDI values are estimated using VIT of the surface-air temperature difference and NGRDI, and WDI maps are generated from the UAV-based thermal and MS imageries for potential detection of crop water stress. The conventional Crop Water Stress Index (CWSI) which is solely based on the crop canopy temperature is outperformed by the WDI, which is integration of composite land surface temperature (LST) and degree of greenness, and could be effective enough for irrigation water management.

Keywords:

UAV, Multispectral and Thermal imageries, NGRDI, WDI, and Wheat crop.