Application of UAV in Estimation of Crop Coefficient (K_c) using Field and Remote Sensing Data

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Abstract

Evaluation of spatially distributed crop coefficient (K_c) for estimating evapotranspiration (ET_c) based on remotely sensed imagery has become an essential topic in managing the demand for agricultural water. Currently, satellite (MODIS, Landsat, etc.) imageries are not insufficient to detect variability within the small agricultural field due to its lack of desired spatial and temporal resolutions. Unmanned Aerial Vehicle (UAV) equipped with various sensors like Multispectral (MS), Thermal, and Hyperspectral cameras is becoming an emerging technology to overcome these limitations over small agricultural fields. A field experiment is carried out in the Agricultural and Food Engineering (AGFE) Department, IIT Kharagpur, to estimate K_c over the small Agri. Field using UAV-based MS cameras during Kharif (monsoon) 2019-2020 season. Lysimeters are used for estimating daily ET_c for conventionally irrigated paddy crops. Reference evapotranspiration (ET_0) is also calculated using the weather data of the study area. High-resolution multispectral imageries are acquired using a quad-copter UAV. The imageries are pre-processed using Pix4Dmapper software, and various vegetation indices (such as NDVI, TNDVI, NDRE, RVI, GNDVI, and LCI) are evaluated. The vegetation indices (VI_s) are correlated with ground truth K_c values and spatially distributed K_c maps for the whole study area are generated based upon the excellent correlation between the VI_s and ground K_c. The spatial K_c maps clearly show the variation in K_c within the plots and will be helpful for the calculation of K_c for any field without a lysimeter experiment. Generated K_c maps describe the crop water demand by visual color variations within the field. This approach may be helpful in understanding the variability in crop water requirements within the field Keywords: UAV, Crop Coefficient (K_c), Crop Evapotranspiration (ET_c), Vegetation Indices, Remote Sensing.

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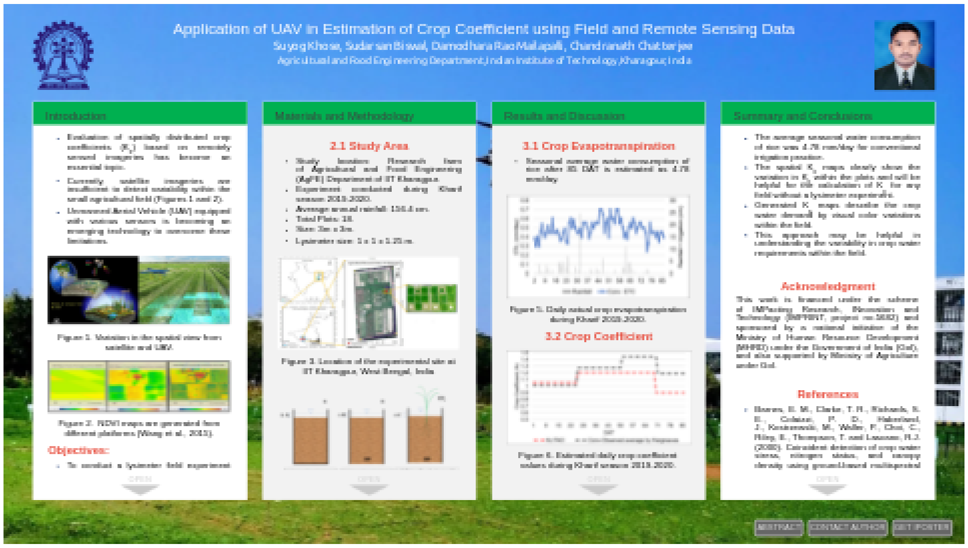

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PRESENTED AT:

INTRODUCTION

- Evaluation of spatially distributed crop coefficients (K_c) based on remotely sensed imageries has become an essential topic.
- Currently, satellite imageries are insufficient to detect variability within the small agricultural field (Figures 1 and 2).
- Unmanned Aerial Vehicle (UAV) equipped with various sensors is becoming an emerging technology to overcome these limitations.

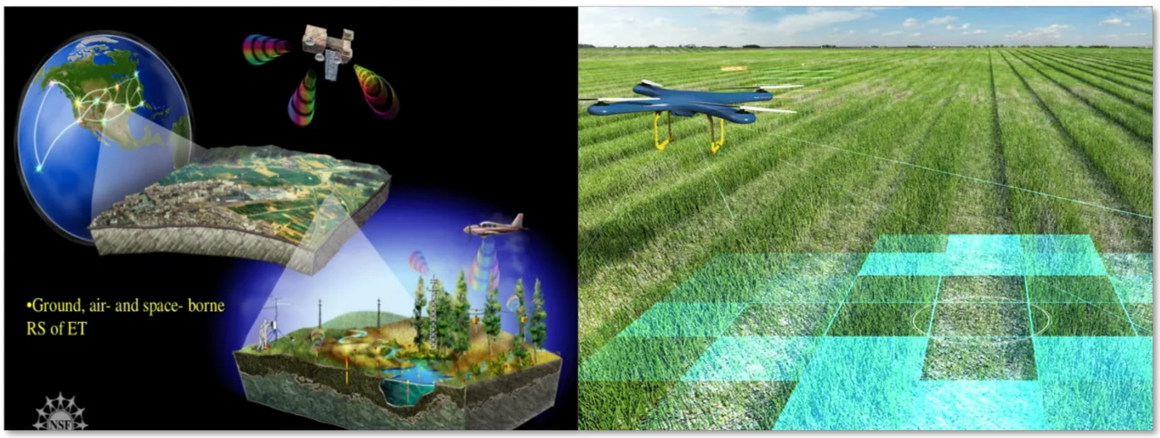

Figure 1. Variation in the spatial view from satellite and UAV.

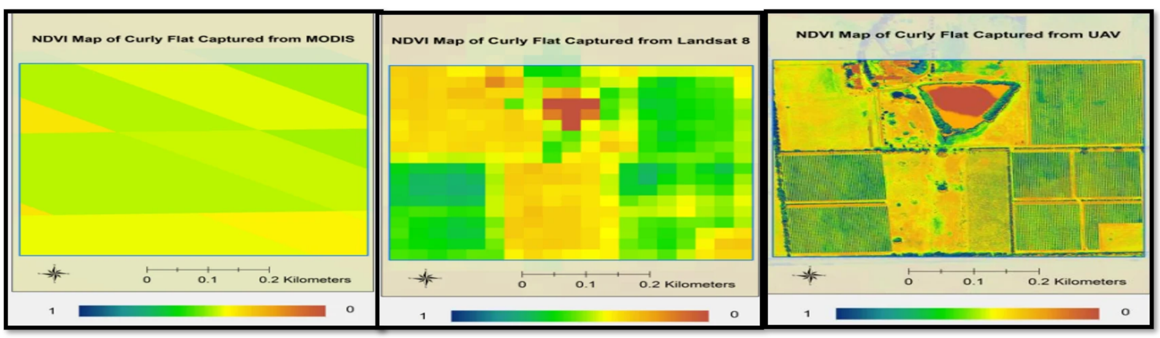

Figure 2. NDVI maps are generated from different platforms (Wang et al., 2015).

Objectives:

- To conduct a lysimeter field experiment for determining the actual crop evapotranspiration for paddy.
- To generate crop coefficient maps using UAV-based multispectral Imageries.

MATERIALS AND METHODOLOGY

2.1 Study Area

- Study location: Research farm of Agricultural and Food Engineering (AgFE) Department of IIT Kharagpur.
- Experiment conducted during Kharif season 2019-2020.
- Average annual rainfall: 156.4 cm.
- Total Plots: 18.
- Size: 3m x 3m.
- Lysimeter size: 1 x 1 x 1.25 m.

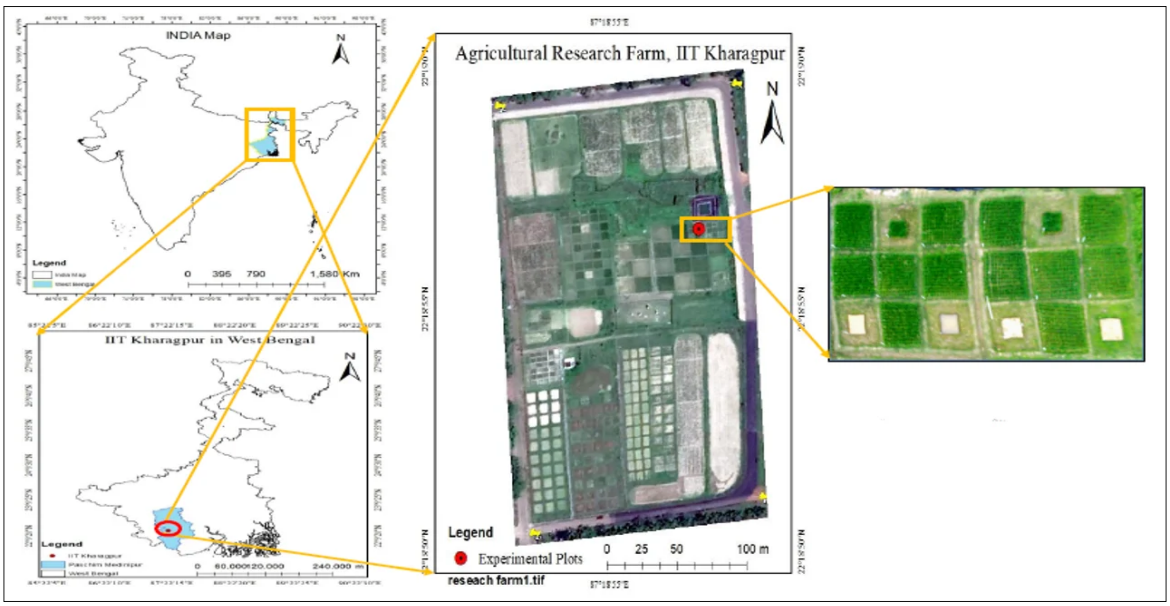

Figure 3. Location of the experimental site at IIT Kharagpur, West Bengal, India

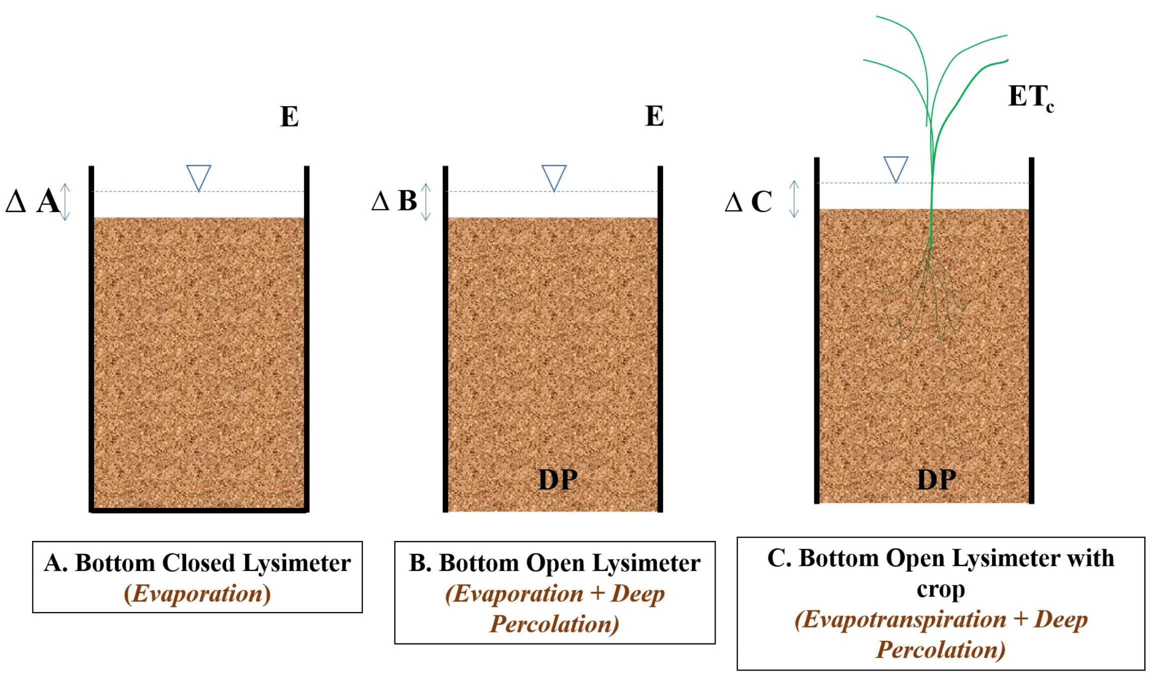

Figure 4. Schematic view of non-weighing type lysimeter A) bottom closed lysimeter; B) bottom opened lysimeter; C) bottom opened with crop lysimeter.

2.2 Crop Management Practices

Table 1. Selected crop management practice for Kharif 2019-2020.

Parameters	Practice
Water Treatment	Conventional flooding
Irrigation Treatment	Maintaining ponding water (2-5 cm)
Transplantation date	Kharif Season; 26^{th} July 2019
Rice Variety	Paddy MTU 1010
Recommended fertilizer dose	(N:P:K) - (120:50:60) Kg/ha
No of splits of N	Four splits at every 20 DAT
Harvesting date	Kharif Season; 6^{th} November 2019

2.3 Data Collection

Table 2. Data collected for research during Kharif 2019-2020.

Parameter		Instruments used	Collection Interval
Water	Standing water level	Scale	Daily
	Piezometer	Water Level Indicator	
	Matric Potential	Tensiometer	
Agronomical Parameters	Plant Height, Tillers Per Hill	Manually	10 Days
UAV data	Multispectral images	UAV	10 days
Meteorologic-al data	Min and Max Temp, Rainfall, Min and Max Humidity, Solar radiation, wind velocity	Automatic weather station	Daily

2.4 Conceptualisation of crop coefficient estimation

Crop evapotranspiration was calculated using a lysimetric water balance (figure 4).

Evaporation, $E = \Delta A$ ------(1)

Deep Percolation, $DP = \Delta B - \Delta A$ -------(2)

Evapotranspiration, $ET_c = \Delta C - DP$ ------(3)

Crop Coefficient:

Crop Coefficient $K_c = \frac{ETc}{ET0}$

Where,

ET_c = crop evapotranspiration,

ET_0 = reference evapotranspiration.

Reference Evapotranspiration:

The Hargreaves temperature equation for estimating ET_0 (mm/day) is given by (Hargreaves and Samani, 1985),

$$ET_0 = \{0.0023Ra\ [0.5(Tmax + Tmin) + 17.8]$$

$(Tmax - Tmin)^{0.5}\}$

Where,

- R_a is the extra-terrestrial radiation (mm/day) (1 MJ/m^2/day = 0.408 mm/day), and
- T_{max} and T_{min} are the maximum and minimum air temperatures (°C), respectively.

2.5 Image Processing

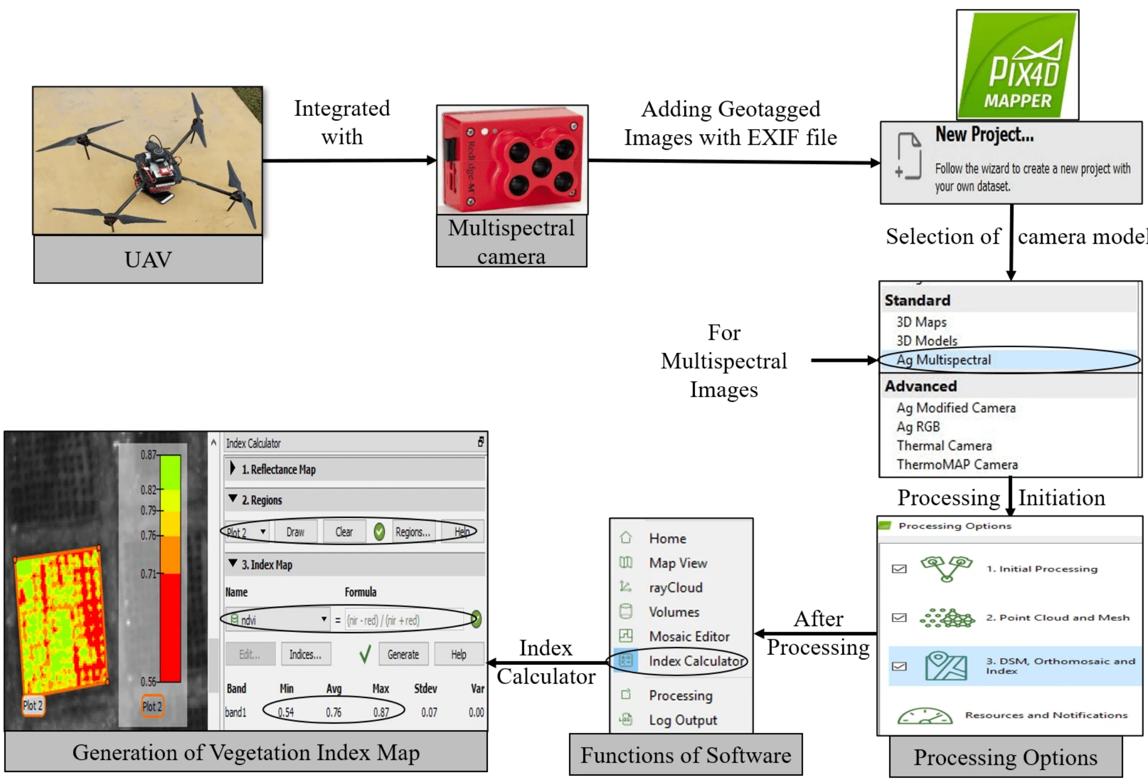

Figure 5. Procedure for vegetation indices calculation using *Pix4D mapper pro* software.

Table 3. Equations of different vegetation indices were used in this study.

Vegetation indices	Abbreviation	Formula	Reference(s)
Normalized Difference Vegetation Index	NDVI	(NIR-R)/ (NIR+R)	Rouse et al. (1974)
Normalized Difference Red Edge	NDRE	(NIR-RE)/ (NIR+RE)	Barnes et al. (2000)
Transformed Normalized Difference Vegetation Index	TNDVI	SQRT[NDVI+0.5]	Sandham et al. (1997)
Green Normalized Difference Vegetation Index	GNDVI	(NIR-G)/ (NIR+G)	Gitelson et al. (1996)
Normalized Green Red Difference Index	NGRDI	(G-R)/ (G+R)	Tucker et al. (1979)
Soil Adjusted Vegetation Index	SAVI	[(NIR-R)/ (NIR+R+L)]x(1+L)	Huete (1988)
Ratio Vegetation Index	RVI	NIR/R	Jordan et al., 1969

RESULTS AND DISCUSSION

3.1 Crop Evapotranspiration

- Seasonal average water consumption of rice after 85 DAT is estimated as 4.78 mm/day.

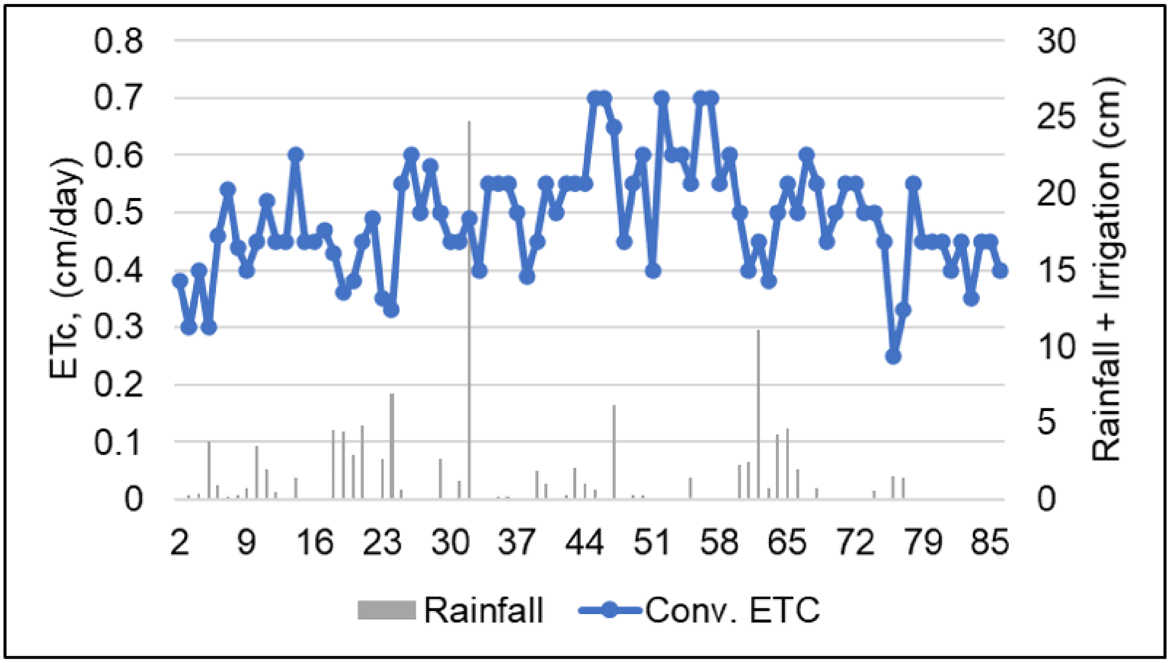

Figure 5. Daily actual crop evapotranspiration during Kharif 2019-2020.

3.2 Crop Coefficient

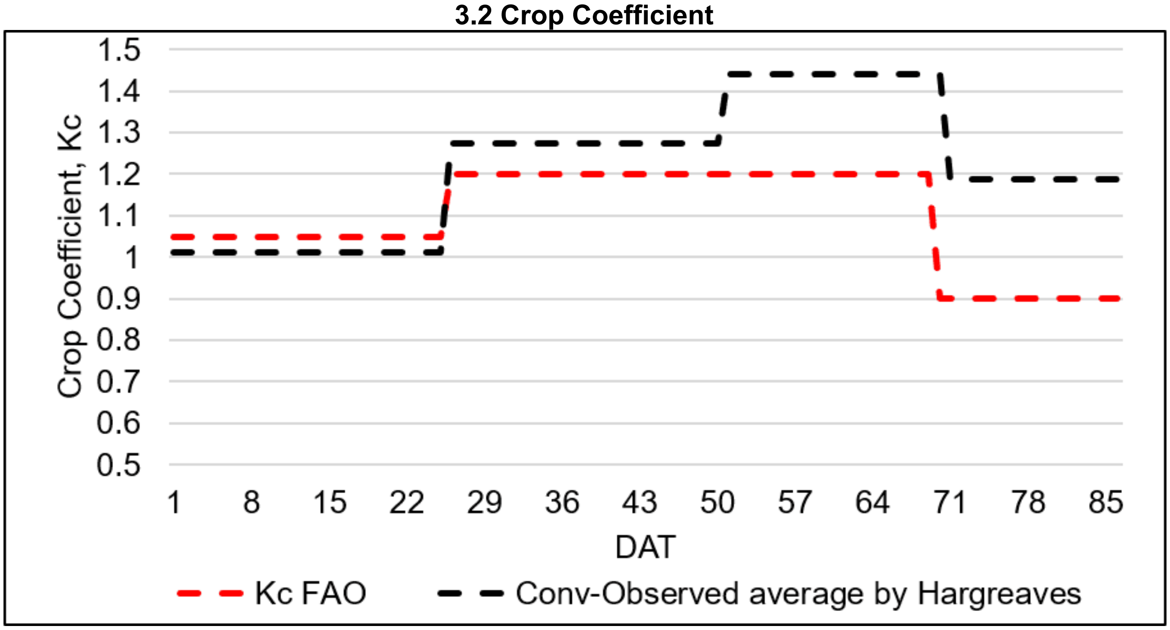

Figure 6. Estimated daily crop coefficient values during Kharif season 2019-2020.

3.3 Crop Coefficient Maps

- Vegetation indices (VI's) were linearly correlated with ground truth Lysimeter-based K_c values.

Figure 7. Generated Kc map using LCI index based on lysimetric K_c values a) 35 DAT; b) 47 DAT; c) 67 DAT; and d) 84 DAT.

SUMMARY AND CONCLUSIONS

- The average seasonal water consumption of rice was 4.78 mm/day for conventional irrigation practice.
- The spatial K_c maps clearly show the variation in K_c within the plots and will be helpful for the calculation of K_c for any field without a lysimeter experiment.
- Generated K_c maps describe the crop water demand by visual color variations within the field.
- This approach may be helpful in understanding the variability in crop water requirements within the field.

Acknowledgment

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References

- Barnes, E. M., Clarke, T. R., Richards, S. E., Colaizzi, P. D., Haberland, J., Kostrzewski, M., Waller, P., Choi, C., Riley, E., Thompson, T. and Lascano, R.J. (2000). Coincident detection of crop water stress, nitrogen status, and canopy density using ground-based multispectral data. In Proceedings of the Fifth International Conference on Precision Agriculture, Bloomington, MN, USA, Vol. 1619.
- Gitelson, A. A., Kaufman, Y. J., and Merzlyak, M. N. (1996). Use of a green channel in remote sensing of global vegetation from EOS-MODIS. Remote sensing of Environment, 58(3), 289-298.
- Hargreaves, G. H., & Samani, Z. A. (1985). Reference crop evapotranspiration from temperature. Applied engineering in agriculture, 1(2), 96-99.
- Jordan, C.F. (1969). Derivation of the leaf-area index from quality of light on the forest floor. Ecology, 50(4), 663-666.
- Rouse Jr, J., Haas, R. H., Schell, J. A., and Deering, D. W. (1974). Monitoring vegetation systems in the Great Plains with ERTS.
- Sandham, L. A., and Zietsman, H. L. (1997). Surface temperature measurement from space: a case study in the southwestern Cape of South Africa. South African Journal of Enology and Viticulture, 18(2), 25-30.
- Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. Remote sensing of Environment, 8(2), 127-150.

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