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Estimation of Single Crop Co-Efficient for Wheat Crop Using Spectral Indices

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Abstract

The majority of the time, real crop water requirements are determined by combining references evaporation with crop coefficients. The crop coefficient accounts for plant transpiration and soil evaporation. The Kc values calculated with the lysimeter setup are point valued with no spatial fluctuation. Remotely detected spectral indices were used to estimate the crop coefficient in both space and time. As a result, this research was carried out to show that crop coefficients may be estimated using satellite data. The corrected satellite data for the research region were obtained/downloaded from the USGS website for the winter growing season (November to March). A hand-held GPS device was used to acquire ground truth valued. Plant heights of randomly selected plants were measured at 15 days intervals at the same time. The downloaded satellite data yielded two spectral indices: the Normalized Difference Vegetation Index (NDVI), and Soil Adjusted Vegetation Index (SAVI).to build relationships between Kc values and spectral indices, basic linear and multiple linear regression approaches were used kc and NDVI had a great individual relationship (R^2=0.92) and SAVI (R^2=0.79) while the combined association of NDVI and SAVI (R^2=0.94) was shown to be superior than each index's standalone relationship. These relationships should be used to determine Kc values for wheat grown in dry areas with plenty of water.

Keywords :
Actual Evapotranspiration, Crop Coefficient, Remote Sensing, Vegetation Index.

1. Introduction

The significance of water assets management is because of the increase of the population and water demand particularly in arid and semi-arid regions. These areas are under threat and will be under threat due to scarcity of water watershed in the future. Pakistan falls among the areas that are confronting intense water deficiencies. This is mainly due to the combination of determined less availability of water in the system, increase in water demand in irrigated agriculture sector and improper management of the water.Information on crop water prerequisites is a significant down to earth thought for structuring and overseeing water system frameworks (Dhotre et al., 2015). The water prerequisite fluctuates broadly from harvest to trim and furthermore during the time of development of individual yields. Consequently, estimation of yield water prerequisite considering the trimming design is a region of study, which needs the consideration of water assets organizers and repeating engineers.

Conservation and measurements of requirements for a specific usage are essential for effective utilizing of existing water sources. It is critical to assess the water requirements of the crop under investigation using a trustworthy appoarch in order to make the greates use of available water resources in the irrigated agricultural sector.

Several methodologies for measuring ETc based on combination of yield demonstrating and remotely detected data have been developed in recent decades. These methods range from simple onces like the vegetation index/ temperature trapezoid to more complicated land surface models (Haboudane, 2004). However, the infrequent recurrence of the required high- goals satellite information combined with the discontinuous nearness of cloud renders these techniques unappreciated for operational application (Er-Raki et al., 2010).

Crop coefficients kc were mostly determined by canopy dynamics (cover fraction, LAI, greenness). Remote sensing data may be used to assess various key-factors associated with vegetation phonology (Kiptala et al., 2018), which open up possibilities for determining the truth variation of kc. At field and regional sized, the use of remotely sensed vegetation records such as the Normalized Difference Vegetation Index (NDVI) and the soil Adjusted Vegetation Index (SAVI) has been used to anticipate crop related information

2. Methodology

2.1. Study Area

The study was conducted in the Khairpur district in northeastern Sindh province, surrounded by Shikarpur and Sukkur in the north, India in the east, Sanghar and Shaheed Benazeerabad in the south, and Larkana and Noshero Feroz in the west. The area is located at 68◦.741 longititude to 27.558 latitude. Most of the agricultural land in the area is in the Indus Plain, which is irrigated by the Indus river. Khairpur is divided into eight talukas,namely Kingri, Khairpur, Kot Diji, Gambat, Sobho Dero, Thari Mirwah, Nara and Faiz Gunj.

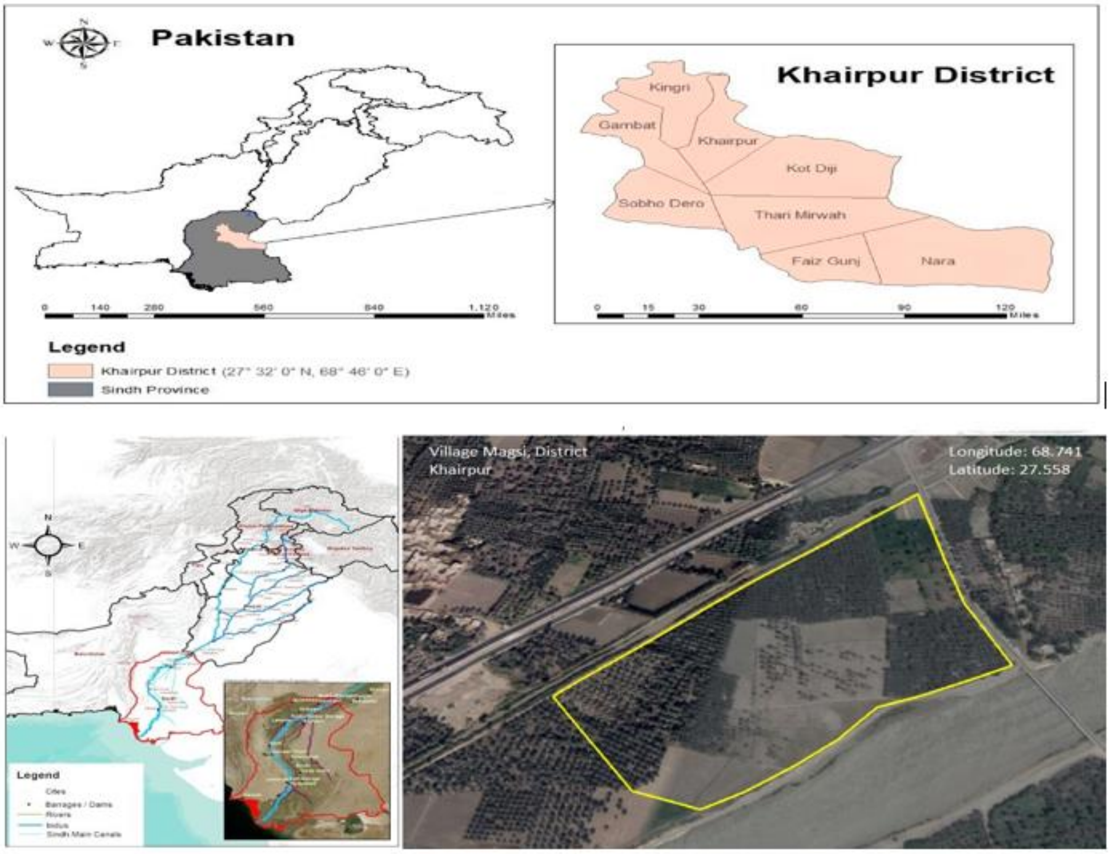

Figure 1. Map showing study area boundary (Village Magsi goth khairpur)

2.2. Data acquisition

For the last ten years, essential metrological data was gathered from Pakistan meteorological department (PMD). Relative humidity, wind speed, maximum temperature, and lowest temperature were all included in the data. PMD also provided crop coefficient for different growing phases of the wheat crop.

2.3. Satellite data

Correction were required. Landsat8 photos from different months (November to March) of 2021-2022 were acquired from the USGS website. The procedure for picture capture are illustrated in Figure 2 as a flow chart.

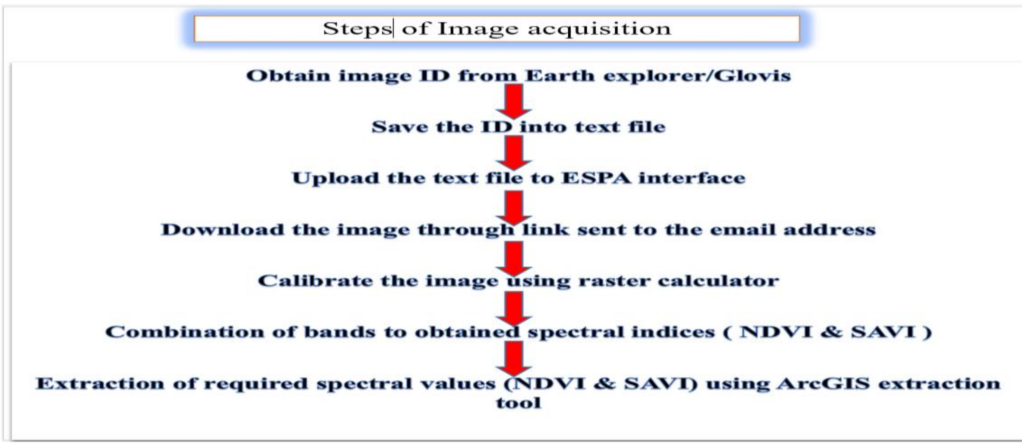

Figure 2. Flow chart showing steps of image downloading

2.4. Description of Indices

Two indices namely Normalized Difference Vegetation Index (NDVI), and Soil-Adjusted Vegetation Index (SAVI), were invoked and tested in this study.

2.5. Determination of Plant Height

With the use of a measuring tape and GPS device, the actual grid based plant height, as well as longitude and latitude, were recorded at 5m of intervals. The plant was branded with a permanent marker at the time of the initial recoding. Then just plant height data for the tagged plant was obtained.

2.6. Determination of Field data based Kc values

$$\mathbf{Kc\ stage(n)} = \mathbf{Kc\ stage\ (n)(tab)} + [\mathbf{0.04(u2-2)} - \mathbf{0.004(RH-45)}](\tfrac{\mathbf{h}}{\mathbf{3}})^{\mathbf{0.3}}) \quad (1)$$

The field-based Kc values for different growth stages of Wheat crop were determined using above equation:

Where,

$K_{cStage(n)\ (Tab)}$= crop coefficient values obtained from DRC for wheat crop

u_2 = the average wind speed [m/s].

RH_{min} = the usual minimum relative humidity [%]

h =the Plant elevation for each growth stage [m]

The average values of relative humidity and wind speed data was used. Kc values for different stages were obtained from PMD.

2.7. Assessment of relationship between vegetation indices and crop coefficients

To test the link between Kc values and spectral indices, the coefficient of regression equation were assessed

$$Kc = \alpha + \beta \times NDVI$$
$$Kc = \alpha + \beta \times SAVI$$

2.8. Validation

Following criteria were used to validate newly developed equation. When values of these two criteria are minimum it means tested models are good

Root Mean square error

$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (Oi - E_i)^2}$$

Where,

n = Total numbers (Observations)

Oi = Field based observed Kc value

Ei = Estimated Kc value

BIAS

$$\mathrm{BIAS} = \frac{\sum_{i=1}^{n}(E_i - Oi)}{\sum_{i=1}^{n} Oi}$$

Where,

n = Total numbers (Observations)

Oi = Field base observed Kc value

Ei = Estimated Kc value

3. Results and Discussion

The pertinent data obtained and collected for assessing spectral indices are present in Table 1. The plant height ranged from 30 to 86 cm. The Kc values obtained from DRC varied from 0.33 to 1.15 for different growth stages. The calculated/actual Kc values ranged from 0.348 to 1.146. The maximum values for temperature, relative humidity, wind speed, and sun shine hours were in the order of 33.12 °C**,** 43.96%, 1.364 m/s and 9 hours for different growing stage

Table 1. Average values of crop coefficients, plant height and pertinent climatic data

Kc (Table)	Plant Height (cm)	Temp (min ℃)	Temp (max ℃)	RH (%)	Wind speed m/s	Sun Shine (hr.)	Kc (Cal)	Stages
0.7	30	18.98	30.63	37.73	0.718	8	0.688	Initial
0.7	33.5	14.54	25.36	41.15	0.701	9	0.681	Initial
1.15	66	12.23	23.42	43.96	1.054	9	1.128	Mid
1.15	73	13.25	23.97	38.06	1.185	8	1.146	Mid
0.33	86	19.21	33.12	31.95	1.364	9	0.348	Final

3.1. Evaluation of connection between NDVI and single yield coefficient.

The result regarding relationship of NDVI and single crop coefficients are portrayed in and table-2. The Developed relation is presented as chart-1 for three growing stages namely; Initial stage, mid stage and late stage.

Table.2: Relation between single crop coefficient (Kc) with NDVI

Initial Stage	Middle Stage	Late Stage
$R^2 = 0.85$	$R^2 = 0.94$	$R^2 = 0.92$

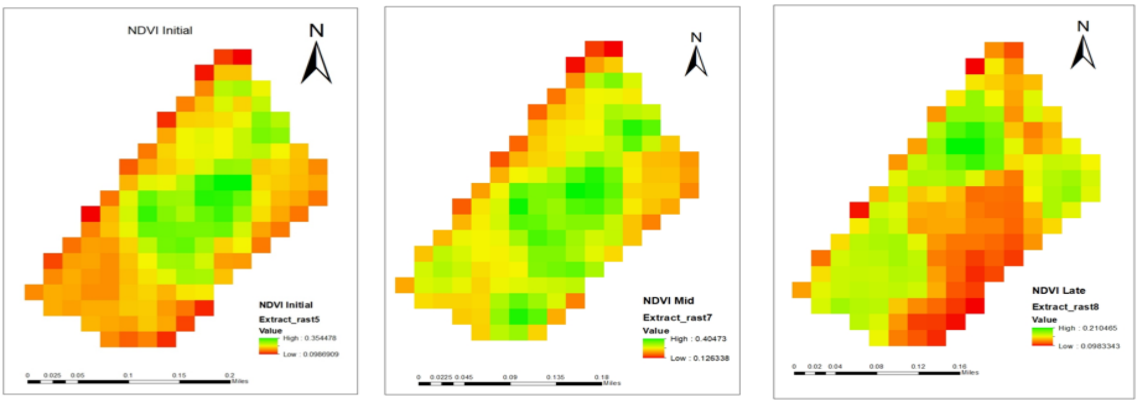

Figure 3. NDVI maps of Wheat crop during growth stages namely initial mid and Late

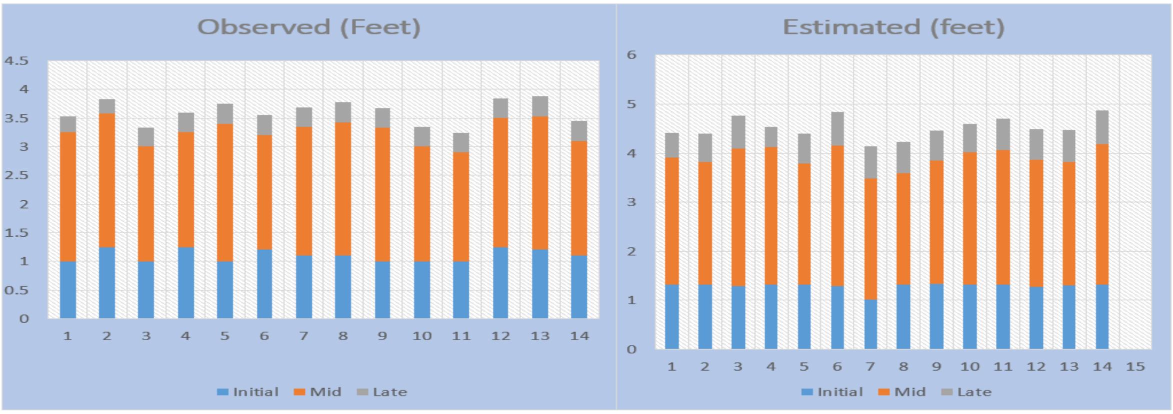

Figure 4. Statically criteria for evaluation relationship of NDVI Chart-1

There is a substantial association between NDVI and single crop coefficient, as evidenced by the R^2=0.92 value, indication that NDVI is responsible for 92 % of the variance in kc values across stages.

It can be shown that the constructed equation performed well when compared to benchmark values, with decreased bias 11% and inaccuracy 0.0083.

3.2. Evaluation of connection among SAVI-1 and single yield coefficient.

The result regarding relationship of SAVI and single crop coefficients are portrayed in and table-3. The Developed relationis presented as chart-2 for three growing stages namely; Initial stage, mid stage and late stage.

Table 3. Relation between single crop coefficient (Kc) with SAVI-1

Initial Stage	Middle Stage	Late Stage
$R^2 = 0.79$	$R^2 = 0.75$	$R^2 = 0.77$

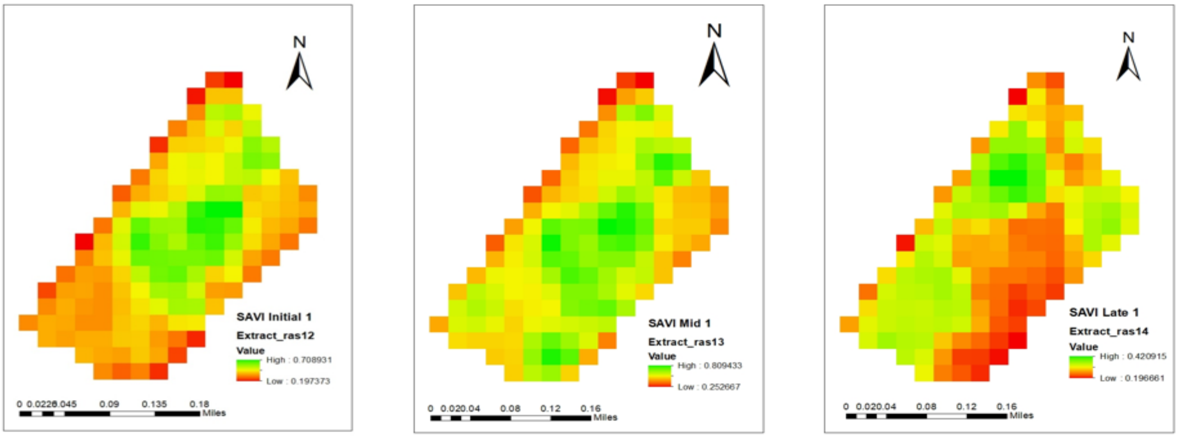

Figure 5. SAV-1 maps of Wheat crop during growth stages namely initial mid and Late

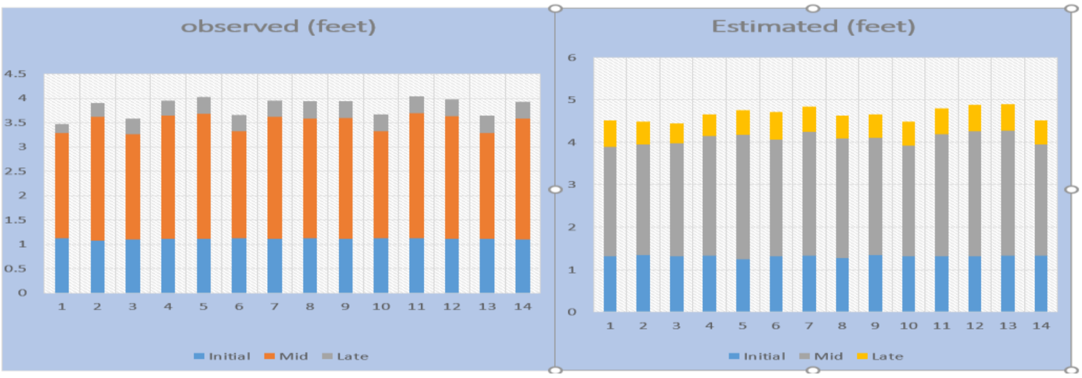

Figure 6. Statically criteria for evaluation relationship of SAVI-1 Chart-2

A substantial association between SAVI-1 and the single crop coefficient, indicated by the R^2=0.79 value Obliquely at table-3, and chart-2 show that equations provided good predictions when compared to bench marks values,with less bias 10% and error 0.009.

3.3. Evaluation of connection among SAVI-0.5 and single yield coefficient

The result regarding relationship of SAVI and single crop coefficients are portrayed in and table-4. The Developed relations presented as chart-3 for three growing stages namely; initial stage, mid stage and late stage.

Table 4. Relation between single crop coefficient (Kc) with SAVI-0.5

Initial Stage	Middle Stage	Late Stage
$R^2 = 0.83$	$R^2 = 0.81$	$R^2 = 0.78$

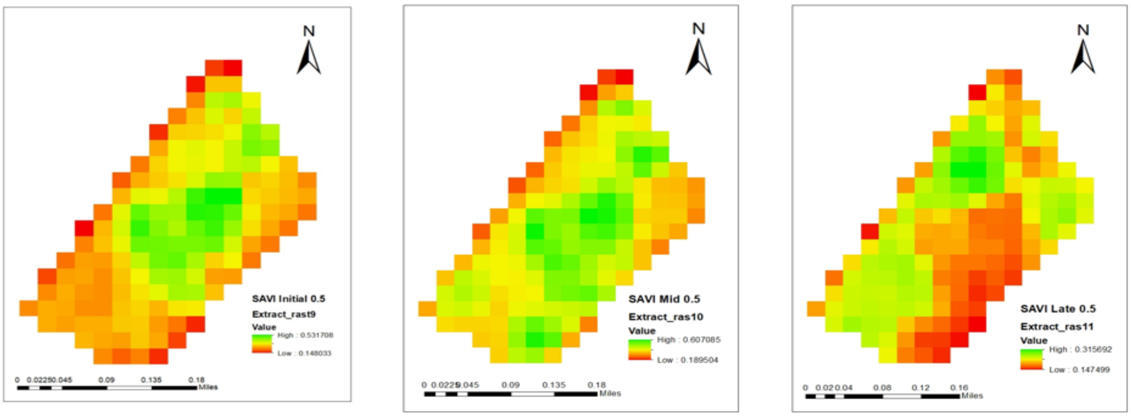

Figure 7. SAVI-0.5 maps of Wheat crop during growth stages namely initial mid and Late

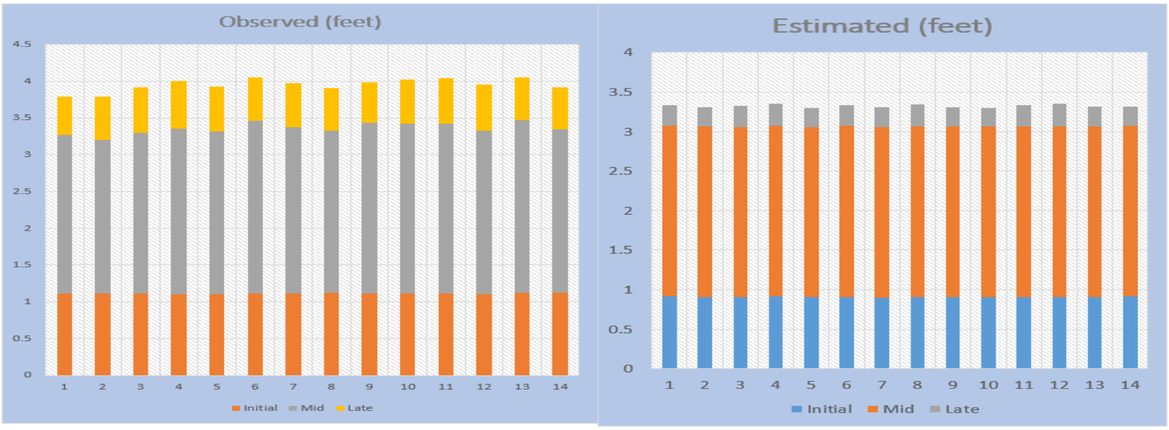

Figure 8. Statically criteria for evaluation relationship of SAVI-0.5 Chart-3

The R2=0.83 result indicates that there is a strong association between SAVI-0.5 and single crop coefficient, shows that the recognized equations performed well in comparison to then bench mark values, less bias 10.5% error 0.0019.

3.4. Assessment of integrated usage of spectral indices for estimating crop coefficient

The relevant result of relationship between various spectral indices NDVI and SAVI-1) and single crop coefficients. The developed relation is reachable as Table.5 for three growing stages namely; Initial stage, mid stag and late stage

Table 5. Relation between single crop coefficient (Kc) with NDVI& SAVI-1

Initial Stage	Middle Stage	Late Stage
$R^2 = 0.82$	$R^2 = 0.89$	$R^2 = 0.87$

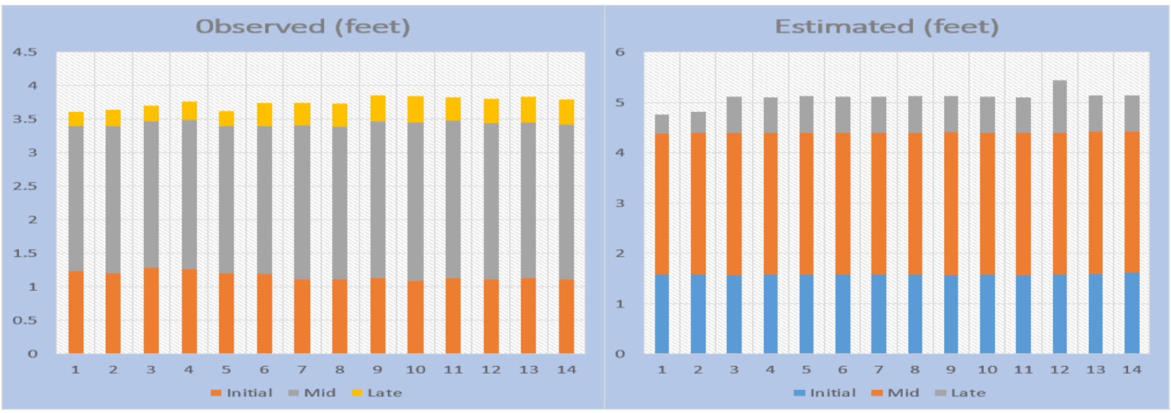

Figure 8. Statically criteria for evaluation relationship of NDVI & SAVI-1 with crop Coefficient chart-4

It is clear that there is a strong relationship between NDVI,SAVI-1 and single crop coefficient, as evidenced by R^2=89 value show that the recognized equation performed well in comparison to the benchmark values with decreased bias 10% and error 0.205.

3.5. Assessment of integrated usage of spectral indices for estimating crop coefficient

The relevant result of relationship between various spectral indices NDVI and SAVI-0.5 and single crop coefficients. The developed relation is reachable as Table.6 for three growing stages namely; Initial stage, mid stag and late stage

Table 6. Relation between single crop coefficient (Kc) and NDVI & SAVI-0.5

Initial Stage	Middle Stage	Late Stage
R^2 = 0.90	R^2 = 0.92	R^2 = 0.94

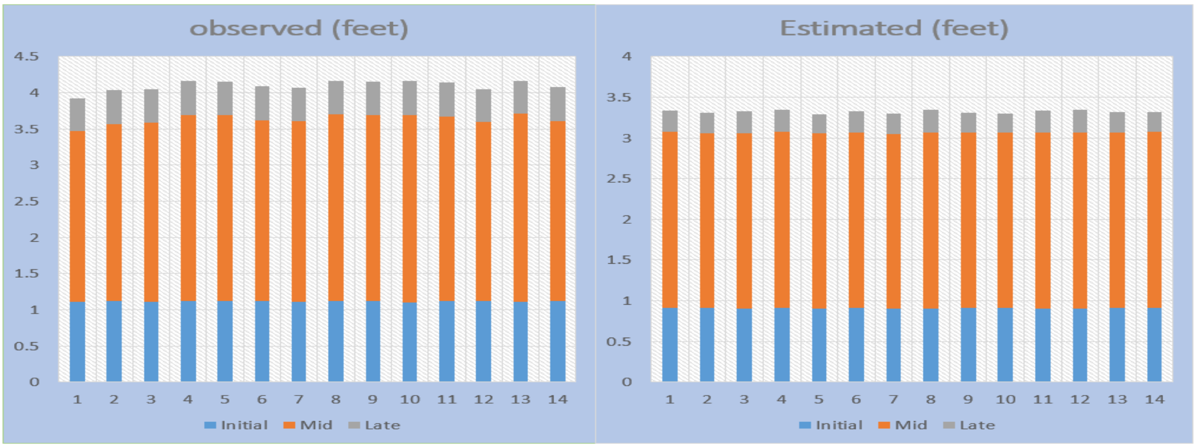

Figure 9. Statically criteria for evaluation relationship of NDVI and SAVI-0.5 with crop Coefficient chart-5

Show that there is astrong association between NDVI and SAVI-0.5 and single crop coefficient, as evidenced by R^2=94 value. It show that the recognized equation performed well against bench values, with decreased bias 12% and error 0.71.

4. Conclusion

This study demonstrated that remotely sensed data can be used to estimate crop coefficients. The method of finding the crop coefficient (Kc) based on (NDVI) and (SAVI) is an effective approach to do so. It is a simple compared to other methods for determining (Kc), such as field methods or relying on FAO publications It is concluded that the kc values and individual spectral index have a strong link. Based on the finding, it can be concluded that the variation in kc values is batter explained by the combined use of spectral indices than by the separate application of spectral indices For wheat crop, the association between NDVI and Kc values is shown to be more significant than the relationship between NDVI and SAVI.

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