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Estimating of Wheat Water Requirement Using Remote Sensing at El-Menia Governorate Desert Fringe-Egypt

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ABSTRACT

In hyper-arid and arid zones, the crop water requirement management is considered the vital component for sustaining the crop production particularly under drought condition. As such, further investigation is needed to determine optimal water requirements to avoid wasting water in zones already facing water shortages.Further, estimating reference Evapotranspiration(ET_0)and Crop Coefficient(K_c)is fundamental requirement of agricultural water management. Thus, the aim of this study is determining an actual crop coefficient(K_c)for winter wheat using remote sensing tools [Normalized Difference Vegetation Index(NDVI)and Soil-Adjusted Vegetation Index(SAVI)] - obtained from Sentinel-2A satellite images, as well as the influence of Accumulated Growing Degree Days(AGDD)for wheat on NDVI and SAVI. Consequently,data were obtained during winter wheat season(November 2019 - April 2020)on El-Menia Governorate Desert Fringe.Data analysis indicated that the total amount of AGDD required to obtain was 1408.37 C°/season for wheat to develop in its life cycle. Moreover, SAVI value recorded the highest value(0.77)in January when the NDVI obtained 0.53 at the same period. Values of NDVI increased dynamically and acquired was 0.53 which was the highest value after wheat obtained 863.79 C°/days(heat unit)in January. Furthermore, there is a linear relation between NDVI and actual K_c which reflect a strong correlation between them for all of the growing stage. Finally, the actual water requirement was 2532.68 m3/fed/season, which is a less than value (2791 m^3/fed/season)calculated FAO method. Actual crop coefficients[K_c (actual)]estimated from remote sensing(RS)using NDVI, SAVI with the AGDD equation is beneficial for irrigation scheduling, evaluation of irrigation, water use efficiency and project performance and agricultural water budgets.

***Keywords**:* AGDD; NDVI; SAVI; RS; K_c; Wheat Water Requirement

INTRODUCTION

Agriculture as a major field consumes a great amount of irrigation water. The hyper-arid and arid regions face a challenge to overcome the limited water resources and security of water. Thus, estimating an accurate crop water requirement is the main target for saving water and sustaining agriculture. Crop irrigation water requirements rely on consumptive use or demand which can be analysed using different methods, i.e., calculating crop water requirements (CWR) or water balance analysis and field monitoring (Allen *et al.*, 1998). In addition, water requirements are a component of water balance that equates to crop Evapotranspiration (ET_c).

Evapotranspiration (ET) is the evaporation of soil plus plant transpiration, which is the primary process of transferring water in the hydrological cycle (Dingman, 2002). Accordingly, the CWR is calculated by multiplying the reference evapotranspiration (ET_0) to the crop coefficient (K_c) (Allen *et al.*, 1998), where ET_0 indicates that the effects of climatic conditions on the CWR and K_c are related to the vapour pressure gradient between the surrounding atmosphere and plant leaf stomata. On the other hand, CWR vary in different locations and time due to different climatic conditions and water managers or farmers who need a comprehensive spatial and temporal perception of its diversity. Due to this variation, a new approach has to be developed and used as the remote sensing techniques.

Consequently, efforts have aimed to overcome the meteorological station's shortcomings. Thus, a number of valuable methods used the remote sensing data for estimating ET (Maeda *et al.*, 2011). Currently, remote sensing data offers a tool capable of finding actual crop Evapotranspiration (ET_c) by saving time and costs (Schmugge *et al.*, 2002). In addition, remote sensing uses the values of ground surface temperature, albedo, and infrared band values to estimate the spatial variations of long and short wave radiations that result in the calculation of ET for each pixel of the images (FAO, 1995). Potential use of remote sensing is for daily farm management decisions for instance; (a) timeliness, (b) frequency, especially for important paramount agricultural practicability (Jackson, 1984). Moreover, the benefits of these methodologies in relation to most classical information sources (field measurements or general knowledge) are that they can cover large areas, allowing for high spatial accuracy and / or integrative sampling over different areas (Allen *et al.*, 2011).

According to Ray and Dadhwal (2001), K_c values can be estimated directly from remote sensing using empirical relationships with remotely sensed vegetation indices (NDVI and SAVI). Analytical approaches rely on relationships between vegetation spectral reflectance and

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certain parameters such as leaf area, albedo, and canopy surface roughness. The K_c is derived from the ratio between actual crop ET_c, estimated through remotely sensed surface energy balance models, and ET_0 (Tasumi and Allen, 2007). With regard to the estimation of ET, Bastiaanssen *et al.* (1998), in their study in different Asian and Europian countries, indicated that the results that have been derived from SEBAL algorithm and remote sensing, about 85% of the cases, were compatible with those taken from field metrological records without any calibration. Bala *et al.* (2016) used Landsat7 in India to obtain the daily ET and compared these results with Lysimetric measurements. The results had RMSE= 0.51 mm/day and MAE (Mean Absolute Error) = 0.19. According to antecedent studies, the Landsat image results are more adequate than some other satellite results; So that Simaie *et al.* (2013) indicated that the ET crop obtained from Landsat is more accurate than MODIS images with 2.5 times.

The temperature is another critical parameter for climate and effect on the potential productivity level of winter crops (Kalra *et al.,* 2008). For most plants, the phonological development from sowing to ripening is related to temperature and the daily accumulation of heat units. The amounts of required heat units to shift the plant to the next growing stage remain yearly constant. However, the actual time period (days) may vary greatly from year to year due to change in weather conditions. For instance, the minimum daily temperature for winter wheat to achieve measurable growth is around 5 ° C. The average daily temperature for optimum growth ranges between 15 and 20 ° C (Doorenbos and Kassam, 1979). In general, wheat production needs to be strengthened by all parameters of the agricultural system such as climate and water resources management to obtain the optimum value.

Noteworthy to mention that, the relation among factors of the agricultural system, especially temperature, irrigation water requirement, and environmental elements, should be controlled to achieve a positive result. Thus, this study aims at estimating the actual water requirement for winter wheat using remote sensing. Consequently, the relation between AGDD for wheat with NDVI and SAVI at El-Menia Governorate Desert Fringe, could be realized.

MATERIALS AND METHODS

The present research is carried out at farm in West El-Menia Governorate's Desert Fringe (28.417 N. – 29.993 E.). This site that has been established in November (2019), falls within the hyper-arid climatic region. Data in table (1) display the average climate characteristics and reference evapotranspiration (ET_0), recorded by the local meteorological station. ET_0 has been calculated according to Penman-Monteith, equation No. (1). These variables were described by Allen *et al.* (1998).

$$\mathbf{ETo} = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \qquad (1)$$

Where:

ET_o = Reference Evapotranspiration (mmd^{-1}),
Δ = Slope vapour pressure curve (kPa°C^{-1}),
Rn = Net radiation at the crop surface (MJ/m^2/d),
G = Soil heat flux density (MJ/m^2/d),
T = Air temperature at 2 m height (°C),
e_s = Saturation vapour pressure (kPa),
e_a = Actual vapour pressure (kPa),
e_s _ e_a = Saturation vapour pressure deficit (kPa),
U_2 =Wind speed at 2 m height (ms^{-1}), and
γ =Psychometric constant (kPa°C^{-1}).

Table 1. Climate characteristic at West El Mania Governorate (2019-2020).

Month	P	T_{max}	T_{min}	Rh	SS	U_2	ET_0
	mm/m	°C	°C	%	h	m/s	mm/d
Nov 2019	0	23.76	15.12	45.157	10.7	2.5	4.02
Dec 2019	25.89	17.21	9.74	62.27	10.3	3.4	3.83
Jan 2020	3.47	14.74	6.87	62.38	10.5	3.06	2.59
Feb 2020	57.12	17.34	9.0	59.8	11.2	3.2	3.28
March 2020	5.9	21.8	11.0	51.5	12	4.14	5.02
April 2020	0.07	27.8	12.2	41.13	12.8	4.31	7.44

P = Precipitation; $T_{min/max}$ = minimum/maximum Temperature; Rh = Relative humidity; SS = Sunshine as percentage of day length; U_2 = wind speed at 2m; ET_o= Reference Evapotranspiration

The soil of the study site is sandy textured, moderately saline 6.69 dS/m, soil depth more than 80 cm, and slightly calcareous. Content of silt and clay is quite low (4.85% and 2.05%, respectively), thus, the field capacity (5.1%) and available water (4.2%) are very low. The pH, electrical conductivity and ion composition were analysed in water samples by standard analytical methods for APHA *et al.* (1992). Table (2) shows the average values of the analyzed parameters in irrigation water.

Table 2. Some chemical parameters of irrigation water.

pH	EC (dS/m)	Soluble Cations (meq/L)				Soluble Anions (meq/L)			
		Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	CO_3^{-2}	HCO^{-3}	Cl^{-1}	SO_4^{-2}
7	3.7	7.8	12.6	15.5	1.8	0	3.4	27	7.3

The crop water requirement, calculated according to Allen *et al.,* (1998) is showed in equation (2). The data of K_c are illustrated in table (3).

$$\mathbf{ET_c = ET_o \times K_c} \qquad (2)$$

Where:

ET_c : Crop Evapotranspiration (mmday^{-1})
ET_o : Reference Evapotranspiration (mmday^{-1})
K_c : Crop coefficients

Table 3. The average crop coefficients (K_c) for winter wheat.

Item	Init.	Dev.	Mid.	Late.	Total.
Days	20	60	70	30	180
K_c	0.7	0.9	1.15	0.4	

Init = initial; Dev. =crop development; Mid. = mid-season; Late = late season; K_c = Crop coefficients

Crop coefficient varies according to growth stage and is also influenced by the growth stage length. The tabulated values were modified to actual values of crop coefficient using equation (3).

$$Kc_{(actual)} = Kc_{(Table)} + [0.04(u_2 - 2) - 0.004(RH_{min} - 45)]\left(\frac{h}{3}\right)^{0.3} \quad (3)$$

Where:

$Kc_{(Table)}$ = Standard crop coefficient values (Allen *et al.*, 1998)
u_2 = Value for daily wind speed at 2 m(m/s),
RH_{min} = Value for daily minimum relative humidity (%), and
h = Plant height for each growth stage (m)

Growing Degree-Days (heat units) (GDD)

Growing Degree Days (GDD) or heat units was calculated using the single sine curve method during growing season of wheat crop (Baskerville and Emin, 1969). That simple linear method requires only daily minimum and maximum air temperatures, which are recorded by the local weather station at the study site. Equation (4) gives explanation to calculate GDD:

$$GDD = [(T_{max} + T_{min}) / 2] - T_{base} \quad (4)$$

Where:

T_{max} = Daily maximum temperature (°C).
T_{min} = Daily minimum temperature (°C).
T_{base} = Base temperature (°C).

Heat units are used often for predicting the phonological development rates of plant species. Developmental rate increases approximately linearly as a function of air temperature (Snyder *et al.*, 1999), therefore the high or low temperature will affect on crop by conditioning of the plant growth and overall yield. So, the lower temperature (T_{base}), for wheat was set at 5 °C (Ash and Raddatz, 1993; Bishnoi, *et al.*, 1995).

Satellite images

The Sentinel-2A satellite images, Multispectral Imager (MSI), Band 8 and 4 with 10m spatial resolution covering the study area and taken on different dates from 03/11/2019 to 01/04/2020, were obtained from the European Space Agency's Sentinel Scientific Data Hub (ESA, 2020). The satellite images were used to calculate NDVI and SAVI. NDVI uses Near-Infrared (NIR) and red wavelengths, where chlorophyll reflects more NIR and green light refer to healthy and dense vegetation. The NDVI was computed by the following equation (5), Tucker (1980);

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (5)$$

Where:

NIR = Reflectance in the near infrared band,
RED = Reflectance in the red band

SAVI was calculated according to the equation (6). Huete (1988) stated that SAVI is the best index for describing vegetation cover in arid zone, knowing the sparse distribution of vegetation among bared soil patches.

$$SAVI = \left(\frac{NIR - RED}{NIR + RED + L}\right)(1 + L) \quad (6)$$

Where:-

NIR = Reflectance in the near infrared band,
RED = Reflectance in the red band,
L = Adjusted factor equal to 0.5.

Both ArcGIS v.10.5 (ESRI, 2017) and ERDAS Imagine v.16.5 (ERDAS Inc., 2018) software were used for analysing, processing, calculating and measuring the values of each vegetation index.

Statistical model

The following equation (7) describe the simple regression models with predictor variables $X_1; \ldots ; Xp$.

$$Y = B_0 + B_1X_1 + \ldots + B_pX_p + k \quad (7)$$

Where:

Y = Responsive or dependent variable,
$X_{(1..p)}$ = Independent or predictor variable,
B_0 = Intercept,
B_{1-P} = Slope parameters,
k = Constant for all values of the repressor as the variability of the error.

RESULTS AND DISCUSSION

A) Values and Distribution of Vegetation Indices (NDVI and SAVI)

Figure (1) clears up that the values and distribution of both NDVI and SAVI show similar trends wherein values increased during the middle stage of growth in comparing with both the first and late season growth. Results also indicated that SAVI recorded the highest value of 0.77 in January, when the NDVI was 0.53 in the same period. On the other hand, in the late season, in particular, the values decreased in April to be 0.31 for NDVI and 0.46 for SAVI. These results can be rendered to the fact that both indices (NDVI and SAVI) reflect especially crop growth characteristics, as interpreted by Kamble and Irmak (2008). Doorenbos and Pruitt (1975) indicated that canopy's dynamics, and roughness, crop physiology, affect turbulence, surface wetness and leaf age.

B) AGDD in relation to vegetation indices (NDVI and SAVI)

Table (4) illustrates the mean 10 days monthly, real and adjusted temperature, growing degree days (GDD) and accumulated growing degree days (AGDD) during wheat growing season. It is evident that as for wheat cultivated on 1st Nov., the required total heat unit's amount was 1408.37 C°/ season. As shown in figure (2) the accumulated growing degree days (AGDD) has an influence on NDVI, meaning that the values of NDVI increased dynamically and acquired 0.53 which was a highest value after wheat obtained 863.79 C °/ days (heat unit) in January. However, the values of NDVI decreased and recorded 0.31 in March (late season) after the (AGDD) obtained 1408.375 heat units. Notable, that the NDVI needs 144.7 heat units to increase 0.1 during developing and mid stage for wheat. Whereupon, the NDVI was used extensively for monitoring vegetation, assessing crop yield and detecting drought (Sellers, 1985). A higher NDVI indicates a higher level of photosynthetic activity (Tucker, 1979).

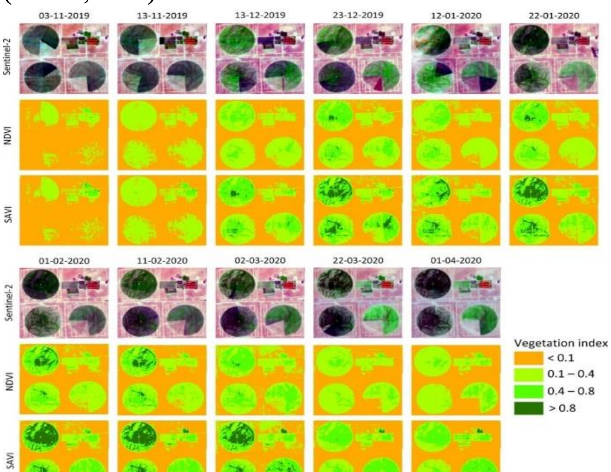

Fig. 1. Images of NDVI and SAVI for wheat growth stages

Table 4. Mean 10 days monthly, temperature, GDD and AGDD for wheat growth stages.

	Cultivate date 1st Nov.				
	Date	T_{max}	T_{min}	GDD	AGDD
2019-2020	D	°C	°C	°C	°C day^{-1}
	1-10	28.9	14.9	169.1	169.1
Nov	11-20	27.9	14.5	161.7	330.84
	21-30	25.4	11.2	133.22	464.06
	1-10	22.0	10.4	112.05	576.12
Dec	11-20	20.1	7.8	89.61	665.73
	21-30	18.7	6.6	76.53	742.26
	31-9	15.6	4.1	48.63	790.89
Jan	10-19	18.1	6.4	72.89	863.79
	20-29	17.7	4.5	61.23	925.02
	30-8	19.1	5.6	73.59	998.61
Feb	9-18	20.0	6.6	83.36	1081.98
	19-28	20.0	7.7	88.28	1170.26
	29-9	23.3	8.1	107.19	1277.45
Mar.	10-19	22.6	9.2	108.8	1386.25
	20-22	19.8	4.9	22.125	1408.375

Nevertheless, in late season, NDVI needs 291.575 heat unit to decrease 0.1. Concerning, the correlation between NDVI and AGDD, there exist a significant exponential relation that can be summarizing by equation (8).

$$NDVI = [(-4)*(10)^{-7}*(AGDD)^2] + [(0.0008)*(AGDD)] + 0.1203 \quad (8)$$

Where:

NDVI : Normalized Difference Vegetation Index.
AGDD : Accumulative of growing degree-days (°C day^{-1}).

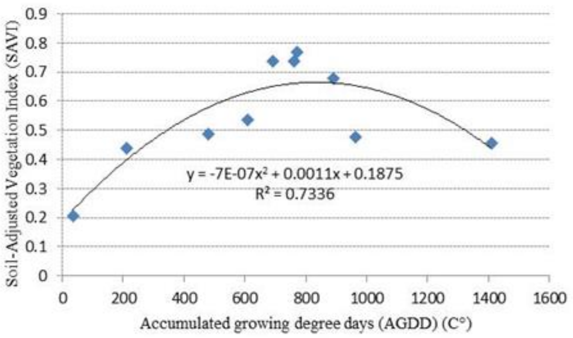

Fig. 2. Relation between NDVI and AGDD for wheat.

Furthermore, data reflect a high response between the AGDD and SAVI, Fig. (3), where the highest SAVI value (0.77) was found associated with 863.79 C°/days, heat unit in the middle season. On the other side, in the late season, the SAVI value was 0.46 after AGDD had recorded 1408.375 C°/days, heat units. It is worthy to state that, in the early stage (from (November to January), 0.1 of SAVI value need 99.6 heat units to be received. However, in the late season (February to April), SAVI needed 206.92 heat units to decrease 0.1. The flowing equation (9) represents the relation between AGDD and SAVI.

$$SAVI = [(-7)*(10)^{-7}*(AGDD)^2] + [(0.0011)*(AGDD)] + 0.1875 \quad (9)$$

Where:

SAVI : Soil-Adjusted Vegetation Index.
AGDD : Accumulative of growing degree-days (°C day^{-1})

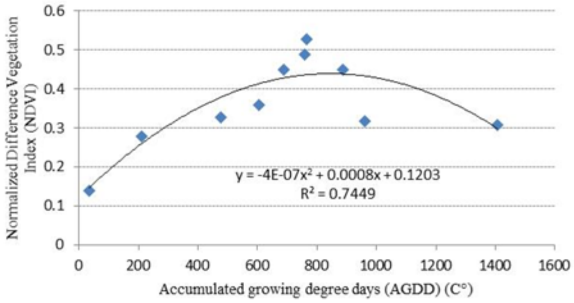

Fig. 3. Relation between SAVI and AGDD for wheat.

C) Crop coefficient (K_c) in relation to vegetation indices (NDVI and SAVI)

Crop coefficient is influenced by climate, soil type, crop growth stage, albedo, crop height, stomata and leaf (Allen *et al.*, 1998). Rationally, during the crop growth stages, the ratio of transpiration to evapotranspiration increases, meaning that most of the evapotranspiration due to the transpiration. This occurs because the interception of radiant energy by the foliage increases until most light is intercepted before it reaches the soil. Hence, using NDVI and SAVI help to develop the model to estimate the crop coefficient from technique of remote sensing. Figure (4) illustrates the linear relation between NDVI and actual K_c which reflects a strong correlation between NDVI and actual crop coefficient for all the growing stages which can be represented in the following model equation (10).

$$K_{c\ (actual)} = (1.2571 * NDVI) + 0.4577 \quad (10)$$

Where:

$K_{c\ (actual)}$: Actual wheat Crop coefficient.
NDVI : Normalized Difference Vegetation Index.

Otherwise, 0.4577 & 1.2571 represent the intercept coefficients and slope, respectively. The correlation coefficient (r^2) is 0.6719, which reflect that NDVI can be used to explain the $K_{c\ (actual)}$ data set. Thus, determine the actual crop water requirement (ET_c) by multiple actual crop coefficients $K_{c\ (actual)}$ with reference evapotranspiration (ET_o). On the other hand, during mid- season, variations of NDVI and $K_{c\ (actual)}$ were larger. This could be attributed to the difference in ET_o, which increases evapotranspiration rates during crop development and senescence, and also, the frequent irrigation condition in irrigated area makes soils more evaporative.

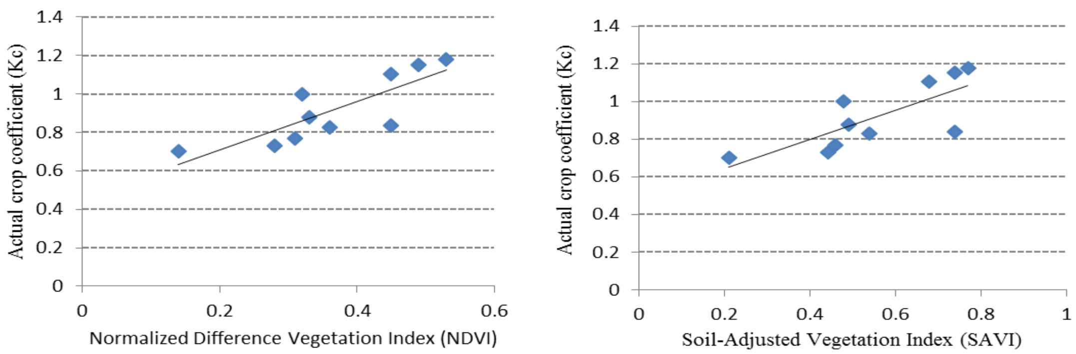

Fig. 4. Actual wheat crop coefficient (K_c) in relation to vegetation indices (NDVI and SAVI)

On the other hand, the Soil-Adjusted Vegetation Index (SAVI) values have a significant relation with actual crop coefficient, comparing with NDVI. This could be that the values of SAVI reflect the leaf area index (LAI) for wheat. Where, Allen *et al.* (2002 and 2014) computed the LAI using SAVI by the following equation.

$$\mathbf{LAI = 11 \times (SAVI)^3, \text{ when } SAVI \leq 0.817}$$
$$\mathbf{LAI = 6, \text{ when } SAVI > 0.817}$$

Thus, using strong correlation between SAVI and actual crop coefficient could be a more accurate to predict an Actual crop coefficient for wheat.

$$\mathbf{K_{c\,(actual)} = (0.7684 * SAVI) + 0.4911} \quad \mathbf{(11)}$$

Where:

$K_{c\,(actual)}$: Actual wheat Crop coefficient.
SAVI : Soil-Adjusted Vegetation Index.

D) Statistical model

Occasionally, a model is a schematic representation of a system concept, an imitation act or a set of equations, which represent the behaviour of the system (Murthy, 2003). More else, water requirement and irrigation management are very effective tools for predicting crop growth and yield. Determining a crop coefficient model is helpful to solve various practical problems especially for amount of water. Thus, the subsequent regression equation (12) is a model which use some parameters(NDVI, SAVI and AGDD) to determine an actual crop coefficient to help in predicting an actual crop water requirement and total water applied for wheat under El Menia governorate soils.

$$\mathbf{K_{c(actual)} = 0.4723 + (5.66 * NDVI) - (2.89 * SAVI) - (3.205 \times 10^{-5} * AGDD)} \quad \mathbf{(12)}$$

Where;

$K_{c\,(actual)}$: Actual wheat Crop coefficient.
NDVI : Normalized Difference Vegetation Index.
SAVI : Soil-Adjusted Vegetation Index.
AGDD : Accumulative of growing degree-days (°C day^{-1})

Finally, an actual water requirement was 2532.68 m^3/fed/season which is a low value comparing with calculated water requirement value (2791 m^3/fed/season) using Allen *et al.* (1998) method.

CONCLUSION

The present study indicates the significance of the integration of both remote sensing and GIS approach in estimating the crop water requirement and the irrigation water demands. It is patently designed the good relation between NDVI and SAVI from one side and AGDD from the other side. Thereon, the values of NDVI increased dynamically and acquired the highest value (0.53) after wheat had obtained 863.79 C°/ days (heat unit) in January. Noteworthy to mention that, from November to January each 0.1 of SAVI value can be realized in response to receiving 99.6 C°/ days (heat units). On the other side, in the late season of wheat (from (February to April), the SAVI value needs 206.92 heat units to decreased 0.1. Noteworthy to state that while both indices (NDVI and SAVI) are determiner to the crop at each pixel. K_c is the direct representation of actual crop growth conditions. Results show clearly that K_c disparity is well clarified by dissimilarity in each of the NDVI, SAVI and AGDD. Verification of a simple regression model that given an R^2 of 0.81 is as follows;

$$\mathbf{K_{c\,(actual)} = 0.4723 + (5.66 * NDVI) - (2.89 * SAVI) - (3.205 \times 10^{-5} * AGDD)}$$

Accordingly, the actual crop coefficient ($K_{c(actual)}$) obtained from remote sensing using NDVI and SAVI with AGDD equation may be helpful in scheduling irrigation, evaluating its performance, and estimating water use efficiency.

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تقدير الإحتياجات المائية للقمح بإستخدام الإستشعار عن بعد بالظهير الصحراوي لمحافظة المنيا ـ مصر.

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تعتبر إدارة الإحتياجات المائية للمحاصيل من العناصر الحيوية لإستدامة إنتاجية الأراضى خاصة في المناطق القاحلة و المتأثرة بظروف الجفاف. وعلي هذا النحو فان هناك إحتياج لمزيد من البحوث والدراسات التي تهدف الي تحديد الإحتياجات المائية المثلي والفعلية لتجنب إهدار المياه في المناطق التي تواجة بالفعل نقصاً في المياه. هذا بالإضافة إلي أن تحديد البخر النتح المرجعي (ET_o) و معامل المحصول (K_c) يعتبر من الركائز الرئيسية لعملية إدارة المياه الحقلية. ومن هذا المنطلق يهدف هذا البحث الي دراسة وتحديد معامل المحصول الفعلي للقمح بإستخدام أدوات الإستشعارعن بعد وهي دليل التباين الطبيعى للغطاء الخضرى (NDVI) والدليل المعدل للغطاء الخضرى والتربة (SAVI) بإستخدام صورة القمر الصناعي (Sentinel-2A) وتأثرهما بالوحدات الحرارية المتراكمة (AGDD) لمحصول القمح. ولتحقيق ذلك فقد تم الحصول على البيانات الخاصة لمحصول القمح المنزرع فى الموسم الشتوي (نوفمبر ٢٠١٩ – ابريل ٢٠٢٠) بمنطقة الظهير الصحراوي لمحافظة المنيا ومعالجة وتحليل تلك البيانات باستخدام برامج نظم المعلومات الجغرافية والبرامج الأحصائية . وبتحليل البيانات تبين أن إجمالي الاحتياجات الحرارية لمحصول القمح خلال الموسم الشتوي هي ١٤٠٨,٣٧ وحدة حرارية. بالإضافة الي تسجيل أعلي قيمة لدليلى الغطاء الخضرى المستخدمين (SAVI) و(NDVI) لتصبح (٠,٧٧) و (٠,٥٣) علي الترتيب خلال شهر يناير. وقد سجل دليل NDVI الزيادة الديناميكية لتصل الي ٠,٥٣ بعد أن تعرض محصول القمح لـ ٨٦٣,٧٩ وحدة حرارية . كما بينت النتائج إلى وجود علاقة خطية بين دليل التباين الطبيعى للغطاء الخضرى (NDVI) و معامل المحصول الفعلي (K_c) والذي يعكس قوة الارتباط بينهما خلال مراحل و فترات النمو المختلفة. و أخيرا وبتقدير الأحتياج المائي الفعلي لمحصول القمح خلال الموسم الشتوي فقد وجد أن قيمتة هو ٢٥٣٢,٦٨ مترمكعب للفدان و هو أقل من القيمة المحسوبة بإستخدام طرق منظمة الاغذية و الزراعة (FAO) و الذي قدر بنحو ٢٧٩١ مترمكعب للفدان. كما يمكن إستخدام العلاقة الرياضية المتحصل عليها لحساب معامل المحصول الفعلي لنبات القمح وبإستخدام المدخلات و العوامل (NDVI, SAVI, AGDD) وبالتالي تقدير الإحتياجات المائية والاروائية الفعلية التي تؤدي الي دقة في جدولة مياه الري و سهولة تقييم ومراقبة كفاءة مشاريع الزراعة المروية وإدارتها.