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The influence of vegetation on evapotranspirationin Al -Musayab, Bābil, Iraq.

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ABSTRACT

Temperature affects the path of many important processes such as plant growth and evaporation. The two separate processes through which soil and plant water is lost are referred to as evapotranspiration (ET). Both evaporation and transpiration occur together and there is no method to isolate them. The objective of this study is to investigate the effect of the vegetation cover in the surface heat and evapotranspiration, and to obtain thermal maps and evapotranspiration maps for the Musayab project area in the city of Babil in Iraqusing the SEBAL and the Landsat-7 satellite images. After the SEBAL was calibrated and applied, heat maps and evapotranspiration maps were obtained for the months of the study17/02/2016, 24/06/2016, 28/09/2016,17/11/2016. The results showed an inverse relationship between surface temperature and NDVI values. There was a positive correlation between net radiation flux and NDVI values. An inverse correlation between soil temperature flux values and NDVI values was associated. There was a positive correlation between the calculated heat flux values and the NDVI values. There was an inverse relationship between ET values and NDVI values.

Keywords: SEBAL, evapotranspiration, surface temperature, Musayab project

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INTRODUCTION

The understanding of natural cycles in the Eco system such as the energy and water cycle and the interplay of system components and human events, particularly those related to climate change, has been identified in many studies and researches as an important research trend (2). Heat is one of the energy forms that can't be destroyed or created and can be transformed from one form to another, and the heat has a significant impact on the growth of plants through its impact on the process of water absorption and growth and development of the roots and the vegetative part and the vital events and absorption of nutrients. The high temperature increases the activity of microorganisms which increases the nutrient readiness, temperature also controls the movement and availability of soil water, evapotranspiration and the soil air content. Evaporation is the process by which liquid water turns into vapor which is lost from the evaporation surface. The transpiration is a process similar to the evaporation represented in the loss of water in the tissues and parts of the plant, especially the leaves. The two separate processes through which soil and plant water is lost are referred to as evapotranspiration.

A lot of attention was given to the measurement of temperature by the scientists in many fields of knowledge and for a long period of time to identify many methods of its estimation. Therefore, many methods have been developed to measure the thermal flux. These techniques are somewhat complex and are dedicated in laboratory work and are allocated to small spaces. In addition to that, they require a lot of time and are characterized to be high cost if they are need to be published to obtain the field results in the large fields although earth mean give accurate estimate of heat flux, they show impractical solutions when information is needed for temporal and spatial changes on a large scale (5; 8).

SEBAL algorithm is an effective method for estimating temperature and evapotranspiration. This algorithm relies on energy balancing and requires ground monitoring data as key inputs alongside the satellite images which considered as the main source of radiation data. The use of SEBAL in estimating evapotranspiration is considered an economical and effective method, as it can be used to estimate the evapotranspiration of large areas. In contrast to the conventional methods which relatively small areas and high cost. The evapotranspiration can also be estimated for different previous years and dates to allow comparison between different time scales.

LandSat-7 satellite images were used as the main input to the radiation information required by the SEBAL, noting that the satellite images are free of clouds above the area of theevapotranspiration estimation. the SEBAL accuracy ranges from 85% to 95% based on the accuracy of the earth data that is represented by the wind speed and the evaporation pond data and the calculation of the sensible heat flux (H) which depends on the accuracy of the selection of wet (cold) pixel and dry (hot) pixel, many studies have shown that the SEBAL can be used in dry and semi-arid climates to estimate heat and evaporation. There for, this study is aimed to :

1. Use of the satellite images to show the effect of the vegetation on the surface temperature and the evapotranspiration rates in the study area at different times scales.
2 - Obtain thermal maps and evapotranspirationmaps for the area of the Musayab agricultural project using the remote sensing method and identify the variance obtained during different.

Surface Energy Balancing Algorithm for Land (SEBAL)

SEBAL is a model for the processing the satellite images to estimate the actual evapotranspiration by determining the energy balance of the visible and infrared thermalelectromagnetic spectrum (6). the SEBAL model is designed to calculate the energy sections of large areas of remote sensing data with little earth data, such as air temperature and wind speed. Determining the dry and wet surfaces in the study area is necessary to extract primary values. The model requires maps for net radiation flux (R_n), surface temperature (T_s), Normalized Difference Vegetation Index (NDVI) and surface albedo(α).The experimental relationship of estimation the emissivity, momentum roughness length(z_{om}) and soil heat flux(G) from plant indexes is calculated. the sensible heat flux (H) is calculated from the reflective flux of the dry earth units where there is no evaporation atdifferent types of wet surfaces. latent heat flux is calculated as residual from the energy balance. This model has been used in various applications to estimate the monthly evapotranspiration and it has been applied under different irrigation conditions in several countries (3).

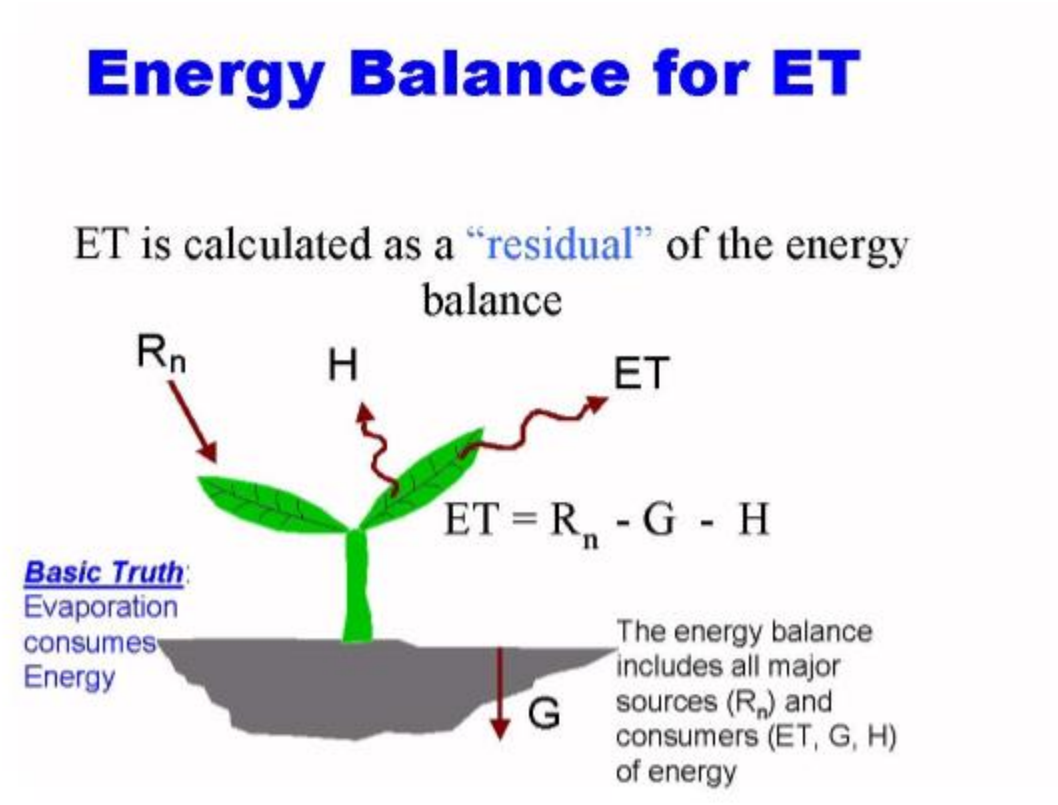

Figure 1: Surface Energy Balance

MATERIALS AND METHODS

Net radiationflux(R_n)

The net radiationflux represents the real energy available at the surface, which is calculated from subtracting the outgoing or reflected radiationfrom the incoming radiation (1). R_n depends on the solar radiation of the atomosphere and the reflectivity, emission and heat of the surface (9). Various plant indexes are also used as Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and Leaf Area Index(LAI)which are calculated using reflectivity values from Landsat-7 images. The α and $T_s$values are usedas inputs to calculate the incoming shortwave radiation, the incoming longwave radiation, and the outgoing longwave radiation, which are used in the calculation of R_n and according to the equation:

$$R_n = R_{S\downarrow} - \alpha R_{S\downarrow} + R_{L\downarrow} - R_{L\uparrow} - (1-\varepsilon_o)R_{L\downarrow}$$

where; $R_{S\downarrow}$ is the incoming shortwave radiation (W/m^2), α is the surface albedo (dimensionless), $R_{L\downarrow}$ is the incoming longwave radiation (W/m^2), $R_{L\uparrow}$ is the outgoing longwave radiation (W/m^2), and ε_o is the surface thermal emissivity (dimensionless).

Soil heat flux(G)

Soil heat flux (G) is the rate of heat storage in the soil and the plants depending on the thermal conductivity and SEBAL calculates G/R_n ratio. The remote sensingcalculation of G depends on the net radiation flux and plant Indexes. the ratio of G/R_n needs to be calculated from inputs including R_n, NDVI, α and T_s. therefore, G can be estimated as R_n dependent. according to the following equation:

$$G/R_n = T_s/\alpha\ (0.0038\alpha + 0.0074\alpha^2)(1 - 0.98NDVI^4)$$

where; T_s is the surface temperature (^{o}C),

Sensible heat flux(H)

The sensible heat flux (H) is the rate of heat loss to the air by the thermal conductivity and the convection depending on the temperature difference, or it is the used energy to heat the air above the surface. It is considered as one of the most complex energy inputs in SEBAL model. The model uses the values of NDVI and α in the z_{om} calculation, which is used to estimate the friction velocity, which in turn is used to estimate aerodynamic resistance to heat (r_{ah}), which needs to be calibrated according to the stability of the atmosphere. The relationship between the surface temperature and the temperature difference ($T_1 - T_2$) between two heights (dT) of the selected (hot and cold) pixels is then determined. The two selected pixels have known values of evapotranspiration, soil heat flux and surface temperature, in order to estimate the dT per pixel. After estimating all these variables and climatic data, the following equation is applied:

$$H = (\rho \times cp \times dT) / r_{ah}$$

where; ρ is air density (kg/m^3), cp is air specific heat (1004 J/kg/K), dT (K) is the temperature difference ($T_1 - T_2$) between two heights (z_1 and z_2), and r_{ah} is the aerodynamic resistance to heat transport (s/m).

Estimation of the actual evapotranspiration(ET)

The last step in SEBAL model is the evapotranspiration estimation. the latent heat flux (λET) is extracted after estimating the R_n, G and the H. As follows:

$$\lambda ET = R_n - G - H$$

The latent heat flux is converted to evapotranspiration values (mm/hr) and is calculated as follows:

$$ET_{inst} = 3600(\lambda ET/\lambda)$$

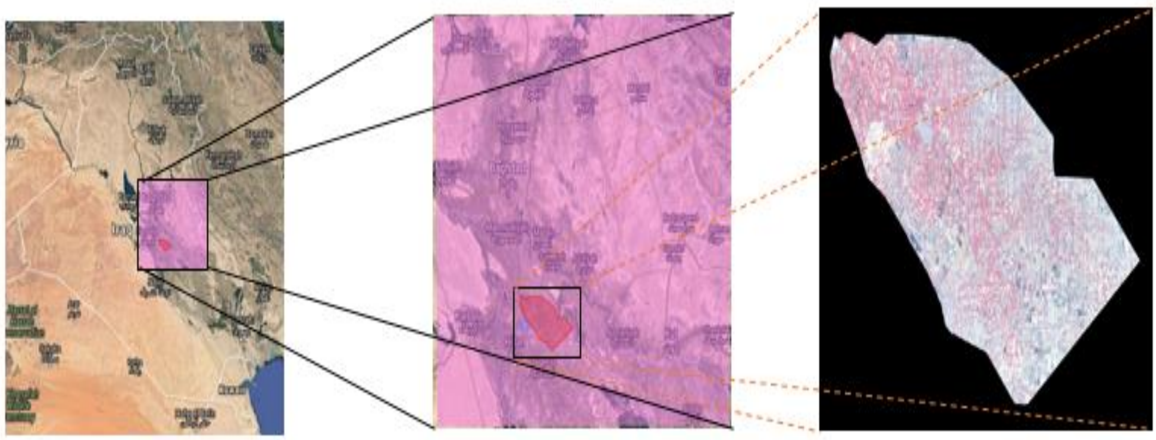

Figure 2: map of Iraq showing the study area

where; ET_{inst} is the instantaneous ET (mm/hr), 3600 is the time conversion from seconds to hours, and λ is the latent heat of vaporization or the heat absorbed when a kilogram of water evaporates (J/kg).

RESULTS AND DISCUSSION

Normalized Difference Vegetation Index (NDVI)

The NDVI was calculated for all the images that taken with the sensor ETM +. The table (1) shows the variance of the NDVI values and the cultivated area for each month of the study months. The results show that there is a variance in the density of the vegetation cover in different months for the years of study. This is due to the prevailing climate in the study area, which has a significant impact on the change of species and natural plant spread and also affects on the dates of cultivation and the land suitability for crops.

Table 1: average NDVI values and cultivated area in the study area

Cultivated Area (m^2)	Average NDVI	Date	No.
437,155,750	**0.303**	**2016/02/17**	**1**
40,122,000	**0.165**	**2016/06/24**	**2**
42,146,325	**0.182**	**2016/09/28**	**3**
236,238,500	**0.232**	**2016/11/17**	**4**

Influence of vegetation on T_s

The image taken on 17/02/2016 showed a decrease in the surface temperature by 1.8C° with an increase in the value of NDVI by 0.1, and the image taken on 24/06/2016 showed a decrease in the surface temperature by 2.3 C° with an increase in the value of NDVI by 0.1 , and the image taken on 28/09/2016 showed a decrease in the surface temperature by 2.0 C° with an increase in the value of NDVI by 0.1, and the image taken on 17/11/2016 showed a decrease in the surface temperature by 1.2C° with an increase in the value of NDVI by 0.1 .(Figure 2).

The vegetation plays a role in reducing the surface temperature. where the Increasing of the vegetation density reduces the surface temperature and reduces the temperature of the atmosphere surrounding the plants through the evapotranspiration. The thermal energy is used for the evapotranspiration instead of heating the atmosphere and the surface (4) Which reduced the temperature by a certain amount for each increase of 0.1 in the NDVI value.

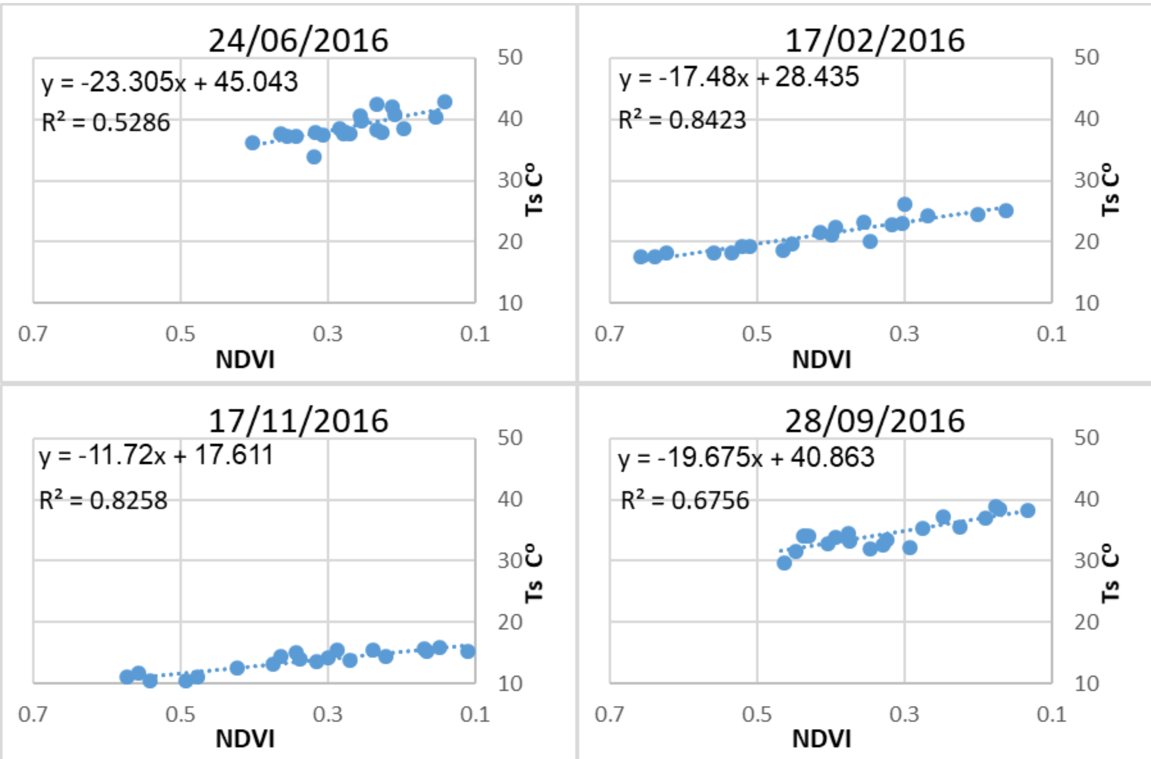

Figure 3: The influence of vegetation on T_s

Influence of vegetation on R_n

In the image taken on 17/02/2016 showed an increase in the value of the $R_n$up to 14 W/m^2. for each increase of 0.1 in the value of NDVI, the image taken on 24/06/2016 showed an increase in the R_n up to 22 W/m^2 for each increase of 0.1 in the value of NDVI.(Figure 3).

The vegetation takes most of the solar energy preventing it from reaching and heating the surface of the soil, and the plants greatly affect on the energy balance in a number of ways, such as changing the surface values of the surface and isolating the soil surface to reduce the heat exchange (9) and because plants have low α values, they have high R_n values as with the water bodies (11).

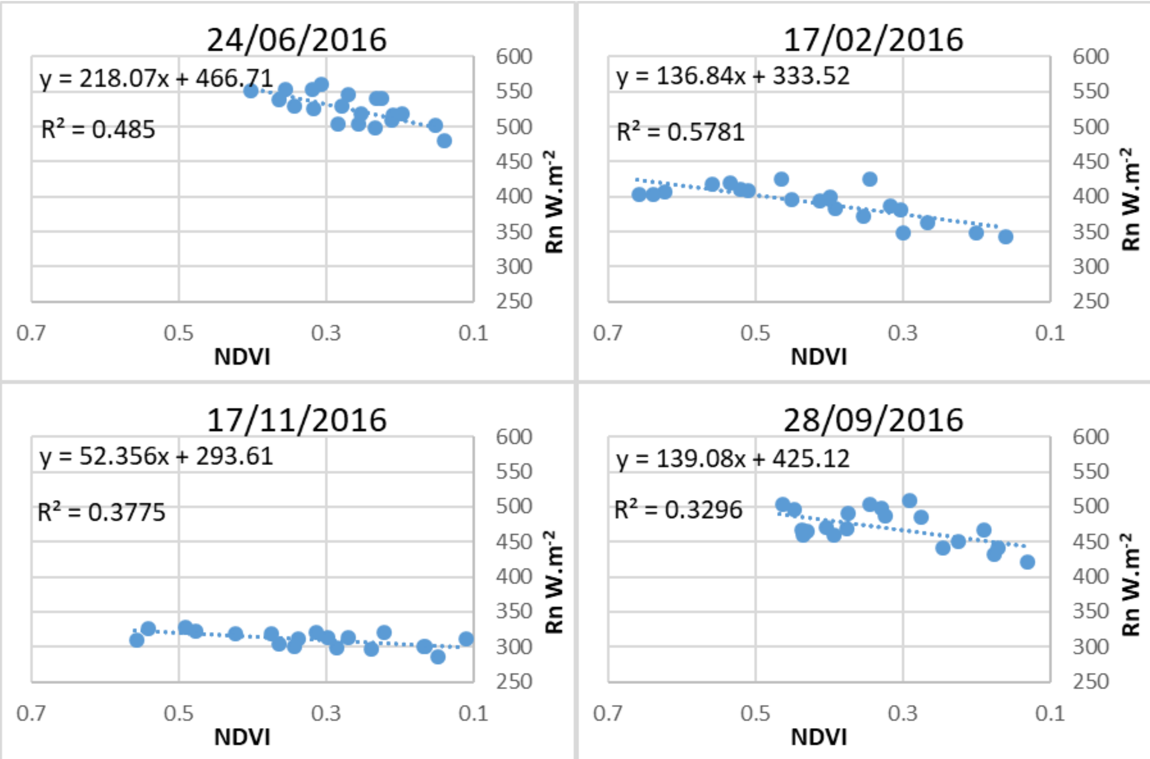

Figure 4: The influence of vegetation on R_n

Influence of vegetation on G

In the image taken on 17/02/2016 and 24/06/2016, the relationship between G and NDVI were inverse. An increase of NDVI by 0.1 leads to a decrease in G value by 4.0W/m^2. the image taken on28/09/2016 showed increase of NDVI by 0.1 leads to a decrease in the value G by 3.6 W/m^2, while the image taken on 17/11/2016 showed an increase of NDVI by 0.1 led to a decrease in the value of G by 2.0W/m^2.(Figure 4).

The vegetation covered isolates the surface of the soil from the direct solar radiation and thus it reduces the penetration depth of the solar radiation (9). Therefore, increasing vegetation density reduces the flux of heat to the soil.

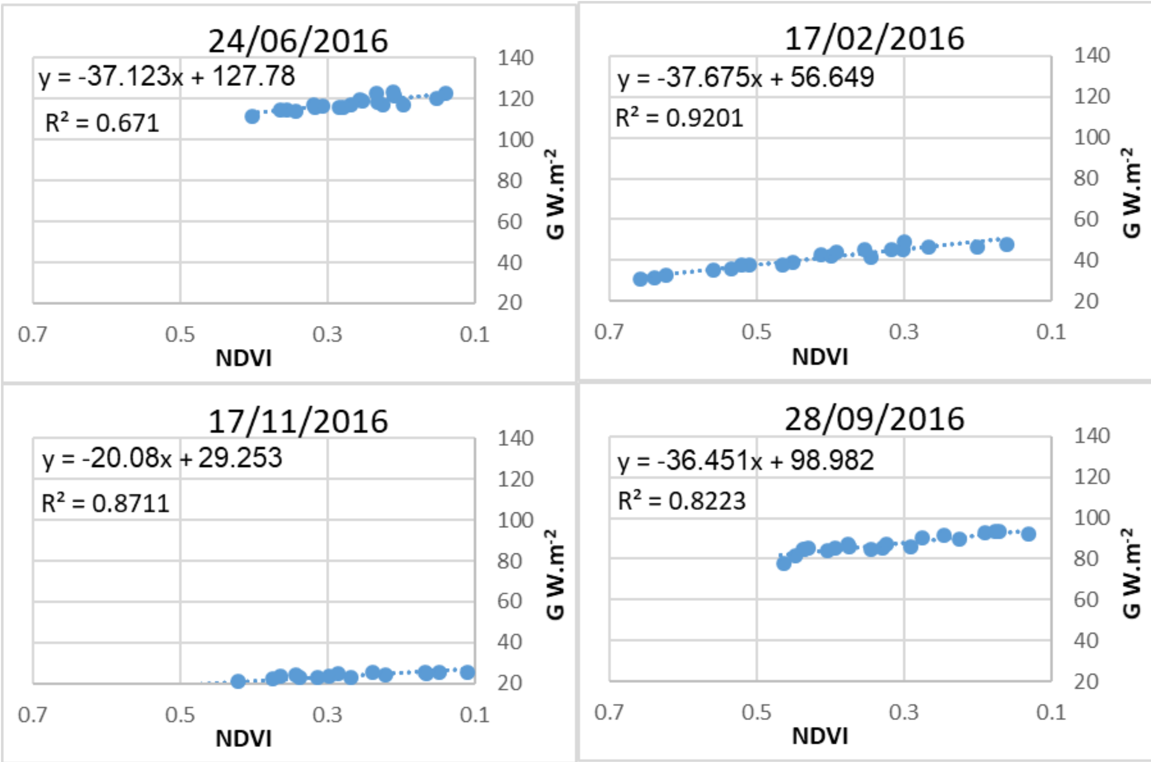

Figure 5: The influence of vegetation on G

Influence of vegetation on H

The image value taken on 17/02/2016 showed a significant increase in H of 43.7 W/m^2 for each increase of 0.1 in NDVI, and the image taken on 24/06/2016 showed that H decreased by 39.8 W/m^2 for each increase of 0.1 in the value of NDVI, while the image taken on 28/09/2016 showed increased that H by 14.9 $W/m^2$for each increase of 0.1 in the value of NDVI, and the image taken on 17/11/2016 the value of H increased in it by 18.1 $W/m^2$for each increase of 0.1 with the value of NDVI.(Figure 5).

H depends on several factors such as wind velocity, vegetation type, plant height, and aerodynamic resistance value. The increases of surface roughness increase the H values. Therefore H value is high for the plant surfaces depending on their roughness and resistance while the water bodies and not planted semi flat land have low H values (7).

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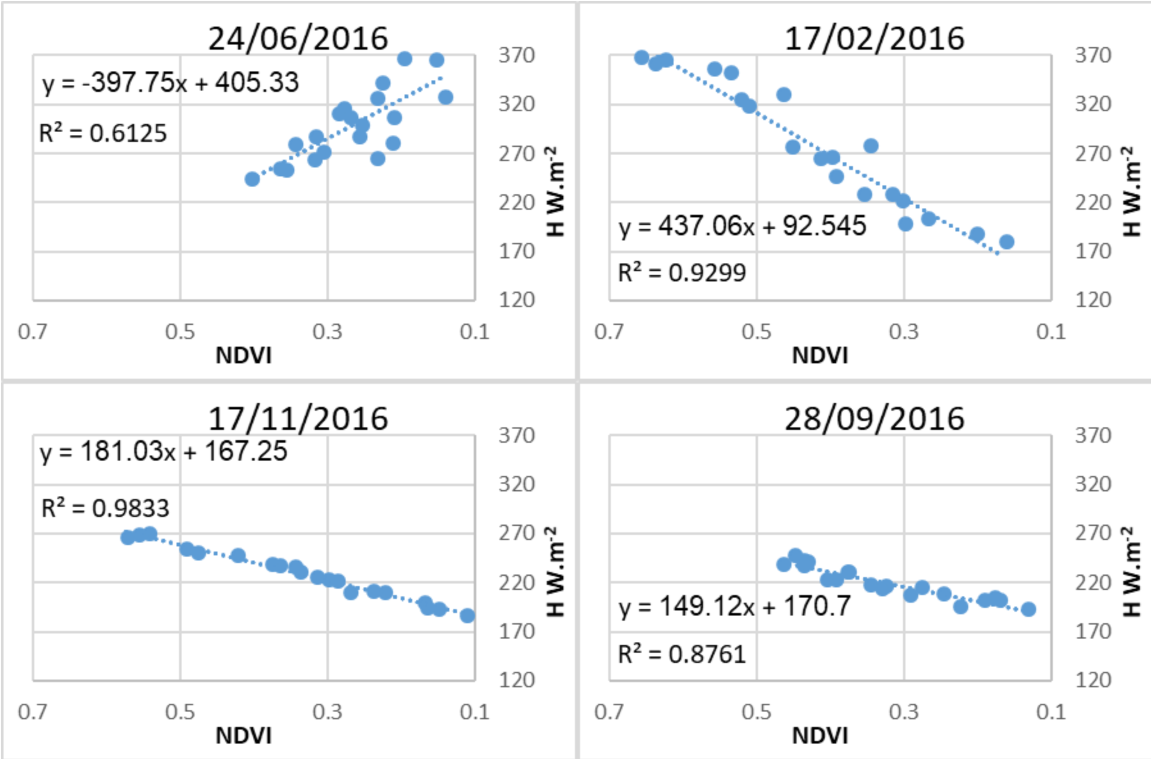

Figure 6: The influence of vegetation on H

Influence of vegetation on ET

The image taken on 17/02/2016 found an inverse relationship between ET and NDVI as an increase of 0.1 in NDVI leads to a decrease in the evaporation of 0.05 mm/hr, while the image taken on 17/11/2016 showed a positive relationship between ET and NDVI as an increase of 0.1 in NDVI increases ET by 0.02 mm/hr. (Figure 6).

The availability of water, the diffusion of plants, their variety and their ability to compensate the shortage of water play a major role in determining the relationship of NDVI and ET, in addition to that role of the climatic conditions such as the temperature, speed of wind and the amount of energy available to use for the evaporation and heating of the soil and what is used in ET (10).

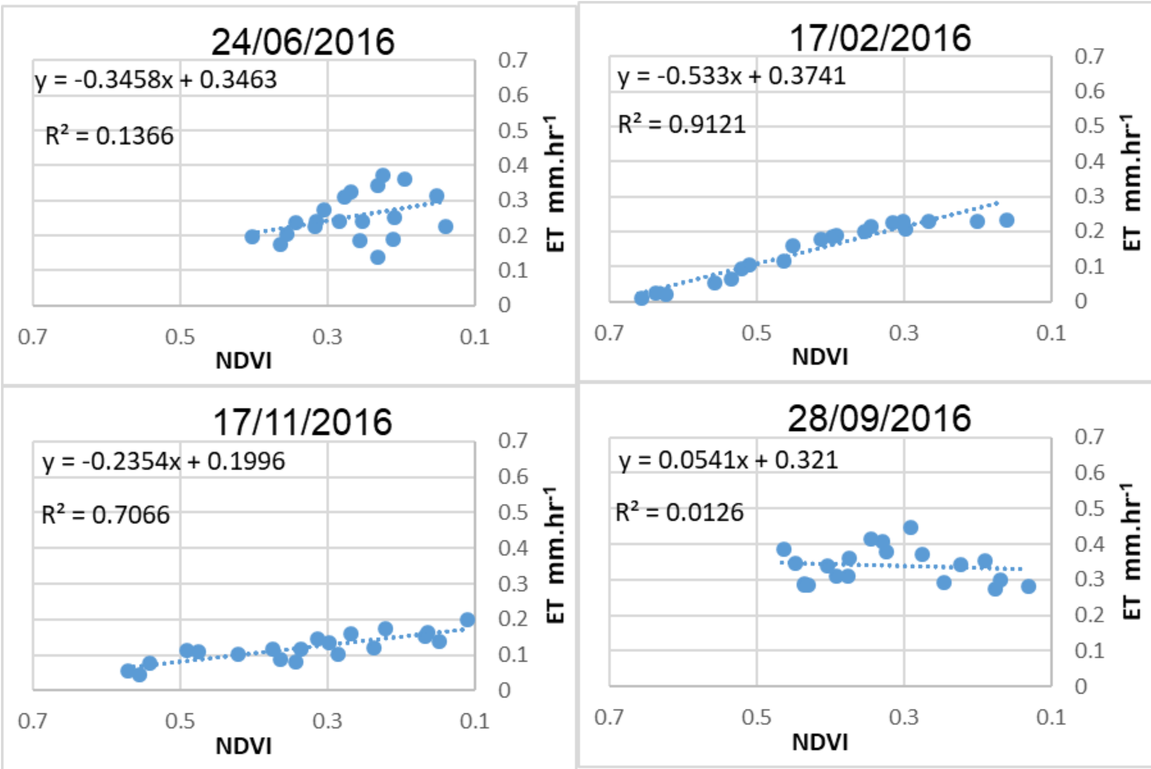

Figure 7: The influence of vegetation on ET

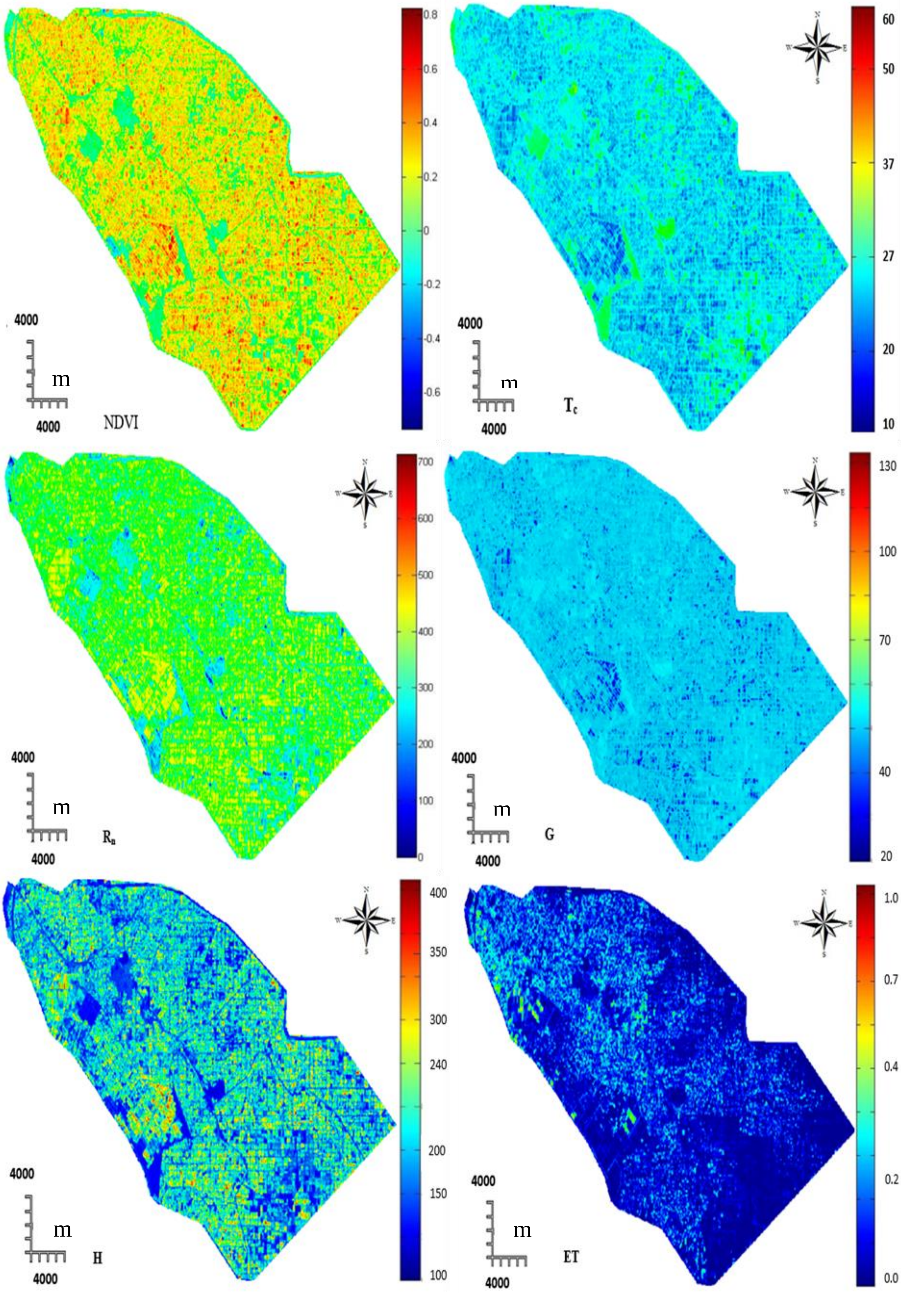

Figure 8: Satellite images taken on 17/02/2016 for the area of the great Musayab project

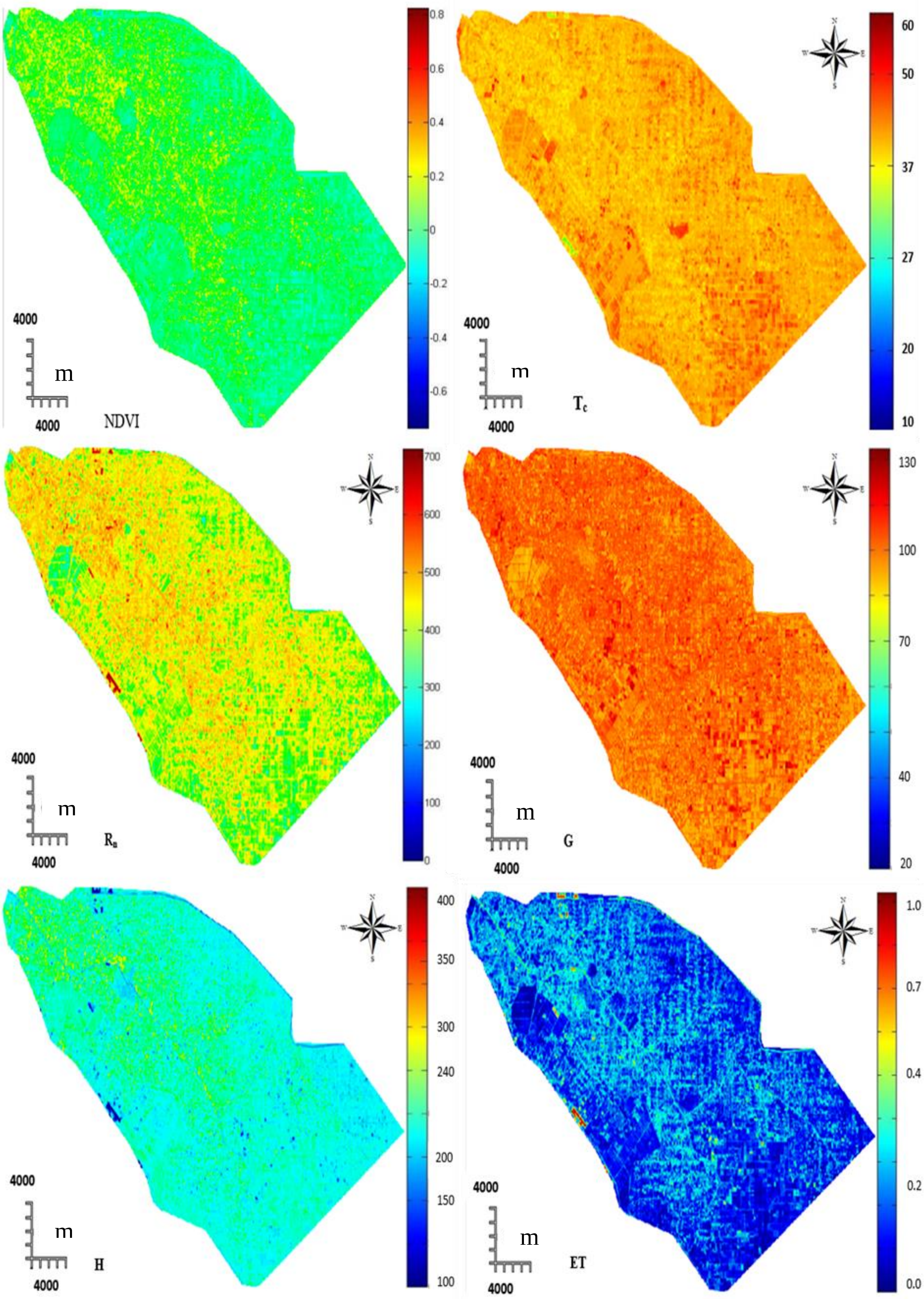

Figure 9: Satellite images taken on 24/06/2016 for the Greater Musayab project area

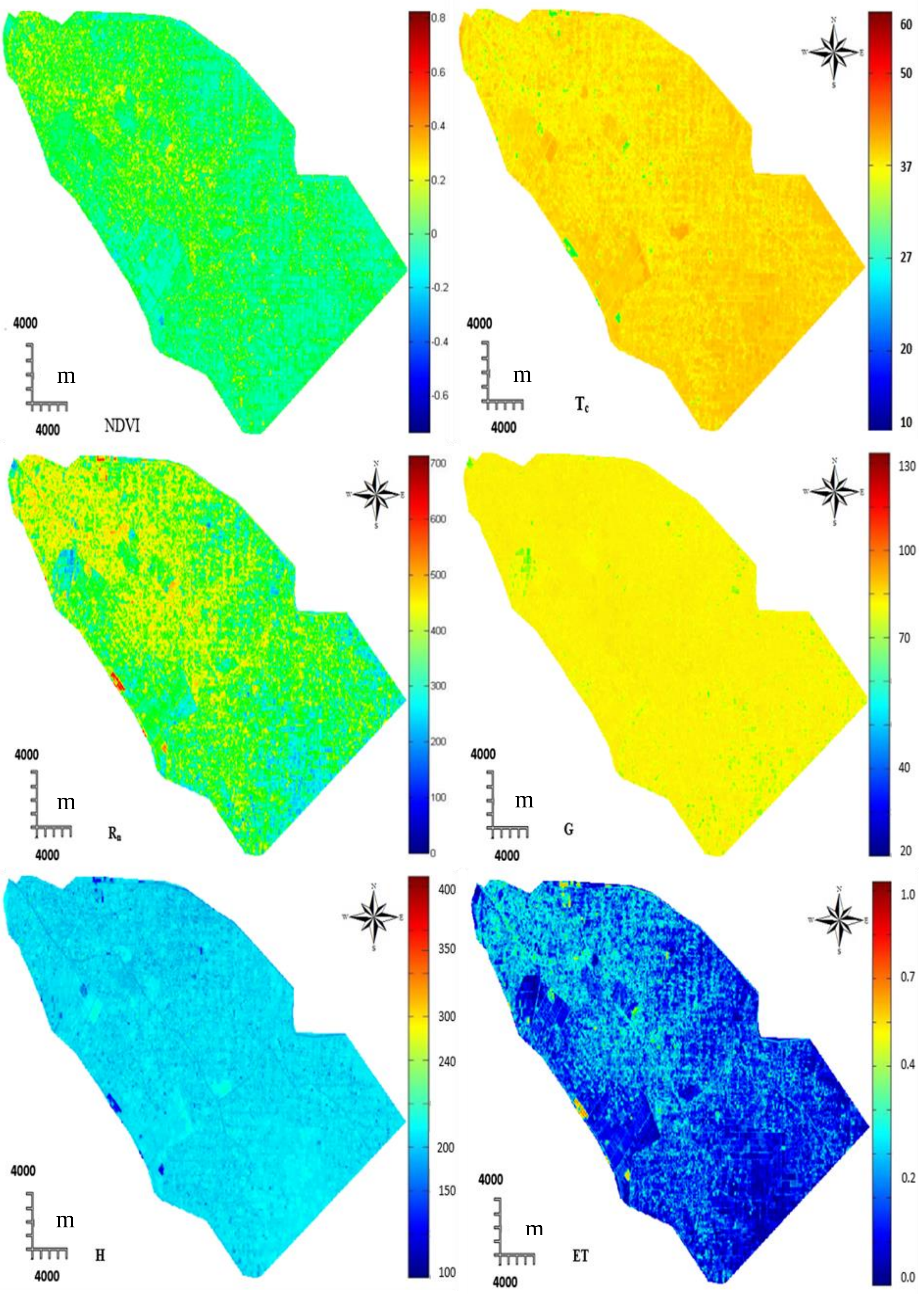

Figure 10: Satellite images taken on 28/09/2016 for the area of the Great Musayab Project

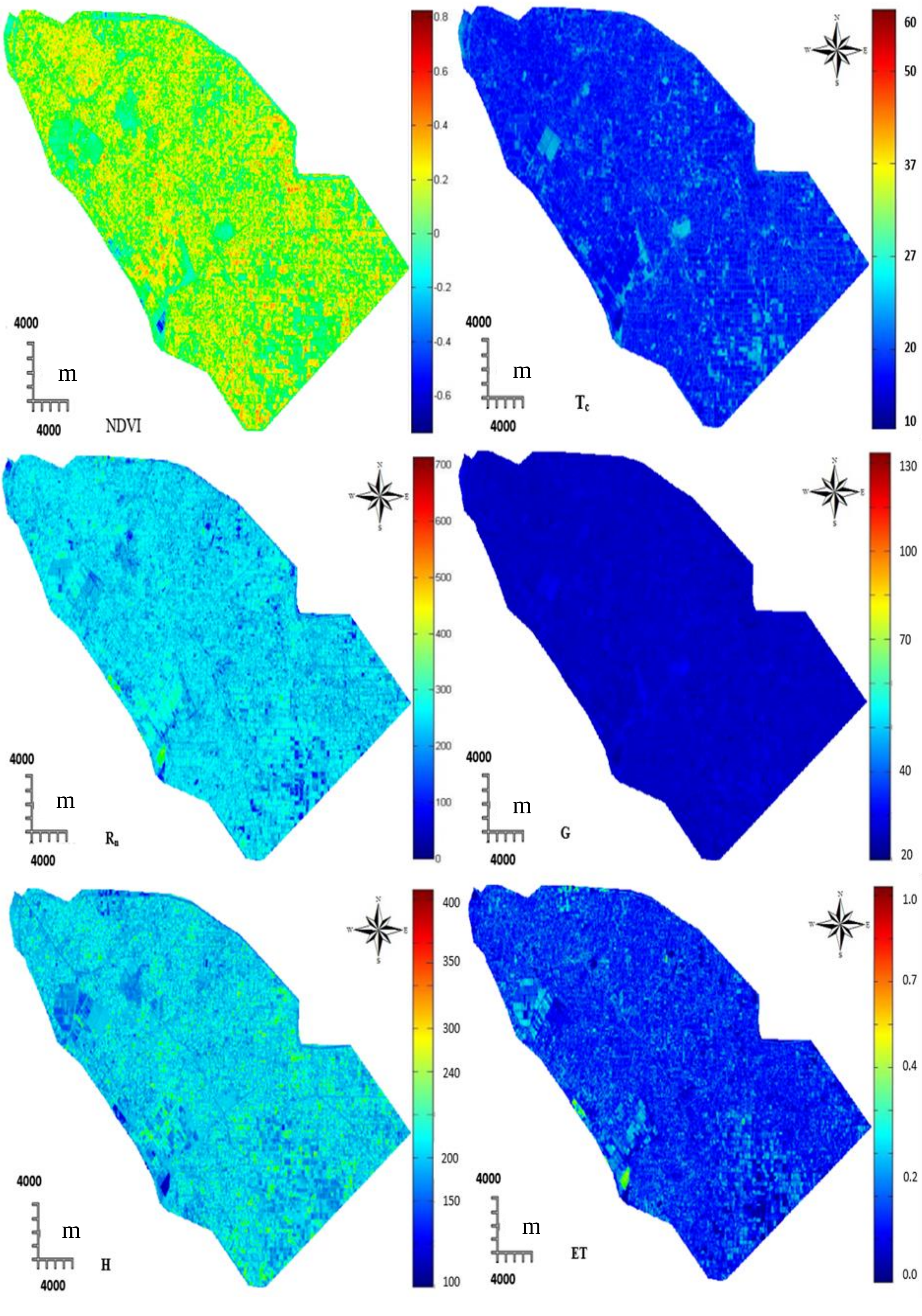

Figure 11: The satellite images taken on 17/11/2016 for the area of the great Musayab project

CONCLUSIONS

Remote sensing is an effective tool for estimating surface temperature, energy balance and evapotranspiration. In this study, surface temperature and evapotranspiration were estimated using SEBAL and ERDAS IMAGINE 2014. That provided an easy, economical and efficient method for estimating evapotranspiration from Landsat-7 images and climate data. The results showed an inverse relationship between the NDVI values and the T_s. The increase in the vegetation density leads to a decrease in the surface temperatures compared to dry and uncultivated soil. There was an inverse relationship between NDVI and ET values, since increasing vegetation densities leads to a reduction in surface temperature and thus decreases ET.

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