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Crop Mapping and assessment of Water-Energy Nexus consumption by irrigation

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ABSTRACT:

Crop identification is vital to make an inventory of the crops grown in a given area and their cultivation period. The Remote sensing (RS) techniques can provide information on the distribution of cultivated land, crop types, and areas for the agricultural sector's effective management.

In remote sensing, various vegetation indices (VI) can analyze and evaluate multiple phenomena and themes. The Normalized Difference Vegetation Index (NDVI) is an essential and highly significant remote measurement widely used in agriculture for phenological monitoring and crop health (Ray and Dadhwal, 2001).

In this work, we present a methodology for the contribution of NDVI from Landsat 7 (TM) and (ETM+) images to crop mapping in the Gharb region using a classification based on the pixel approach and estimating crop coefficient from NDVI.

The classification results concern six main types of crops planted in this region (beet, maize, sugar cane, market gardening, cereals, and rice). The classification map showed differences in agricultural practices adopted by farmers in crop spatial distribution. The classification results showed the ability of this methodology to discriminate between crops. The precision of classification for all classes is 90%, and the kappa indicator index is 0.88, which indicates a good classification.

Crop coefficients were deduced from the NDVI extracted from the images. Due to meteorological data collected from the meteorological station TCSC of SK Tlet, the estimation of the reference evapotranspiration was made and subsequently the potential evapotranspiration of each crop during the agricultural season 2019-2020.

The highest values for ETC were obtained when the crop was in its full development when water was mainly lost through transpiration after a slight decrease in the ratio values observed during the phase of the vegetative cycle (maturity). The water requirements (daily, monthly and annual) for the crops were determined and their electrical energy consumption.

KEYWORDS

CROP, REMOTE SENSING, EVAPOTRANSPIRATION, NDVI, CROP COEFFICIENT, LANDSAT

1. Introduction

Agriculture is a vital and crucial element in the economy of the Gharb region. To ensure efficient management of agriculture, geospatial data and statistics are indispensable. However, traditional data collection techniques are expensive and unsuitable for monitoring seasonal crop development. The RS allows the mapping of crop types by monitoring their seasonal development using multidate images covering the crop growing cycle.

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The use of RS for crop identification in semi-arid areas is significant and useful [5].

Several research projects have been conducted to monitor the evolution of the crop growing cycle and evaluate crop yields using RS combined with modeling approaches (Bastiaansen and al. i 2003; Doraiswamy and al.. 2004; Inoue and al..2008, etc.). [6]

These models simulate the entire crop cycle's biophysical processes, considering as many components of the soil, the atmosphere, etc. description of crop growing (Doraiswamy et al. 2004). [9]

Research has shown a good simulation of crop coefficients derived from VI from multispectral images (Hunsaker et al., 2003). [15]Several researchers (Allen and al.. (2011)), Hunsaker and al.. (2005), Gonzalez-Dugo and al.. (2009) have studied and defined the correlation and the best possible relationship between the crop coefficients of multispectral NDVI images based on the vegetation surface's reflectance. The VI allows bio-physical parameters to emerge from multispectral images using empirical equations. The VI can be used to define and monitor different crop parameters. [20]

Different formulae were developed to estimate evapotranspiration; there are formulae based on energy balance (Penman, 1948; Allen and al.., 1998b; Nouri and al.., 2013) [18], formulas referring to the air temperature (Thornthwaite, 1948; Blaney, 1952) [19].

The FAO-56 PM equation is more accurate in ETO estimation because it uses many parameters and is the most widely used formula for estimating evapotranspiration in agriculture (Allen and al.., 1998b; Allen, 2000).

Many research studies have been carried out on estimating Kc values for vegetable crops (peas, onions, and tomatoes) [26, 22].

Researchers have revealed that VI extracted from satellite images can be used to estimate crop coefficients. [24-25-29].

2. Materials and methods

2.1 The region of study

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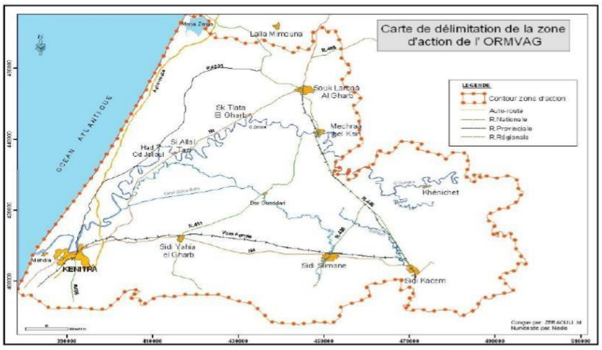

Figure 1 : The region of Gharb

The region of Gharb constitutes one of Morocco's most important agricultural perimeters, with a surface area of 116 000 ha. The perimeter is experiencing a real dynamic concerning the transition to drip irrigation.

2.2 Meteorological data

All meteorological data were collected from the TCSC weather station located in SA TAZI. The data are temperature (T_{max}, T_{min}, $T_{average}$), wind speed, net radiation, relative humidity, and reference evapotranspiration during the season 2019-2020.

2.3 Penman Monteith equation

The FAO-56 PM formula is expressed by the following equation : [1]

$$ET_O = \frac{0.408\Delta(R_n - G) + \gamma \frac{C_n}{T + 273} U_2(e_s - e_a)}{\Delta + \gamma(1 + C_d U_2)} \qquad [Eq.1]$$

Where :

ET_O = reference evapotranspiration (mm/day)

R_n = crop's net radiation surface (MJ/m2/day),

G = soil heat flux density (MJ/m2/day),

T = mean daily air temperature (2m height),

u_2 = wind speed at 2m height (m/s),

e_a = actual vapor pressure (kPa),

Δ = slope vapor pressure curve (kPa/C),

γ =psychrometric constant (kPa/C).

e_s = saturation vapor pressure (kPa),

All the meteorological data were recorded at the 2 m elevation point.

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The FAO-56 PM equation requires standard climatological data of solar radiation, humidity, air temperature, and wind speed. [16].

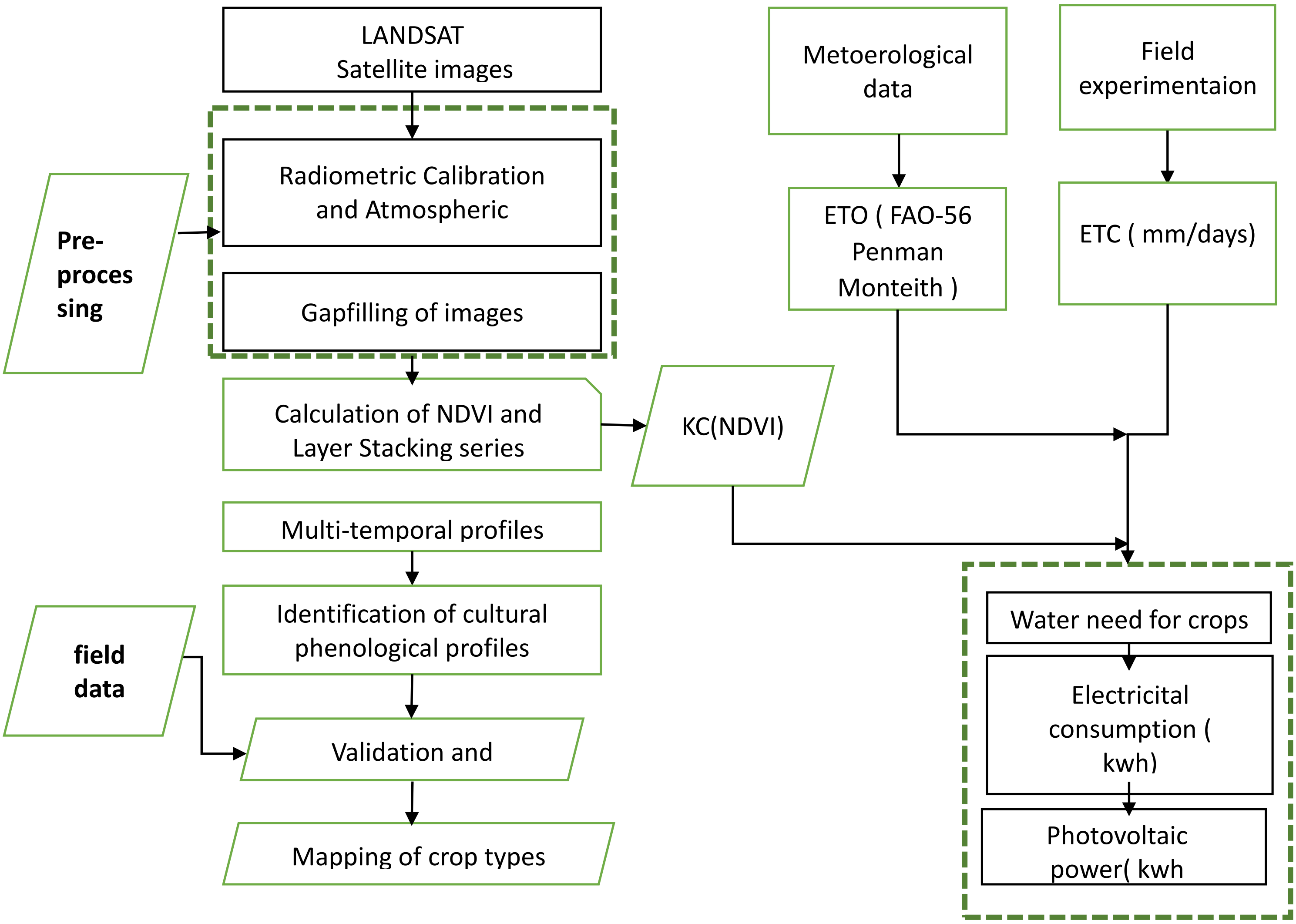

Figure 2 : THE METHODOLOGY FLOWCHART

2.4 Estimation of crop evapotranspiration :

The following formula expresses crop evapotranspiration: [2]

$$ETC = ETo \times Kc \qquad \text{[Eq.2]}$$

ETC is the potential evapotranspiration of the crop, and Kc is the crop coefficient; it is a parameter that depends on the crop's growth stage. The crop coefficient indicates various environmental factors and the influence of the crop on evapotranspiration. Multiple comparisons of ET_O and Kc measurements have been provided for different locations under differing conditions. [21]

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The NDVI is derived from LANDSAT 7 satellite images (TM and ETM+) for six different crop stages according to the following equation : [3]

$$\boldsymbol{NDVI} = \frac{(P_{NIR} - P_{red})}{(P_{NIR} + P_{red})} \quad [Eq.3]$$

Monitoring the evolution of the growing cycle of crops and agricultural production is often carried out using VI, particularly the NDVI.

The NDVI is the parameter that allows monitoring the evolution of the spectral response of the crop to applied irrigation rates while giving the different quality statuses of the crop (Bell and al.., 2009) [10]. The NDVI is an indicator of the chlorophyll activity in vegetation. [4]

Researches were made by (Doorenbos and Pruitt, 1977; Allen and al.., 1998) to elaborate the Kc values of different crops during their growing cycles. [11] Kc is estimated from NDVI due to the strong relationship between the NDVI and the Kc (Ray and Dadhwal, 2001) [12].

Due to the relationship between NDVI and KC, NDVI has always been considered as a parameter for monitoring and control of vegetation during its growth cycle (Justice and Townshend, 2002) [13]. High photosynthetic activity leads to high NDVI values; in contrast, high temperatures lead to low NDVI values (Boegh et al. 1999). [14]

Efficient and rational management of irrigation water requires a reliable quantitative estimate of evapotranspiration.

2.5 Data collection

The data used to validate classification results are the field data of the types of crops existing in the region of Gharb at the date of 14/04/2019. The data distinguishes six types of crops in addition to 3 land uses. The data presenting the crop types in plots have been divided to distinguish the data to validate the results and the characterization during the classification.

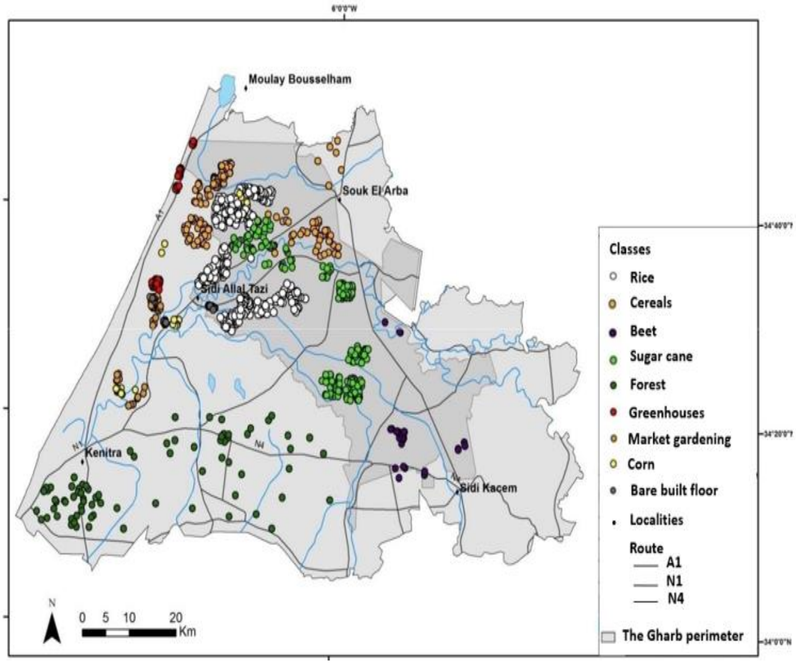

Figure 3 : Field Data

The crop identification based on phenology requires temporal monitoring during the stages of crop evolution. Crop mapping in our study was carried out for the agricultural season 2019-2020 according to field data availability.

Table 1 . The series of images used in the study

Image	sensor	Date
1	ETM+	21-10-2019
2	ETM+	06-11-2019
3	TM	18-02-2020
4	TM	06-03-2020
5	TM	22-03-2020
6	ETM+	15-04-2020
7	TM	09-05-2020
8	ETM+	18-06-2020
9	TM	28-07-2020
10	TM	14-09-2020
11	TM	16-10-2020

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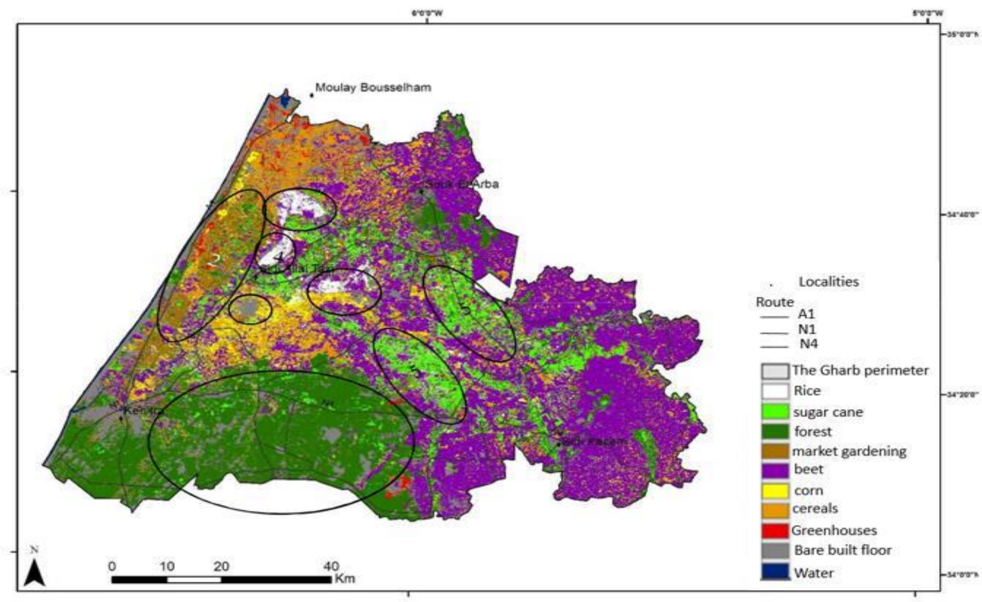

Figure 4 : Result of the SVM classification based on pixel

3.RESULTS AND DISCUSSION

The results concern six main types of crops planted in the study area (beetroot, maize, sugar cane, market gardening, cereals, and rice). The classification map showed the differences in crops sown by farmers in corp's spatial distribution. The rice crop is practiced in the SA TAZI on both banks of the Oued Sebou; market gardening is widespread in the north-western part of the study area, while the sugar cane is generally located in the central part of the study area. Cereal and beet crops are generally scattered throughout the region. The classification also allowed the characterization of the forest in the south of our study area, where the el-Maamoura forest is located.

3.1 WATER NEED FOR CROPS :

The ETC varies according to the season and the crop during a given period. ETC determines the amount of water to be used for irrigation. ETC is defined as the process by which water is lost by evapotranspiration. (Doorenbos, 1984; Running and al.., 2017). [7]

The two processes of transpiration and evaporation are simultaneous and closely related (Ding et al., 2013). [8]

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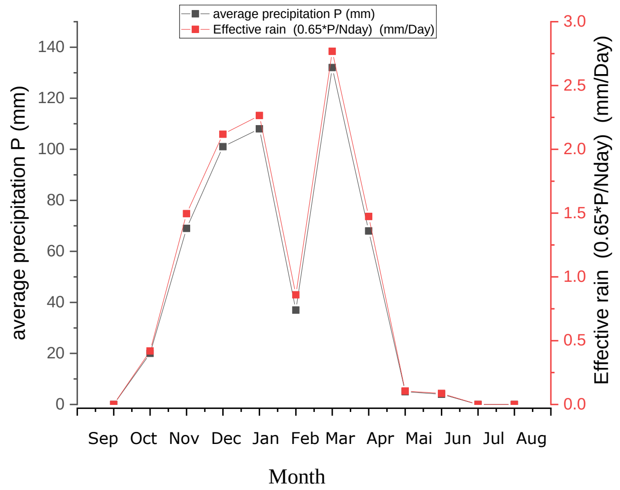

Figure 5 : Effective rain and average precipitation for the 2019-2020 compaign

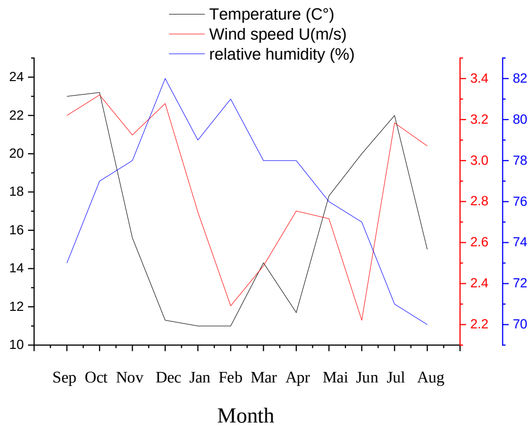

Figure 6: climatic data during the 2019-2020 compaign

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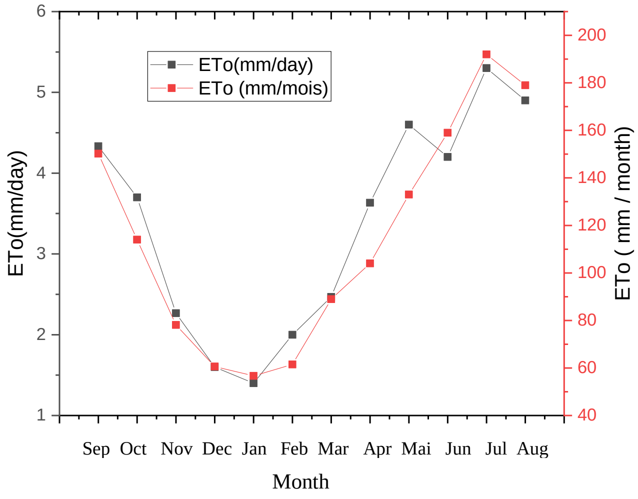

Figure 7 : The reference evapotranspiration during the 2019-2020 compaign

3.2 ESTIMATION CROP COEFFICIENT DERIVED FROM NDVI :

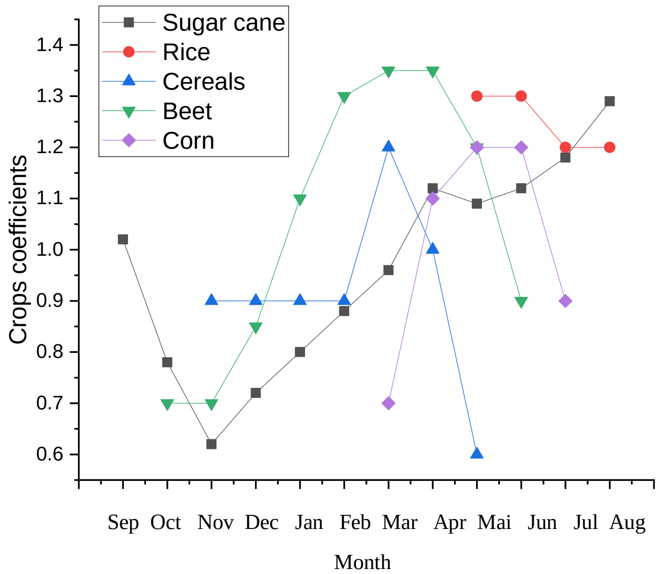

Figure 8 : The evolution of corps coefficients during the growing cycle

(2019-2020 compaign)

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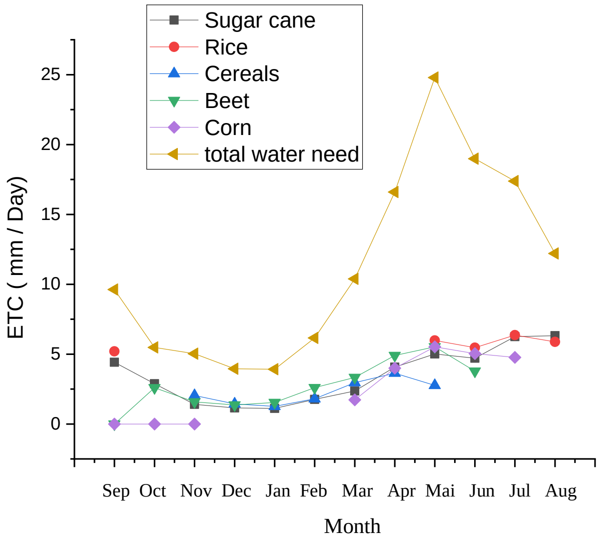

Figure 9: The daily ETC of crops during the growing cycle (2019-2020 compaign)

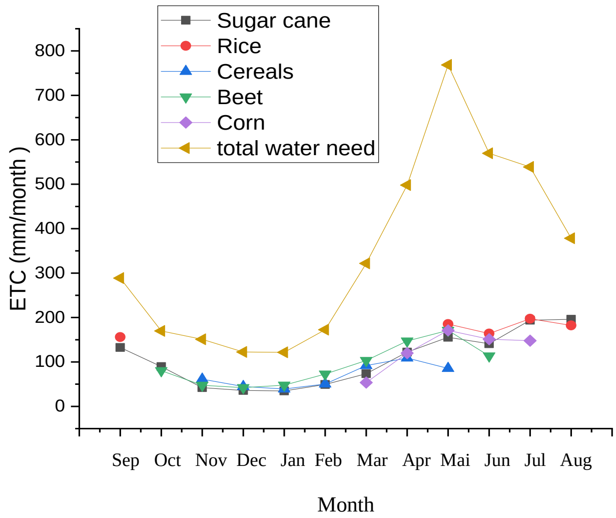

Figure 10: The monthly ETC of crops during the growing cycle (2019-2020 compaign)

3.3 Load energy assessment

The case study consists of six man crops supplied by irrigation water by pumping station connected to the electricity grid. Fig. 12 shows the distribution of the monthly electricity consumption throughout the year 2019-2020 for the six man crops on the Gharb region .

A maximum of monthly consumption is seen over the months of July and August with an average value of 1891.2 kWh and the minimum in January with the average of 1140.12 kWh.

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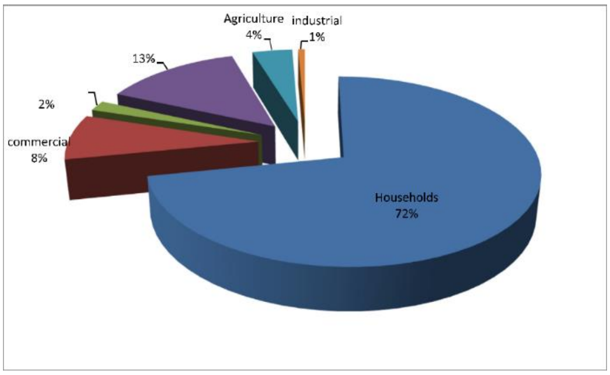

Figure 11 : Distribution of electricity consumption by sector.

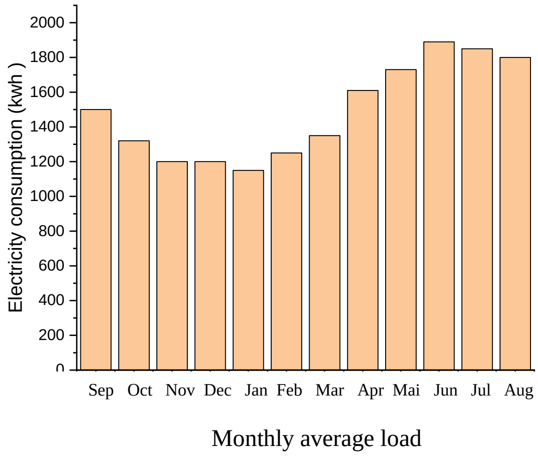

Figure 12 : Monthly average load for irrigation compaign saison 2019-2020

3.3.1 Energy performance

The energy performance of irrigation systems must therefore be analysed by distinguishing two aspects : In order to irrigate agricultural areas, it has often been necessary to fetch water from further away, and sometimes from deeper ground: in the first instance, it is therefore pumping and transporting water that are responsible for the high energy consumption for irrigation. However, the development of irrigation has been accompanied by the appearance of new techniques that often consume a lot of energy.

- The energy required to mobilise the water resource and bring it to the plot (the pumping station and the supply network);

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- energy needed to apply the water and distribute it over the whole crop (the irrigation equipment at the plot).

3.3.2 Energy for resource mobilisation

In order to bring the volumes needed by the plant to the cultivated plot, the topography imposes energy consumption:

a) The difference in level between the resource and the plot requires the water to be supplied with gravitational potential energy: the quantity required corresponds to the product of the volume of water and the difference in level converted into units of pressure.

b) The distance from the water resource to the plot causes head losses. Of course, hydraulic engineers express these losses in units of pressure, but it is interesting to give orders of magnitude in units of energy: for example, a steel pipe of 120 mm in diameter carrying a flow of 80 m3/h causes an energy loss of 340 joules per metre for each m3 of water transported. This quantity will be negligible if irrigating from a borehole close to the plot, but can reach significant values in the case of collective networks, where the length of the pipe is measured in kilometres.

The power consumed is expressed in kW, whatever the source of energy: it is the power demanded at the pump unit, the power consumed is partly dissipated at the pumping station, another part in the form of load losses in the distribution network and the rest at the level of the equipment at the plot.

We speak of "final energy" efficiency when we are interested in the energy available at the end of the distribution chain, i.e. in this case upstream of the pumping station: this is the energy that is invoiced to the irrigator. But if we want to reason more globally and compare different energy use strategies, we must consider the "primary energy" consumed, which includes not only the final energy, but also all the losses and consumption of producers and transformers throughout the energy production chain (Jacques Granier and all 2013).

4. Conclusion

The monitoring of agricultural fields in terms of production and irrigation water management efficiency at the regional level can be based on the extraction of information from satellite images through the temporal dynamics of biophysical variables that affect crop photosynthesis.

The annual NDVI LANDSAT series has been processed according to the classification based on the pixel approach.

The results showed the ability of this methodology to discriminate between cultures. The distribution of the monthly electricity consumption throughout the year 2019-2020 for the six man crops on the Gharb region . A maximum of monthly consumption is seen over the months of July and August with an average value of 1891.2 kWh and the minimum in January with the average of 1140.12 kWh.

The energy performance of irrigation systems must therefore be analysed by distinguishing two aspects :

- The energy required to mobilise the water resource and bring it to the plot (the pumping station and the supply network);
- The energy needed to apply the water and distribute it over the whole crop (the irrigation equipment at the plot).

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