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RESEARCH PAPER

Analysis of drainage channels by remote sensing: The case of the plain of Bouteldja in Northeastern Algeria

***Sennaoui Foued[1] and Saihia Abdallah[2]**

[1]Department of Hydraulics, Badji Mokhtar University Annaba- Algeria

[2]Department of Development, Badji Mokhtar University Annaba- Algeria

[1,2]Soils and Hydraulics Laboratory, Faculty of Engineering Sciences, Badji Mokhtar University Annaba- Algeria

Email: saihia_a@yahoo.fr[2]

*Corresponding Author

* Sennaoui Foued

Department of Hydraulics, Badji Mokhtar University Annaba- Algeria

*Corresponding Author Email: sennaoui-foued@hotmail.com[1]

Abstract

This research presents an analysis of flows in relation to the adequacy of drainage channels. Once validated the Mockus concentration time equation among others from the current topographic data obtained on fields in 2018. This gives Nash performance criteria equal to 0.86 and the correlation coefficient R^2 equal to 0.92. Also, compare the observed concentration time for all channels in the study area with a total length of 29635m compared to the appropriate concentration times calculated as a function of critical slopes, using the Mockus equations. Using ARC GIS with the HEC Geo Ras extension, the results of this modeling show that the concentration time with a significant effect on flow and drainage efficiency. It makes it possible to determine a rehabilitation schedule and a maintenance plan for drainage systems without moving them to the site. This study is a better tool in the sustainable maintenance of drainage networks.

Keywords: Drainage channels, Concentration time, Mockus equation, ARC GIS

Introduction

The maintenance and monitoring of agricultural drainage systems is the most important strategic program to improve agricultural yields. Monitoring the siltation rate provides information on the siltation rate and allows for better planning of intervention programs. This rate can be a good indicator of the state of the environment and its hydraulic, biological and economic functionalities. The widening, deepening and straightening of rivers to achieve a constant bottom slope and cross-section, as well as the clearing of vegetation and other obstacles are maintenance works aimed at ensuring the long-term functionality of agricultural drainage (Västilä, 2011), therefore open channel drainage has become an indispensable development of flat land agricultural areas with low soil permeability and high rainfall. This is the case of the study area (the Bouteldja plain) located in the far east of Algeria (w. El Tarf). This area was developed in 2006 as part of a hydro-agricultural project by creating open drainage channels in the ground, but so far it has been submerged by the flooding of neighboring agricultural land, Williamson al. (2019) uses remote sensing to improve water management in the drainage system. The choice of reasonable design parameters for agricultural drainage channels is very important to improve drainage efficiency. According to the work of Mailhot (2016) was to analyze hydrological data and compare the data measured in the field with the results of calculations obtained from empirical equations estimating concentration times, runoff heights and peak flows that are best suited for small agricultural watersheds. The topographic and location map was used as a guide to locate the drainage channel Adaba et al. 2014). Our study presents an analysis of the adequacy of drainage channels using Google Earth satellite photos on ARC GIS software and using the Hec Geo Ras extension, we easily found physiographic drainage network variables such as slope and length of water path, which assumed equals the length of the channel to estimate the concentration time by different empirical equations such as (Kirpich, Mockus, Ventura, SCS lag-time) and compared these field values for rainfall events in the year 2018.Once the formula adopted for our area has been validated, by comparing the calculated concentration time for all the channels in the study area with their adequate concentration times, from this comparison, it is easily monitored and remotely detected the drainage system without moving it to the site and most importantly to establish a schedule for maintenance and priority intervention.

Materials and Methods

Study Area

The study area located in the northeast of Algeria is an agricultural plain in the wilaya of El Tarf, precisely the Bouteldja plain. This plain covers an area of around 110 km^2 limited: - To the North by the dunes of Bouteldja. - To the south by the Chaffia mountains. - To the east by the plain of El-Tarf, characterized by the geomorphological form of the Oued Kébir valley - To the west by the plain of Ben m'hidi and the wilaya of Annaba (Figure 1).

The El Tarf region is subject to a temperate, rainy and humid Mediterranean climate in dry winter and hot in summer. According to climatological data from the Bouteldja station (1999-2009) (source A ANRH CONSTANTINE). The region is among the wettest regions of Algeria; the annual average rainfall is 755.96 mm / year. The average annual temperature of 17.72 ° C, the minimum value is recorded in January with a value of around 10.74 ° C on the other hand the maximum value is reached in August with a value of 25, 66 ° C. The lower and upper peaks of the average monthly evaporation were recorded in January with 21.80 mm, and in July of 147.9 mm.

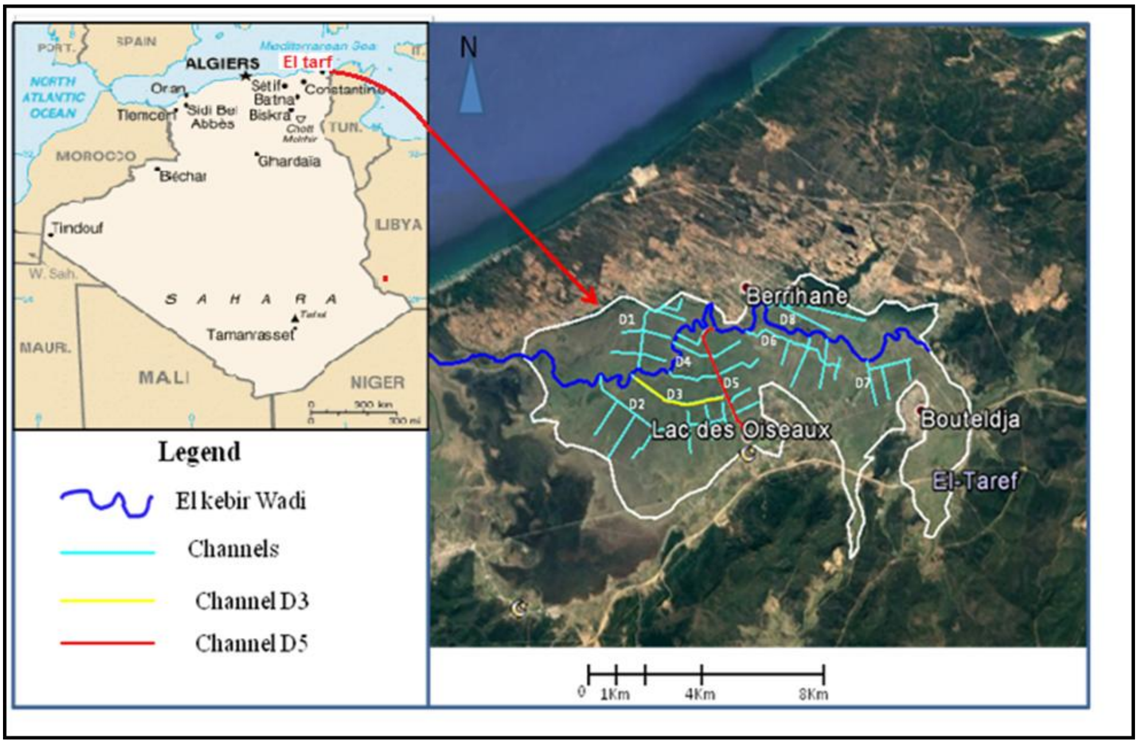

Figure 1: Location of the study area

Methodology

To manage drainage channels well, you need to know. The first prerequisite for "adequate" management is the constantly renewed refinement the knowledge of the canals functioning, whether through modeling, measurement techniques or inventories. In our methodology presents an analysis of the adequacy of drainage canals.

The equipment used to level the bottom of canals on fields is: The Leica ST06 device with the test pattern for concentration time measurements of each channel, we used tape, stop watch and small pieces of polystyrene (Figure 8b) poured into the water during rainy events.

The precipitations of each event of the year 2018 it was obtained from rainfall station of Bouteldja. The network of drainage channels and their locations were identified using a 2018 satellite photo on Google Earth imported on ARC GIS 10.5 software, from the TIN map (Triangular Irregular Network) and the Hec Géo Ras extension under Arc Map we determined the slopes of each section of all the channels, the (Figure 2) represents the organization chart of the methodologies.

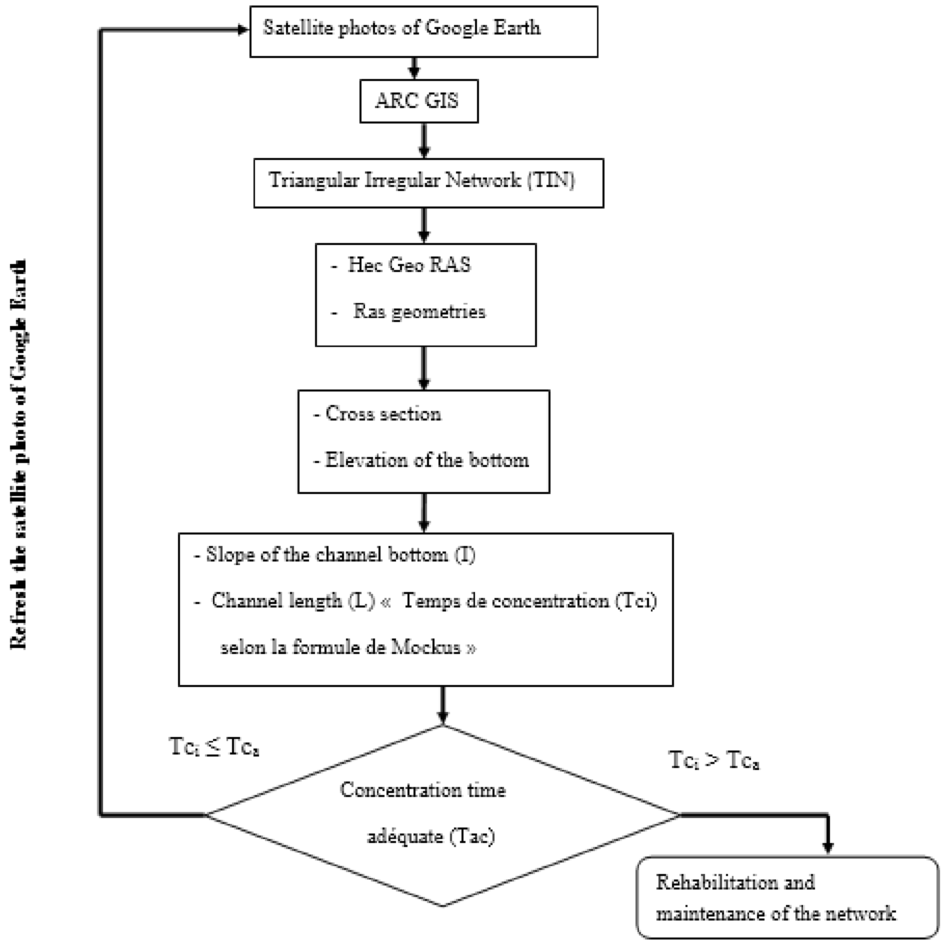

Figure 2: Organization chart of the methodology

Peak flow assessment

Peak flow is the maximum flow of the catchment area, there are several empirical formulas in literature that generally take into account three essential factors: rain intensity, catchment area, concentration time, in our case three methods were used:

The rational method:

$$Q = C \cdot i \cdot S \qquad (1)$$

Where

C: Runoff coefficient we take 0.05 according to the type of soil (plant), i: Rain intensity in mm /h., S: area of the catchment area in ha

***CRUPEDIX (1982) method*:**

The Crupedix method allows the estimation of the 10-year peak flow (Q10) by the following formula:

$$Q = S^{0.8}(pj10/80)^2 . R \qquad (2)$$

Where

Q: maximum annual ten-year instantaneous flow rate, S: area of the catchment area in km²
Pj10: maximum daily rainfall per year in mm, R: regional coefficient that we will take equal 1

SCS method:

The SCS (Curve Number) method is the best known and estimates the runoff height

$$Hru = \frac{(p-Ia)^2}{(pi+Ia)+Rm} \qquad (3)$$

$$Ia = 0.2 . Rm \qquad (4)$$

Where

Hru: height or runoff blade (mm), Pi: rainfall height (mm), Ia: initial interception (mm)

Rm: maximum retention (mm).

$$Rm = \left(\frac{1000}{CN} - 10\right).25.4 \quad (5)$$

CN: The Curve Number values vary from 0 to 100, 82 is taken for all sub-basins according to the CN table (cereals, contour, poor infiltration condition, C)

The peak flow is written:

$$Q = \frac{0.75.Hru\,.\,S}{3600.Tp} \quad (6)$$

Considering Tp and Tc (concentration time) equal,

The results of peak flow calculations using the three formulas: Rational, CRUPEDIX, SCS Method are shown in (Table 1)

Table 1: Peak flow calculation results by applying the three formulas

N° Channel	S B V (ha)	Rational peak flow method ($m^3.s^{-1}$)	Crupedix method peak flow rate ($m^3.s^{-1}$)	Peak flow rate SCS Curve Number method ($m^3.s^{-1}$)	Qc ($m^3.s^{-1}$)
D1	805	7.51	7.86	4.86	14.37
D2	1662	15.51	14.04	7.94	28.16
D3	350	3.27	4.038	2.15	14.25
D4	135	1.26	1.884	1.29	19.57
D5	810	7.56	7.9	5.49	25.96
D6	689	6.43	6.94	4.23	18.25
D7	667	6.22	6.76	8.01	16.04
D8	1071	9.99	9.88	10.97	15.51

The drainage capacity (Qc) for all channels is estimated by applying the Manning-Strickler formula (7) and presented in the setting curve Fig 3.

$$Q = \frac{1}{n}.R^{2/3}.I^{1/2}.S \quad (7)$$

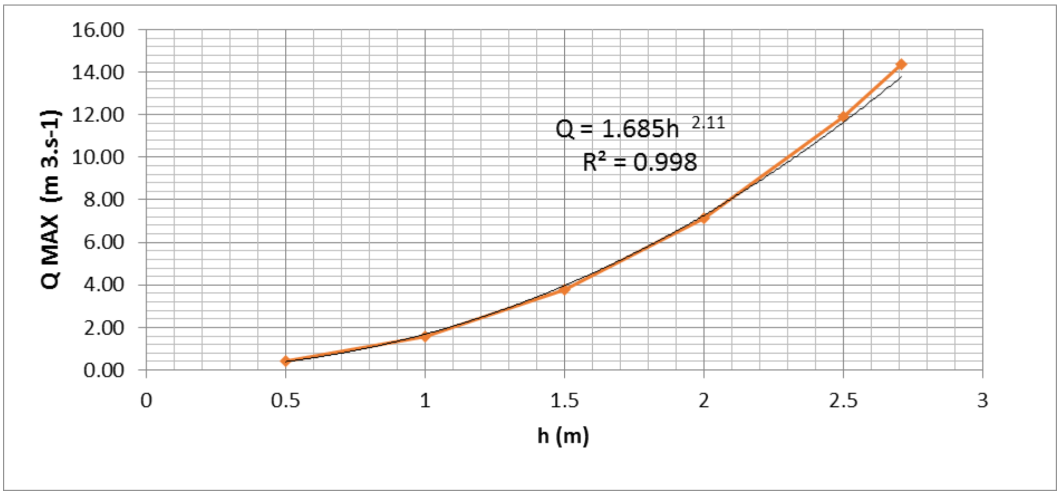

Figure 3: Channel calibration curve (drainage capacity "Qc" in water depth function "h")

Evaluate the concentration time

The concentration time is the time elapsed between the beginning of a precipitation event and reaching the maximum flow at the outlet of the watershed. It is the time required to allow water to flow from the most remote point of the watershed to the outlet.

Several methods for estimating concentration time are based on two variables: the maximum flow length and the mean longitudinal slope of the watershed, among these methods:

Kirpich method:

This method is suitable for watersheds with an area of between 0.4 ha and 81 ha, clay soils and an average slope of between 3% and 10%. The concentration time is then calculated from the following equation:

$$Tc = \frac{(0{,}000325 .\ L^{0.77})}{(I^{0.385})} \qquad (8)$$

Where

Tc : Concentration time (in h), L: Maximum length of the water path in the watershed (in m), I : Mean longitudinal slope of the watershed, following the flow of water.

Mockus method (1961):

This method is suitable for watersheds with a surface area of between 4 ha and 1000 and which are characterized by an average longitudinal slope of less than 1% and by silty or clay soils.

$$Tc = \frac{L^{0.8} . \left[\frac{1000}{CN} - 9\right]^{1.67}}{2083.(100.\ I)^{0.5}} \qquad (9)$$

Where

L: Maximum length of the water path in the basin (in m). This parameter is defined in the sectionprevious.CN: Curve number (no units). This factor represents the effect of watershed surface conditions on the runoff.

SCS lag time method:

$$\boldsymbol{Tc} = L^{0.8} . \left(\frac{1000}{CN} - 9\right)^{0.7} . (4407 . I^{0.5})^{-1} \qquad (10)$$

Where

The maximum length of flow (L) is in meter, the average slope of the catchment area (I) is in meter/meter and the CT is expressed in hours.

Ventura method:

$$TC = \mathbf{76.5} \cdot \sqrt{\frac{S}{I}} \qquad (11)$$

OrTc: Concentration time in hours S: Surface area of the catchment area (Km^2), I: The slope (%)

Adequate drainage

Adequate drainage ensures the excess sanitation of water in the soil to the outlet without overflow, erosion and deposition, this requires an effective design taking into account the flow regime and the appropriate (critical) slope calculated by equation 13.

Critical speed Froude number Fr = 1

$$\sqrt{\frac{Q^2 .\ B}{A^3 .\ g}} = 1 \qquad (12)$$

$$Icr = \frac{A .\ g}{\frac{1}{n^2} . R^{4/3} .\ B} \qquad (13)$$

B: width of the channel mirror, g: acceleration of gravity, Icr: critical slope.

Results and Analysis

According to the field concentration time measurements for each channel, we found the values calculated by the Mockus equation to be closer to the results observed in the events of the period (22/05/2017- 15/12/2018) which leads us to verify the performance criteria (R^2 = 0.97 and Nash =0.86) represented in (Figure 4). By this validity we have adopted the Mockus method and according to (Nicolas Stämpfli 2007) This method is adapted to watersheds with a surface area varying between 4 ha and 1000 ha and which are characterized by an average longitudinal slope of less than 1% and for silty or clay soils.

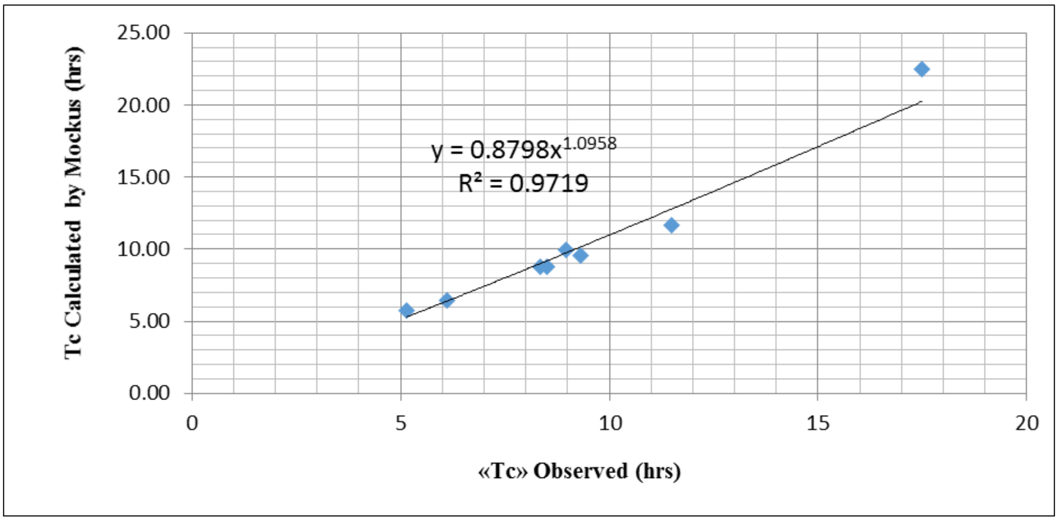

Figure 4: Comparison of Tc observed and calculated by the Mockus equation in events for the period (22/05 /2017- 15/12/2018)

The application of the three concentration time equations: kirpich, Mockus, SCS lag time, SCS lag time, SCS lag time, from the topographic data since the initial design, each gives different values, it can be seen that more that the slope increases more than the concentration time decreases the (Figure5) represents the variation in concentration time of channel D3 as a function of the slope.

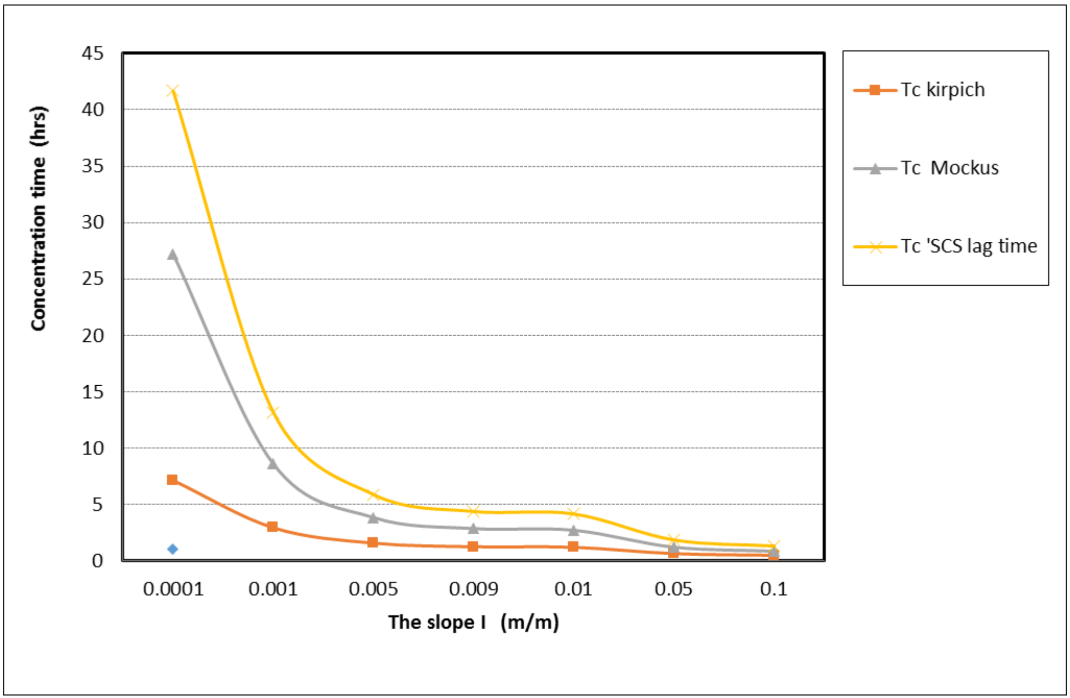

Figure 5: Variation of Tc of channel D03 as a function of slope

Based on the comparison of the results of the concentration time results, it is also a new technique used for the analysis of drainage channels based on the extract of topographic data, such as the slope and length of the channels from Google Earth maps of the study area imported on an ARC GIS 10.5 software, without moving on the site the (Figure6) represents the Google earth image transferred from TIN map on Arc Gis.

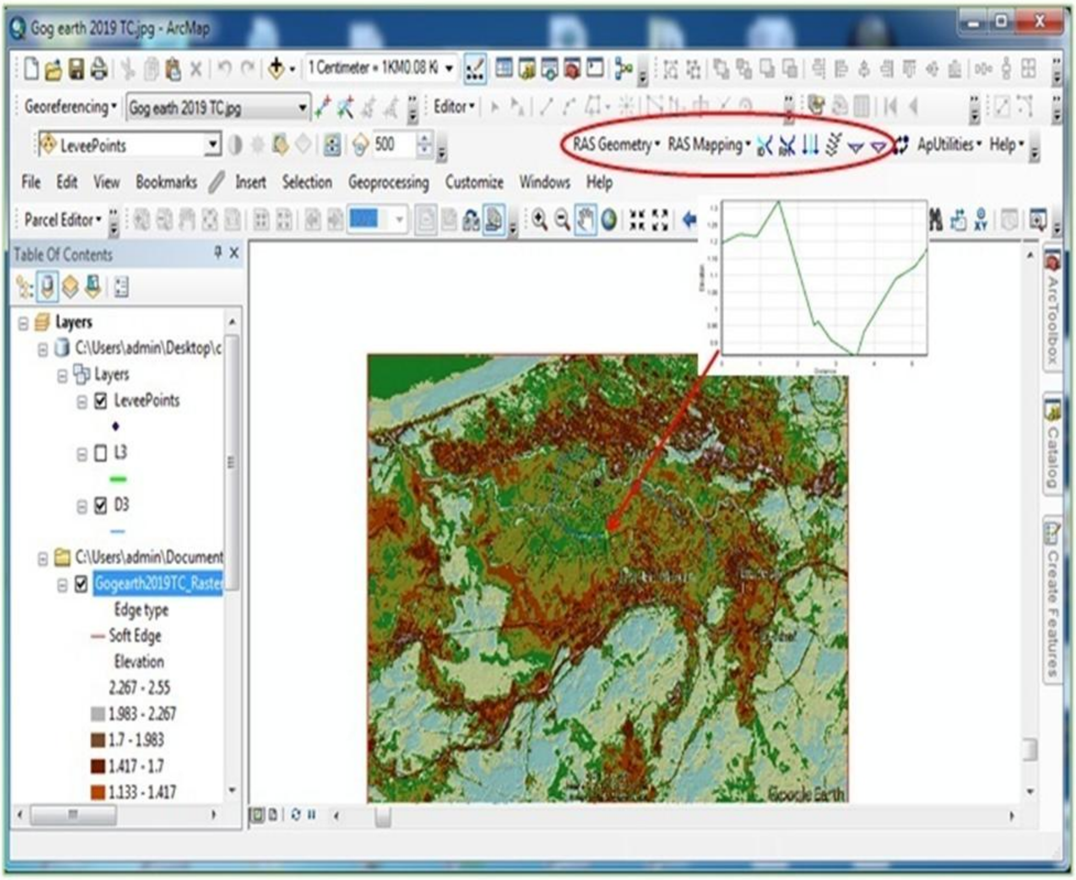

Figure 6: TIN map of the study area on Arc Map

Finally, from the results represented in (Figure 7) we can analyze the channel status and record the following recommendations:

- In the initial design of the canals, the slope of the bottom does not ensure adequate drainage.
- All canals require maintenance and rehabilitation, the most priority channel for maintenance is channel D5 and conformed Following our visit to the field to check the condition of each channel on 15/12/2018, we found the channel D5 clogged by siltation and grass see (Figure 8a), The classification of channels in priority maintenance presented in Tab 2.

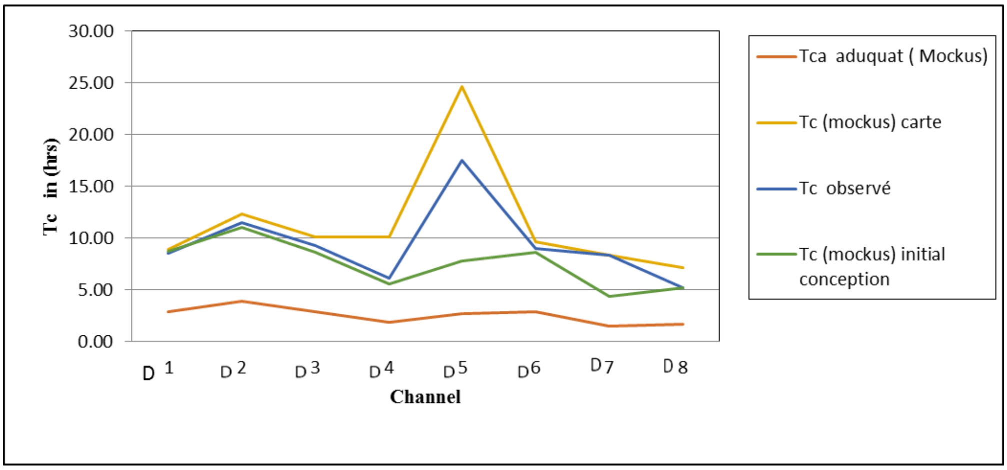

Figure 7: Comparison of Tc observed and calculated by the Mockus equation, initial design, map 2018, adequate.

Table 2: Comparison of Tc results of channels and ranking of priority maintenance

N° channel	adequate TCa(Hrs)	Tc Tin map(Hrs)	Tc observed (Hrs)	Tc initial design(Hrs)	Δ Tc (Hrs)	maintenance classification
D1	2.89	8.93	8.5	8.75	6.05	6
D2	3.91	12.29	11.5	11.06	8.38	2
D3	2.84	10.14	9.3	8.60	7.30	4
D4	1.85	10.08	6.1	5.52	8.23	3
D5	2.66	24.67	17.5	7.80	22.01	1
D6	2.88	9.62	8.95	8.60	6.73	8
D7	1.47	8.33	8.35	4.41	6.86	5
D8	1.71	7.18	5.15	5.17	5.47	7

TCa: Adequate concentration time in hours, **Δ Tc:** Deference between the concentration times estimated by the topographic data extracted from the Tim map and the appropriate concentration time.

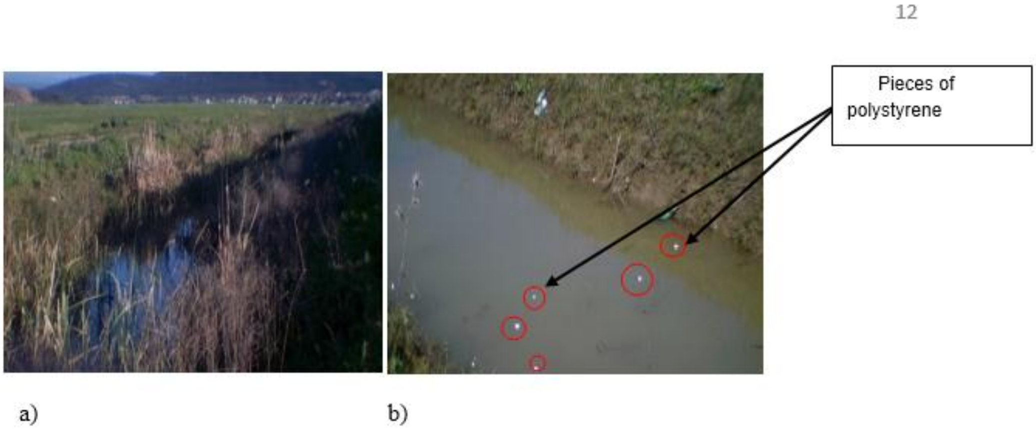

Figure 8: Channel D5 dated: 15/12/2018 **a),** channel D3 during test **b)** On: 03/12/2017 (Photo: Sennaoui F)

Conclusion

There are different methods that can be used for the design of drainage channels. This design is essentially intended for the determination of the cross-section and slope to ensure satisfied capacity. Our study presents an analysis for the determination of the capacity and adequacy of the drainage channels of the North East Bouteldja plain of Algeria based on the flow concentration time. The transformation of the Google Earth annual satilitarian photo on ARC GIS, meteorological data and the application of the Crupedix method to estimate peak flow, the new equation of Mockus concentration time as a function of critical slope, were used to model the system in order to know the operating condition of the drainage channels and their maintenance without moving on site. The results obtained from the analysis show that a relationship exists between the slope of the bottom and the concentration time. If the slope increases, the concentration time decreases. Finally, all the drainage channels in the study area currently require maintenance and rehabilitation. The most important channel to be maintained at present is the D5 channel, so through this analysis it is possible to establish a maintenance schedule and the priority intervention of drainage channels, in order to avoid flooding of agricultural land, thus intervening in sustainable development in the agricultural sector.

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