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Use of the Arc hydro Tools for the extraction of the hydrographic network of watersheds: case of sub-watershed of Oued Laussif (w) of Sétif, Algeria.

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ABSTRACT/RESUME

Abstract: *This research paper deals with the study of the morphological characteristics of the oued Loussif sub-catchment, located in the Wilaya of Sétif, Algeria. This study is part of a more general study on the hydrogeological study of the Kherzet Youcef deposit.*

In all fields interested in the study of spatial phenomena, a need for automation is emerging, especially for 'network' type geographic structures, given their systemic organization of space which is not explained in geographic data bases. In order to meet this need for automation, the use of Geographic Information Systems has proven to be profitable.

Morphological features such as flow accumulation, flow direction and stream network were extracted based on the digital elevation model (DEM), and the results were interpreted and analyzed. The Geographic Information System (GIS) based approach with the use of DEM facilitates the understanding of different morphological features represented in the thematic raster data maps, and the correlation between flow accumulations, flow direction, stream order and stream network was well explored.

The study represents the morphological features extracted from the DEM. The software used to perform the overall analysis was ESRI ArcGIS version 10.8 with ESRI Spatial Analysis Analyst extension and ArcHydro. The morphological features are effective in understanding the spatial distribution of the stream network and identifying potential groundwater locations.

I. Introduction

The management and preservation of water resources is a major global concern [1], [2], especially in countries with arid and semi-arid climates where the water heritage is constantly tested, given the growth of water needs (industrial development, population growth ...).

The study of watersheds is essential for hydrological reviews. Understanding the hydrological setting of rivers is a key elementary fact for decision making in several areas typically environmental planning and water resources use in the river watershed. The essential geographic boundaries of the watersheds, sub-watersheds, and stream network help to evaluate the data for watershed management activities.

Morphology plays a major role in understanding the controls on river process variability. Assessment of morphological parameters includes upstream and downstream, stream order, flow direction, flow accumulation, stream connection, and stream network that can be interpreted using a digital elevation model (DEM).

In the early days, topographic maps were the main sources of information for the origin of watershed characteristics in hydrological models; currently,

DEM is very important in hydrological studies, topographic characterization because it provides quick, economical and consistent information. [3]
We propose a methodology for watershed extraction and delineation using a geographic information system. Specifically, we will use a GIS to process SRTM data. From the digital elevation models, we will extract a representation of the hydrological network. This will allow for the delineation and characterization of individual basins, which are a key component of any hydrologic management [3], [4].
Automatic DEM extraction data has largely replaced manual demarcation of stream networks and watershed boundaries from topographic maps [5]. A few research works have suggested that the stream networks present in topographic sheets and also in satellite images correspond to the DEM data of the delineated stream network [6].
To analyze spatial morphometric parameters, it is essential to delineate the flow network [7]. DWS derivatives have a wide range of applications in engineering, such as elevation mining, cut and fill analysis, land reclamation, and slope determination to understand the geomorphology of the area [8]. Remote sensing (RS) and GIS have yielded critical results in delineating geography and landforms [9], [10], [11].

II. Materials and methods

II.1. Presentation of study area

The Kherzet Youcef deposit is located in the south-western part of the Ain Azel depression (north-eastern Algeria). This depression is part of a vast hydrological basin which spreads over more than 9580 Km² from the region of Ain Beida in the East to that of El Eulma in the West. The HRNA assigned it the number 07, under the name of the Constantinian highlands (Figure 1). The Ain Azel plain occupies the westernmost sub-watershed (s/BV), coded 07-01, Chott El Beida.

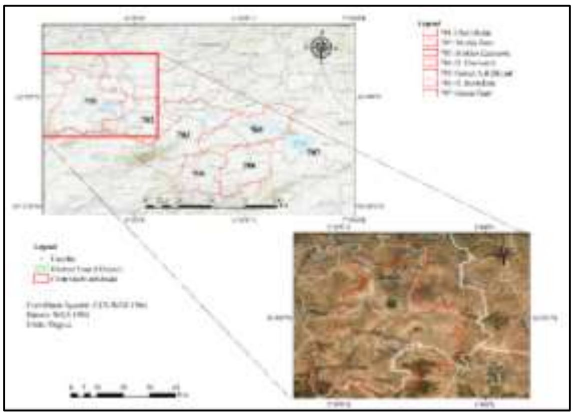

Figure 1. *Localization of Chott El Beida watershed*

At the scale of the Chott Beida sBV, the hydrographic network was disorganized by the combined effect of the tectonic phases of the upper Pliocene and the drying of the climate. This explains the existence of endoreic phenomena in the High Plains, crossed in the past by the upper branches of the Oued Rhumel, in particular Oued Dehamcha and Oued Dehab.
It is not very dense, and corresponds to a set of short and temporary wadis that drain most of the slopes, and are lost in the detrital formations of the plain. The drainage points correspond to the chotts and sebkha, which are very frequent in this region (Figure 2).

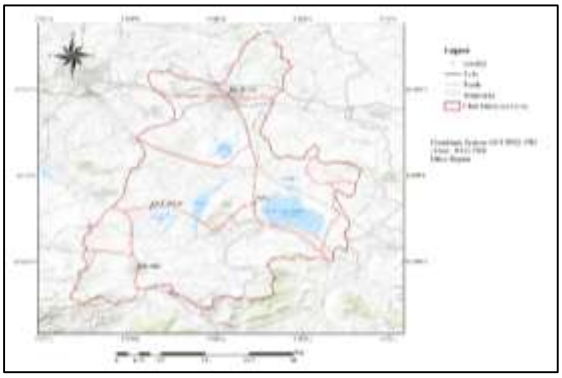

Figure 2. *Chott El Beida sub-watershed*

II.2. Methods

The extraction of morphological aspects using geospatial technology is the key objective of this study. This study also shows the interest of using GIS in the process of extraction of hydrological networks and delineation of the watershed.
The methodology adopted consists of exploiting and interpreting SRTM one-arc elevation data (30m spatial resolution) in order to map the watershed boundary and hydrographic network. These data were downloaded from the US Geological Survey website. The spatial reference for the study area is the World Geographic System of 1984 (WGS 1984) and UTM31N.
This methodology will also allow us to describe the different topographic parameters (slope, ridge, length of the river ...) and then delineate the slopes of the basins.
In the bibliography, many authors are interested in this approach, whose study requires the vectorization of the topographic background of the different areas of interest in order to generate the DEMs. According to Hingrey (2009) [12], this method of production leads to inaccuracies in some areas, hence the importance of remote sensing.
However, our approach has the merit of being simple and inexpensive. Indeed, the only medium required will be SRTM data, which are available on the Internet. Using the Archydro extension, the basic watershed parameters are derived. The flowchart of the methodology is shown in Figure 3. The results obtained using SRTM DEM are the flow direction,

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flow accumulation and flow network using Arcgis GIS software, version 10.8.

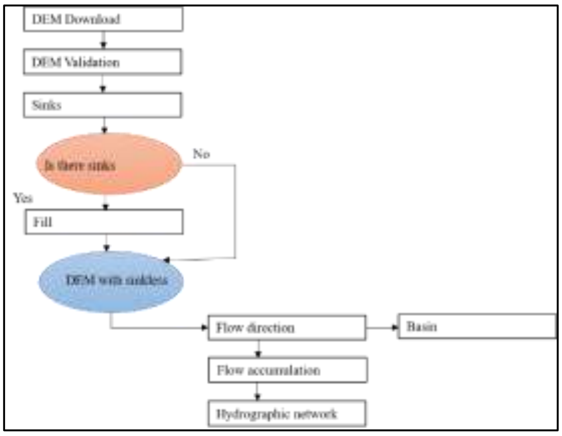

Figure 3. *Flowchart methodology*

III. Results and discussion

The Acrhydro module integrated with the ArcGIS 10.* provides solutions to various water management problems [13]. It has two components: the first concerns the management of the geospatial database related to water resources and the second includes all the analysis and data integration tools.
First, we proceed to the correction of ground anomalies, in order to avoid either calculation errors linked to altimetric artifacts or the generation of interruptions in the waterways. The sink-fill function is used to eliminate depressions in the DEM.
The process of delineating the watershed and extracting the hydrologic network from a DTM is as follows:

III.1. Validation of DEM

First of all, we proceeded to a validation of the DTM:
- We generated contour lines from the DTM, then overlaid them with those of the topographic map, (Figure 4)
- We also digitized the side points and entered the elevation values in the attribute table. At these same points, we extracted the height values from the DTM (thanks to the command: extract point values). The statistics on the height values are shown in figure 5.

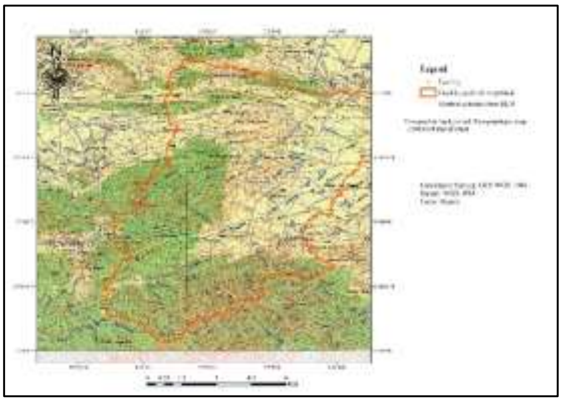

Figure 4. *DEM validation*

On the whole, the height values are close. Slight differences were recorded.

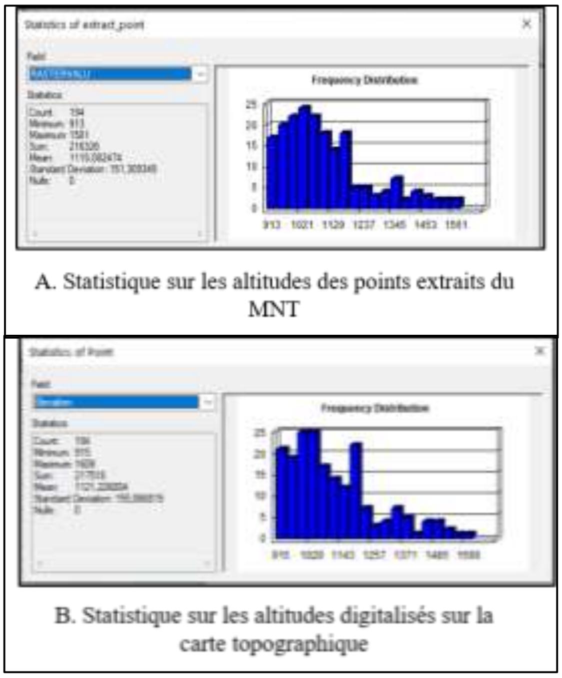

Figure 5. *Comparison of altitude statistics to validate the DEM*

III.2. Correction DEM

Afterwards, we proceed to the correction of the ground anomalies, in order to avoid either calculation errors related to altimetric artifacts or the generation of interruptions in the waterways. The pit fill function is used to eliminate depressions in the DTM.

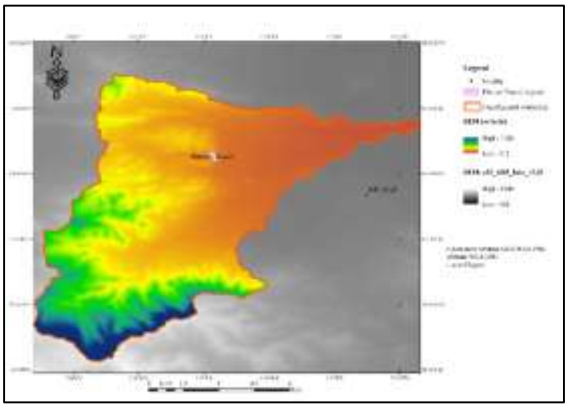

Figure 6. *DEM Correction*

As show above in Figure 6, the value of altitude in Oued Laussif sub-watershed vary between 912m and 1626 m.

III.3. Determination of flow direction

This method assumes that the topography is a good indicator of the gravitational potentials involved in surface flow processes [14]. The program then uses the D8 algorithm [15] which determines the direction of flow using the maximum slope gradient (unidirectional diagram) (Figure 7). This calculates the direction of flow in each cell. It corresponds to the path with the largest gradient.

The flow direction raster presents the different direction of flow possible, as presented in table 1 each code presents a direction (i.g. the code 1 presents the direction East).

The table 1 shows the surface of each direction in percent. We notice that the dominate direction flow are North (24%), and South and East (15.18 % and 15.01 successively).

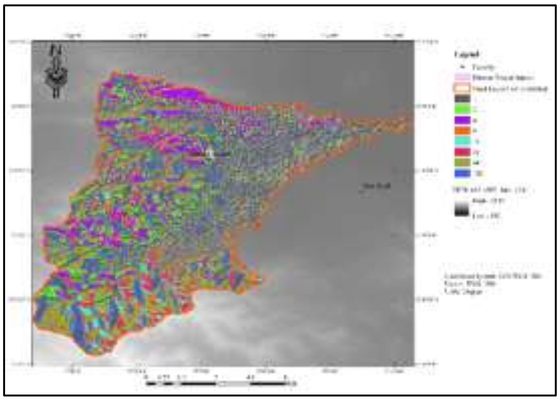

Figure 7. *Flow direction raster*

III.4. Determination of flow direction

The result of this operation is a grid representing the cumulative number of upstream cells (in the direction of gravity flow) flowing into a given cell (Figure 8). The calculation requires the determination of a threshold corresponding to the minimum drainage area and a well-defined cumulative number of cells. The result represents a drainage network with a number of cells at least equal to the threshold set from the beginning. Figure 8 shows that the cells located at the mouths take high values, a predictable result since they receive all the water generated by the basins.

Table 1. *Surface of each direction in percent*

Value	Direction	Count (Pixel)	Percentage (%)
1	East	14306	15.01
2	South-East	11516	12.08
4	South	14470	15.18
8	Southwest	4225	4.43
16	West	5779	6.06
32	Northwest	7663	8.04
64	North	22831	23.95
128	North-East	14523	15.24

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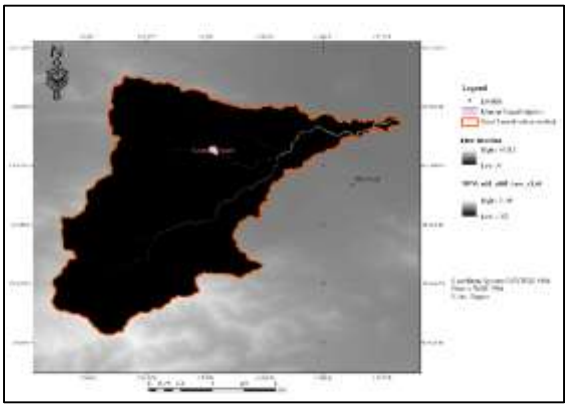

Figure 8. *Flow accumulation raster*

The value of 95312 presents the accumulation of numbers of cells passed on the flow direction raster.

III.5. Classification of hydrographic network

The hydrographic network obtained was validated by superimposing it on the topographic map (Fig. 9). We observed a significant discrepancy and mismatch in geographical position between the stream network derived from the digital terrain model (DTM) and the reference document, specifically the 1:25000 topographic map. This discrepancy is due to the different geodetic system used in different data.
The hydrographic network obtained has a unique identification, it is coded by order 1. However, a classification of the branches is based on the number of tributaries by applying the Strahler method (Fig. 10).

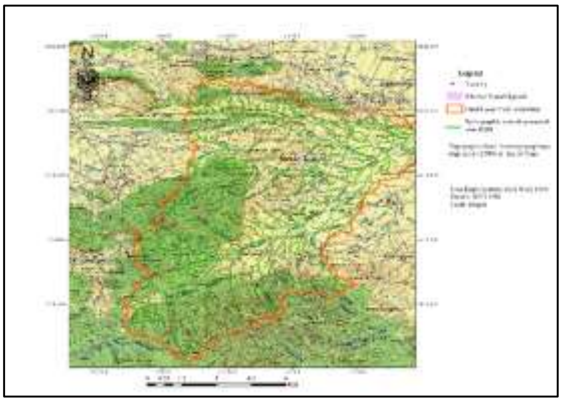

Figure 9. *Hydrographic network validation*

This classification provides an unambiguous description of the development of the drainage network of a basin from upstream to downstream [16]. Once classified, the modeled network is converted to a vector. The transition from raster to vector mode is an integrated operation and one of the key concepts of the Arc Hydro model.

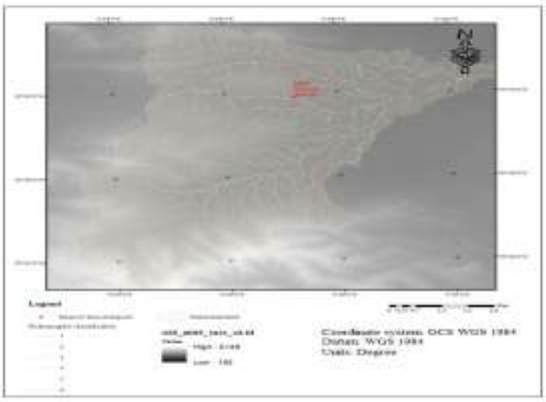

Figure 10. *Hydrographic network classification*

Table 2. *Comparison between the length of wadi tributaries (topographic map and automatic extract)*

Name of the affluent	Length on the map (m)	Length automatic extracted (m)	Difference (m)	Percentage (%)
Oued Loubibat	5753.46	5646.52	-106.94	-1.86
Oued Loussif	6311.08	6269.36	-41.72	-0.66
Oued Guetrane	11606.33	11725.72	119.39	1.03

IV. Conclusion

The hydrological network was extracted from the SRTM datasets. The modeled drainage map shows a flow that is mainly from the southwest to the northeast.

The SRTM data covering the Ain Azel plain area is integrated into a GIS.
We then proceeded to a morphometric characterization of the different hydrological units (calculation of indices of shape, relief, drainage density ...).

To validate the methodology, we cross-reference the results obtained with the digitized network from a topographic map covering the study area. It should be noted that the network modeled in Arc hydro almost coincides with most of the main rivers, with some local differences of metric order. These differences may be related to the resolution of the SRTM data (1 arc second) and the different geodetic system used for different data. This study also demonstrated the acceptable accuracy of the SRTM data and the possibility of using them to conduct hydrological studies in Algeria.
However, it should be noted that the issue of the accuracy of the results remains in question when applied in practice. The results obtained in these studies are typically considered with caution, as they may not be applicable to smaller watersheds such as micro-basins or partial basins. In particular, when conducting hydro-morphological studies, a high level of precision is essential when conducting modeling studies. This is particularly important in the case of small basins, where the results obtained can have a significant impact on the overall understanding and management of the watershed.

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