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Using cartographic documents and GIS for creation a hydrodatabase. Application on Hodna Basin, Algeria

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ABSTRACT

Context and background

Rains, which are the main source of surface and ground water resources, provide a quantitative explanation of variations in the components of the hydrological regime in its broadest design. The Hodna watershed, situated in northeastern Algeria, is strongly marked by an arid climate highlighted by low rainfall. The latter, although weak, fall in the form of showers resulting in flooding flows.

Goal and Objectives:

Creating a Hydro database by multi-criteria approach is a line of research to provide a methodological framework for thematic and numeric mapping. This work is intended to establish a models of geographic hydrodatabase and models of mapping with "thematic and spatial" analysis through a GIS (Geographic Information System) approach.

Methodology:

The study used is to create thematic maps by combining in GIS, by representing the information collected in the form of maps and the Data tables, was carried out using the software "ArcGIS" by the exploitation of the data available at our level: DRE (Water Resources Directorate) and ANRH (National Agency of Water Resources).

Results:

As a result, a hydrodatabase was identified (DB), followed by the creation of Models of a Geographic Database (MGDB) for this basin and the assessment and estimation of groundwater and surface water in the Hodna Basin. The analysis of the hydrological data revealed that the surface water flow rate is influenced by physical characteristics and by meteorological parameters. The study provided firstly, the development of several maps with an improvement and an organization of information and rapid decision-making, then the Arc-GIS allows a great user-friendliness at the level of the design and at the level of the use of the application and finally access to the data is simplified, the queries are executed and the results are fed into the statistical calculations and the cartographic representation.

Keywords :

Cartography, HydroDatabase, GIS, Hodna basin, Hydrology.

Utilisation de documents cartographiques et SIG pour la création d'une hydrobase de données.
Application sur le bassin du Hodna, Algérie

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Résumé

Les pluies sont la principale source de ressources en eaux de surface et souterraines. Elles fournissent une explication quantitative des variations des composantes du régime hydrologique. Le bassin versant du Hodna, situé au nord-est de l'Algérie, est fortement marqué par un climat aride accentué par de faibles précipitations. Ces derniers, bien que faibles, tombent sous forme d'averses entraînant des crues. La création d'une Hydro-base de données par approche multicritères est un axe de recherche visant à fournir un cadre méthodologique pour la cartographie thématique et numérique à travers une approche par Système d'Information Géographique (SIG). L'étude consiste à créer des cartes thématiques en combinant dans des SIG, en représentant les informations recueillies sous forme de cartes et de tableaux de données, a été réalisée à l'aide du logiciel « ArcGIS » par l'exploitation des données de la base de données disponibles à notre niveau : DRE (Direction des Ressources en Eau) et ANRH (Agence Nationale des Ressources Hydrauliques). En conséquence, une hydrodatabase a été identifiée (DB), suivie par la création de modèles de base de données géographiques (MGDB) pour ce bassin et l'évaluation et l'estimation des eaux souterraines et des eaux de surface dans le bassin du Hodna. L'analyse des données hydrologiques a révélé que le débit des eaux de surface est influencé par les caractéristiques physiques et par les paramètres météorologiques. L'étude a fourni dans un premier temps, l'élaboration de plusieurs cartes avec une amélioration et une organisation de l'information et une prise de décision rapide, puis l'Arc-GIS permet une grande convivialité au niveau de la conception et au niveau de l'utilisation du l'application et enfin l'accès aux données est simplifié, les requêtes sont exécutées et les résultats alimentent les calculs statistiques et la représentation cartographique.

Mots clés :

Cartographie, HydroDatabase, SIG, Bassin du Hodna, hydrologie.

1. INTRODUCTION

The Hodna watershed was chosen as an area of application of our work because of its vast surface area therefore a maximum number of sub-watersheds (08 sub-watersheds) and so on a great variability of the physical characteristics which influenced by the flow of water where Zeiringer et al., (2018) reports that the water cycle and climatic conditions form the boundary conditions for the hydrological regimes that define distinct seasonal flow patterns. The characterization of the time and space variables that govern the hydrological cycle, as well as the analysis of changes in surface conditions are essential for the effective management of water in a watershed (Bewket et al., 2005).

New technologies and digital tools appear as tools adapted to knowledge of water resources (Dupont et al., 1998) as well as for their rational management. During the last decades, the use of mathematical models (Singh et al., 2002) has become common in the procedures of development and management of water resources in a given territory such as flow characters are the aim of many hydrological field and modeling studies (Angermann et al., 2017). The coupling of earth observation techniques with mathematical modeling makes it possible to take into account the spatial and temporal variability of the processes and of the various state variables at the basin level (Fortin et al., 1995).

Water is one of the elements of life. Its interest has prompted many scientists to do extensive research in order to better control and model its cycle. Several sciences have arisen from these studies carried out over the centuries, among which we find fluid mechanics, hydraulics, hydrology ....., depending on the goal and the object that we want to model and estimate, we choose the discipline suited to the purpose of the study. Hydrology can be defined as the study of the water cycle and the estimation of its various flows (Laborde., 2009).The interest of these studies is to determine the needs and management of this resource. This resource has become a problem that occupies today's world and that worries hydrologists and climatologists who fear disastrous consequences for human life, the environment and industry.

Geographic Information System (GIS) is a "computer system of hardware, software, and processes designed to enable the collection, management, manipulation, analysis, modeling, and display of spatially referenced data in order to solve complex problematic problems planning and management " (Ficcdc., 1988). It can also be defined as a "set of data identified in space, structured in such a way as to be able to conveniently extract from them syntheses useful for decision-making" (Didier., 1990). The use of GIS for screening is normally done by classifying an individual map, according to selected criteria, into precisely defined classes or by creating buffer zones around the geographic features to be protected. Charnpratheep et al.,1997 ; Keir et al., 1993, the use of raster and vector-based GIS for the large-scale site selection process. Today, the development of modern techniques for acquiring and providing digital information has made it possible to represent both the topography of the environment by means of digital altitude models (DEM) as well as the representation of land use through aerial photographs or satellite data. This information is increasingly used to describe the physical characteristics of watersheds and to digitally map their coverage (Hamenni., 2011). The objective of our work is to make a study on the hydrology of the Hodna watershed, the evaluation, the estimation of the water found in the basin and the creation of a spatial database managed by a GIS.

2. BASIC DATA

2.1. General presentation of the study area

The Hodna watershed with an area of 25856 km^2 is the fifth large basin of Algeria. This watershed is of the endorheic type located between latitudes 36 ° 10 '54.9' 'in the North and 34 ° 21' 3.9 '' in the South and between longitudes 3 ° 10'12 '' West and 6 ° 9 '36.2' 'East (Figure 1).

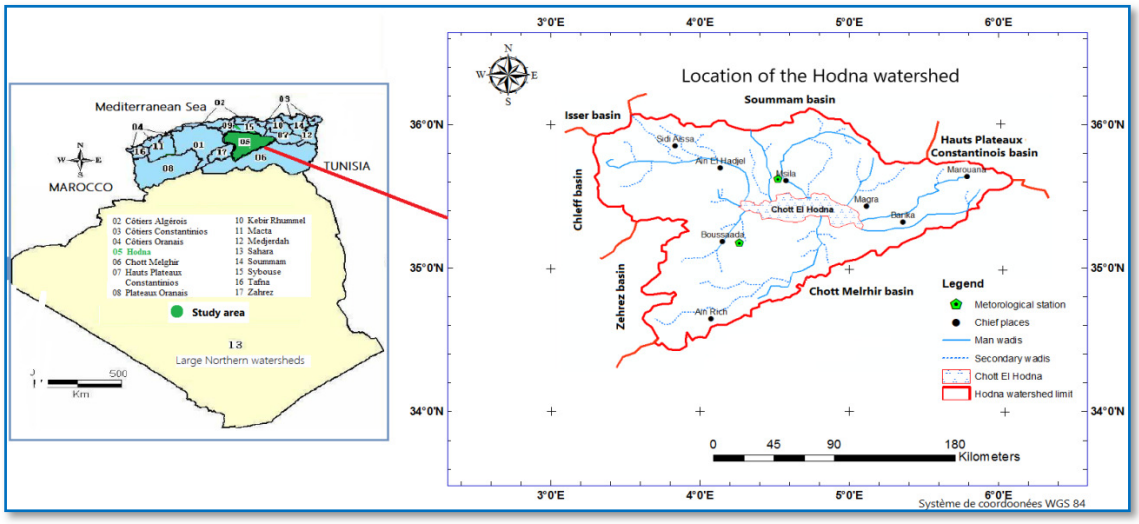

Fig.1. Location map and situation of the Hodna watershed area in the Algerian watershed areas.

It is limited to the North by the montages of Bibans and the Sétifien plateau, to the West by the high Algerian plains, while to the South and to the East, it is limited by the Saharan Atlas. This basin is drained by only four main wadis are perennial, although their flows are very low (Adoui., 2013 and Boumezbeur., 2002), Oued El Ham, Oued K'Sob, Oued Barika and Oued M'Cif. The relief of the basin is characterized by a series of mountains to the North and South around a natural depression called Chott El Hodna almost flat with an altitude of 400 m and an area of 1150 km^2 (Kebiche., 1994).
Stretching from Boussaada to M'doukal, the R'mel region features a landscape of sand dunes and steppes (Zeroual., 2016). The altitude of the peaks of the Hodna Mountains decreases from East to West with an altitude that oscillates between 1900 and 1000 m, while to the South only a few peaks in the Saharan Atlas reach 1200 m.

2.2. Materials and methodological approach

Creation of an "HydroDataBase" for the basin

This is a data bank, spatial and semantic, hydrological and data in relation to water resources.The first phase consists in collecting the necessary geographical, climatic and hydrological information. These data are obtained from field campaigns, consultation of old works (documentation), digitization of existing maps.

Data modeling consists of transforming the real world into an easy-to-process conceptual diagram with computer tools that consists of capturing this information and transferring it digitally into the HydroDataBase using a platform on which the software for our study is located (see the description of the method below).

2.2.1. Hydrological study

2.2.1.1. Data collection

The data collected are rainfall and hydrometric data. These were then subjected to a statistical and cartographic analysis. The hydrometric and hydraulic data concerning the Hodna Basin were collected from the two organizations :Direction des Ressources en Eau : DRE, and the Agence National des Ressources Hydrauliques : ANRH [Water Resources Directorate and the National Agency of Water Resources] of the M'Sila province .The rainfall data collected from the meteorological stations of M'Sila and Boussaâda and also the collected data were compiled from the various works on the Hodna tell that the works of Bouthelja., 2005 ; Hasbaia., 2012 ; Hadjab., 1998 and Roche., 1963 concerned as well as various studies carried out in the region, such as:

- The sheet that contains the characteristics and main wadis of Hodna sub-basins is illustrated in the Table 1 below :

Hodna sub-basins	Characteristics		Main Wadis	
	Area, km²	Average altitude, m	Name	Length, km
El ham	618,00	819	El ham	110
Leham	638,60	710	Leham	30
Lougman	337,00	650	Lougman	60
K'sob	3641,00	870	K'sob	06
Soubella	183,87	790	Soubella	61
Barika	3823,00	920	Barika	102
Boussaâda	2953,70	670	Boussaâda	59
M'cif	5321,00	950	M'cif	104

Table 1. Characteristics and main wadis of Hodna sub-basins (Hasbaia., 2012 and ANRH., 2018)

- Water potential in the Hodna basin

  - **Surface water (Dam and hill reservoirs):**Surface water potential in the Hodna basin is based on the annual flow of the wadi in sub-basins (Tables 2 and 3).

  -

Hodna sub-basins	Average annual rainfall , mm	Average annual Temperature , °C	Concentration time, h	Flowing, Hm³/y
El ham	250	15,44	31,01	66,0
Leham	292	16,20	04,56	62,2
Lougman	300	16,27	07,88	15,0
K'sob	300	15,80	13,36	30,0
Soubella	250	15,70	06,30	12,0
Barika	345	15,00	14,82	54,0
Boussaâda	290	16,50	11,35	09,0
M'cif	251	14,70	28,83	40,0
El ham	250	15,44	31,01	66,0
Leham	292	16,20	04,56	62,2
Lougman	300	16,27	07,88	15,0

Table 2. Surface water potential of the Hodna Basin (D.R.E of M'sila.,2018)

Hodna Sub-basins	Dam / Hill reservoirs	Capacity (m^3)
K'sob	K'sob dam	29, 500,000
	Witlanhill reservoir	850,000
Soubella	Soubella dam	12, 000,000
El ham	Kodia ben abda dam	44, 000,000
	Oued cheair hill reservoir	250,000
	Ouelad Abd El Wahab hill reservoir	3,000,000
M'cif	M'cif dam	18, 000,000
	Kheng Kodia Bo Abd Allah hill reservoir	300,000
	Mizaror hill reservoir	95,000
	Targa hill reservoir	130,000

Table 3. The capacity of the dams and hill reservoirs of the Hodna basin (D.R.E of M'Sila., 2018)

- ***Groundwater:*** The groundwater resources contained in the Northern Algerian aquifers (renewable resources) are estimated at about 2 billion m^3/y. The surface resources are estimated at 12 billion m^3/y (Table 4).

Water tables	Source of the study	Potentiality (million m^3/y)
Chott El Hodna water table	F.A.O	133
Ain Riche water table	A.N.R.H (M'Sila)	08
Zahrez Chergui water table	Design bureau (AQUA-COSULT)	24
Hodna Mountains (Northeast-Northwest) water table	M'Sila Irrigation Directorate	52 *Probable estimates From the M'sila Irrigation Directorate*
Birin Djelfa water table	A.N.R.H (Djelfa)	03

Table 4. Groundwater estimate in the Hodna Basin

2.2.1.2. Data processing tools

GIS helps manipulate computer data to simulate alternatives and make the most effective decisions (Narayan., 1999). The processing of the data collected was carried out in various forms:

- The transfer of data collected from our study area to the Arc Gis software;
- A GeographicDataBase (GDB) created through this software to bring together the various information concerning the hydrology of Hodna;
- Use of Arc GIS 10.7 software for thematic cartographic representations. In general, it should be noted that the analyzes were carried out by the latter.

2.2.2. Cartographic study

2.2.2.1. Maps collection

The maps that were used in this work, as well as other thematic maps, map of watersheds of northern Algeria, map of the Hodna hydrographic network, maps of the hydrographic network (surface water and groundwater) of northern Algeria and the topographical map of the Hodna basin, obtained from the Water Resources Directorates (DRE) and the National Water Resources Agency (ANRH) of the M'sila province (Table 5). Several types of maps were taken into account in the development of the GIS.

Data type	Scale	Support	Date

Hodna watershed situation map in all the Algerian watersheds	1/25000000	Scan	2018
Rainfall map of Northern Algeria	1/2000000	Scan	1993
Map of the Hydro-Climatological Network and Water Quality Monitoring	1/500000	Scan	2005
Hodna basin sub-watershed map	1/25000000	Scan	2002
Hodna basin hydrographic network map	1/25000000	Scan	2002
Map of groundwater resources in northern Algeria	-	Scan	2009
Landsat Image / Copernicus (Google Earth Pro)	-	Digital	2018

Table 5. The map data used

2.2.2.2. Maps processing

It is the choice and processing of geographical information (sources, types of data, forms of distribution, methods of discretization...) then its proper representation through the cartographic design and realization (graphic semiology, background map, dressing and layout of a cartographic image...). In our work, the maps processing was carried out by the software Arc GIS 10.7. The hydrometric and topographic data related to the hydrology of the Hodna Watershed were extracted after appropriate treatment of the maps.

2.2.2.3. Thematic mapping

One of the main strengths of a GIS is the thematic map design (www.sigcours.com).

The establishment of presentation cards is the operation by which the cartographer communicates an idea or a concept to the reader (Monmonier, 1993). The study of surface water distributions, groundwater in the Hodna Basin and their characteristics requires thematic maps for hydrological studies, such as:

- Relief map and altitude classes repartition (Figure 2):

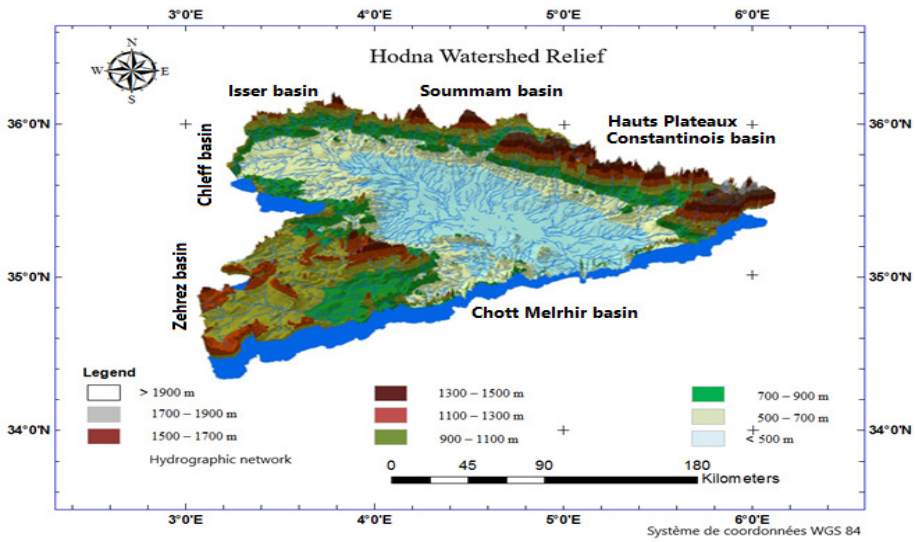

Fig. 2.Hodna Watershed Relief map and altitude classes repartition

- Rainfall map (Figure 3):

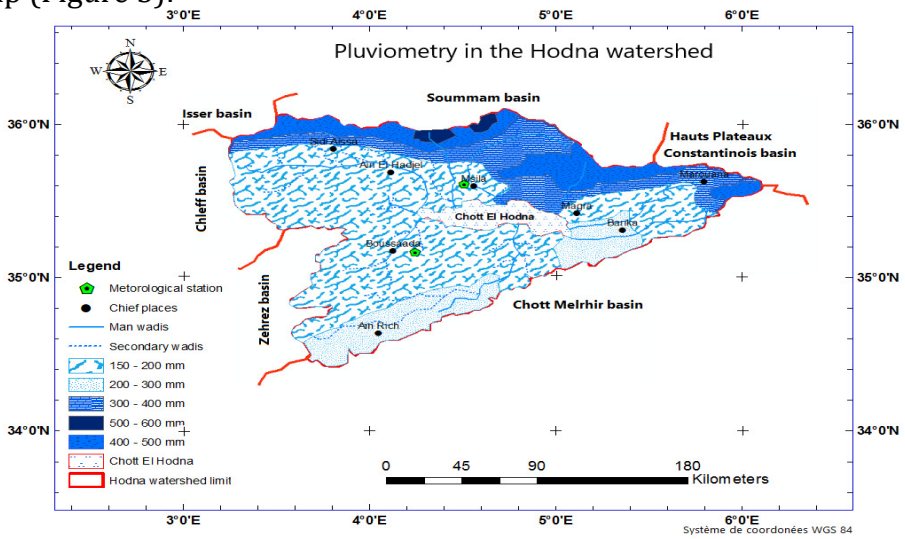

Fig. 3. Pluviometry in the Hodna basin

- Hodna sub-basins map (Figure 4):

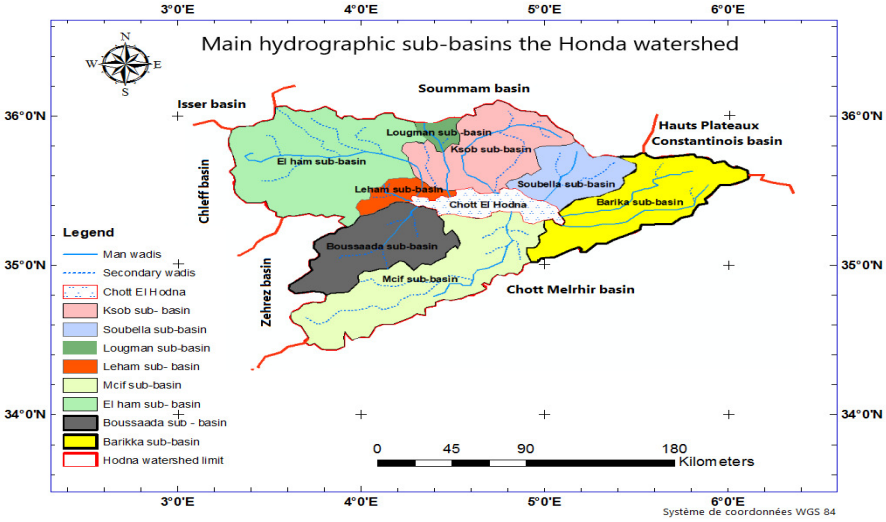

Fig. 4. Main hydrographic sub-basins the Hodna basin

- Surface water map (Figure 5)**:**

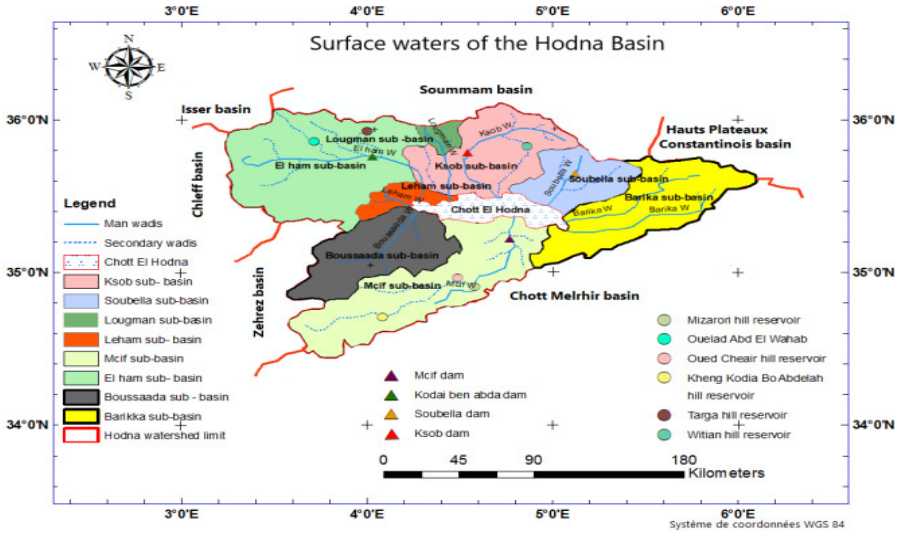

Fig. 5. Surface waters of the Hodna basin

- Groundwater map (Figure 6) :

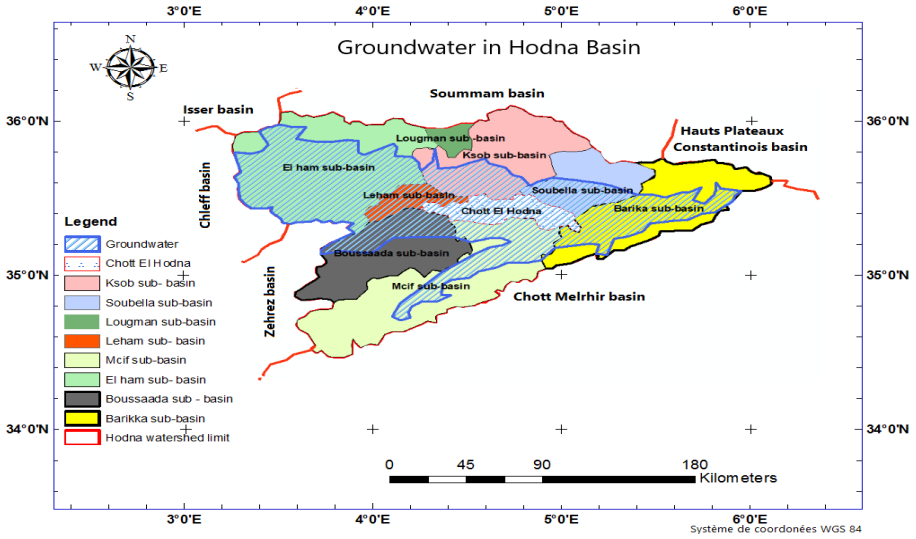

Fig. 6.Groundwater of the Hodna basin

- Hydrographic network Map (Figure 7):

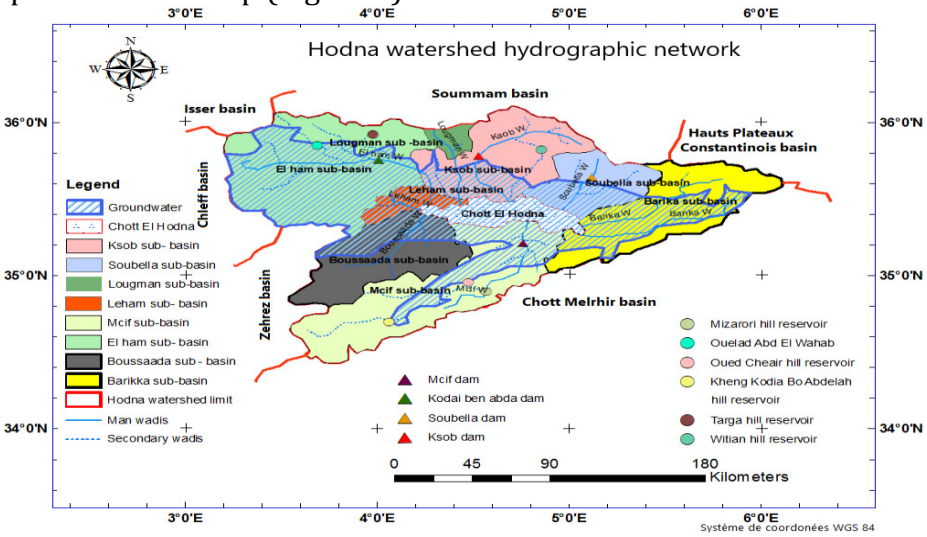

Fig.7. Hydrographic network of the Hodna basin

2.2.3. Description of the method

Referring to Ludwig et al. (2003) we used and exploited firstly hydrological and meteorological data then we operate by modeling the geographic data through several stages, the main ones of which are: data collection, georeferencing, conversion of this data to a digital medium, analysis and visualization of information. Figure 8 represents the 7 steps taken in this work for the implementation of the GIS for the creation of a watershed hydrological database.

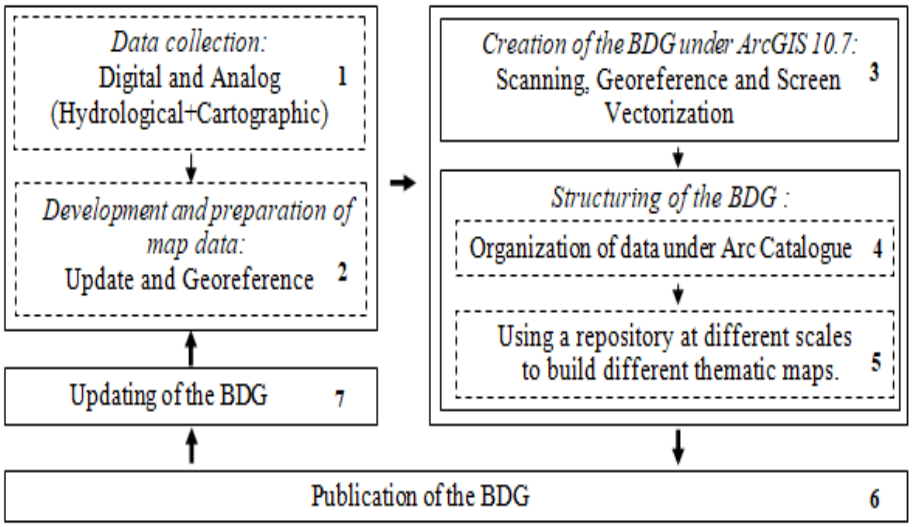

Fig.8. Methodology adopted for modeling geographical data

3. Results

3.1. Climate and hydrology

The region can be subdivided into three different climatic zones: In the south, in the Saharan Atlas, where the altitude is of the order of 800 to 900 m in general, the rainfall is lower with, on the other hand, much softer and even colder temperatures in winter. The interior of the basin of the Hodna, formed of the plains where the altitudes oscillate between 400 and 700 m, is isolated from the maritime influences by the sufficiently high Tell to the north, but subjected to dry sand storms due to the relatively low relief Saharan atlas. The climate is harsh, winters are cold with periods of frost and summers are very hot. To the north, in the Atlas Tallinn which culminates up to 1800 m of altitude, the climate is much more watered, with more inland (the region of BordjBouArreridj), entries of the marine winds. The annual thermal gradient as a function of altitude is 0.75°C for an increase of 100 m altitude, compared to the average gradient allowed in Algeria of 0.55°C/100m (Bouthelja., 2005). A precipitation is very irregular and sometimes rare, with periods without rains of more than six months. Snow cover is required almost every year in the mountains of the two atlases at the rate of 15 days/year. The average annual rainfall is 400 mm in the north and 200 mm in the south (Figure 3). The devastating rains are present almost every year with human damage and huge solid transport. In space, the variability in quantity is also notable, as the watershed encroaches on various latitudes (Grine., 2009).The calculated annual potential evapotranspiration varies between 1085 and 1362 mm; for most of the basin it is about 1250 mm. The annual average evaporation measured at the M'Sila Station (US Class A Evaporation Pan) after its correction for large free surface evaporation is 2120 mm (Hedjazi., 2009).

The basin region is formed by eight (08) sub-watershed of endoreic character, generally. Each of these sub-basins is covered by a main wadi and its effluents the outlets of these sub-basins meet in an almost salty depression, called Chott El Hodna. The most important of these sub-basins are those of El Ham wadi, K'Sob wadi, Barika wadi and M'Cif wadi.

3.2. Assessment of water potential and creation of geographic database models (GDBM)

- **Basin surface water assessment and creation of a Geographic Database Model (GDBM)**

The results of the thematic analyses of the data obtained from the ANRH and DRE give an estimate of the annual contribution of the Hodna watershed at 288.2 a hm^3 / year. It is noted that the annual flow is greater in the sub-watersheds (Barika, El Ham, Leham, M'cif), because of their high precipitation, with a low contribution to the other sub-watersheds (K'sob, Soubella, Lougman) by what it contains dams, but the case of sub-basin of Boussaâda because of their low precipitation (Figure 9a).

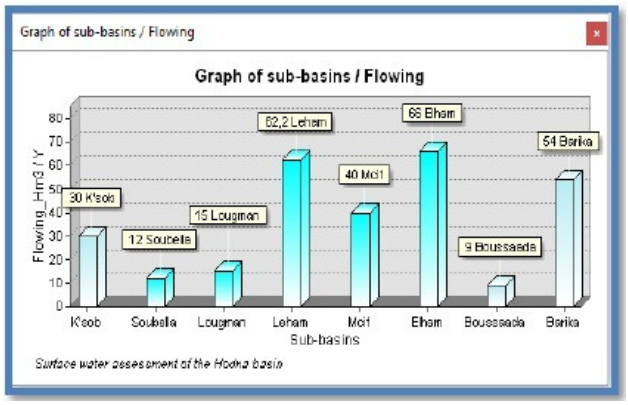

Fig.9a. Surface water assessment of the Hodna basin

A database is a "data structure for receiving, storing and providing data on demand to multiple independent users" (AFNOR-ISO., 1989). The Geographic Database Model (GDBM) is used to formalize the description of the information that is stored in the GIS (Ider., 2004). The core of the GIS-hydrological study is a geographical database incorporating a set of thematic layers (distribution and evaluation of water... etc.) analysis campaigns. In sum, eight (08), main hydrographic sub-basins, their hydrology distributed as follows have been integrated into the GIS (Figures 9b and 12).

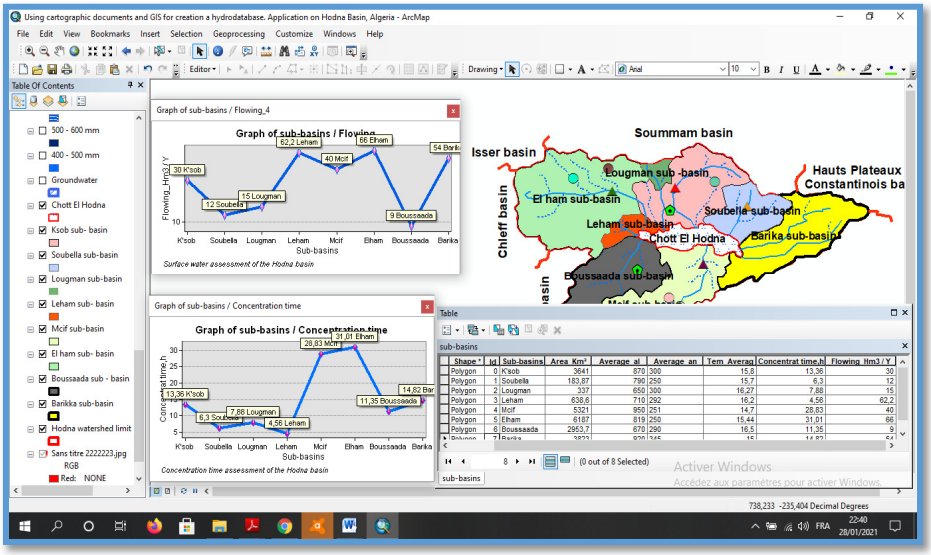

Fig. 9b. GDBM - Distribution of surface water in the Hodna Basin

- **Basin groundwater assessment and creation of a Geographic Database Model (GDBM)**

The assessment and estimation of groundwater in the Hodna Basin based on data analysis at was estimated to be 168 million m^3 divided into four aquifers. With the largest storing in the Chott El Hodna water table 133 million m^3, which affects all sub-watersheds except the Lougman sub-basin, and also the Ain rich water table 08 million m^3, it only affects the M 'cif sub-basin. On the other hand we have the Birin water table of 03 million m^3 it affects a small part of the El Ham sub-basin and the Zahrez Chergui 24 million m^3

water table affects the two sub-basins El Ham and Boussaàda. After the thematic analyzes it is concluded that the El Ham sub-basin contains the largest stock of groundwater in the Hodna basin, which contains three aquifers. The assessment and estimation of groundwater in the Hodna Basin based on data analysis at was estimated to be 168 million m^3 divided into four aquifers (Figures 10a, 10b and 12).

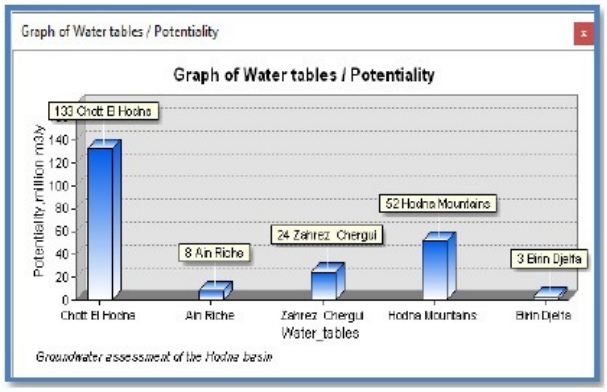

Fig.10a. Groundwater assessment of the Hodna basin

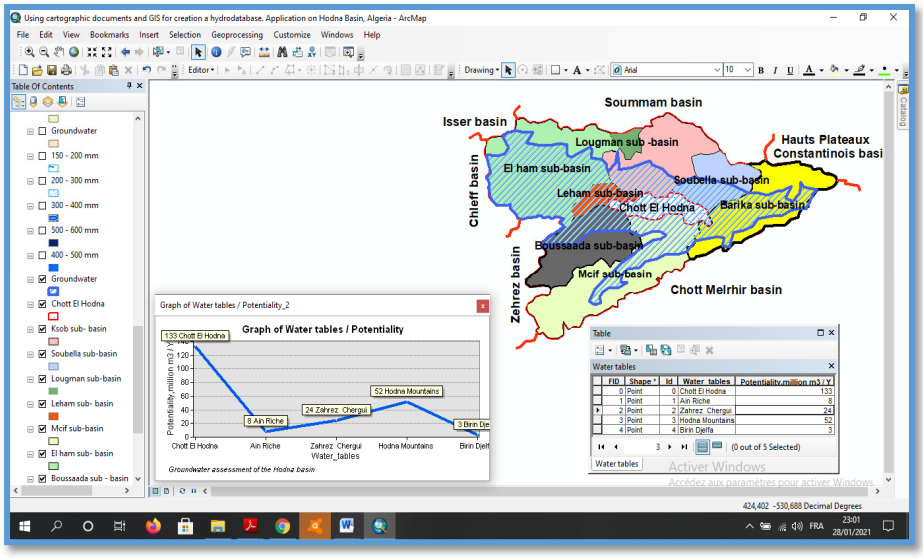

Fig. 10b. GDBM - Distribution of groundwater in the Hodna Basin

- **Basin water resource mobilizations assessment and creation of a Geographic Database Model (GDBM)**

According to the data collected there are four dams and hill reservoirs in the Hodna basin.The K'sob and Soubella dam with a capacity of 29.5 million m^3, and 12 million m^3, the M'cif dam which is under study with a capacity of 18 million m^3, and the kodia Ben Abda dam which is short of realization with a capacity of 44 million m^3, in the future it will be the biggest dam in the Hodna basin (Figures 11a, 12).

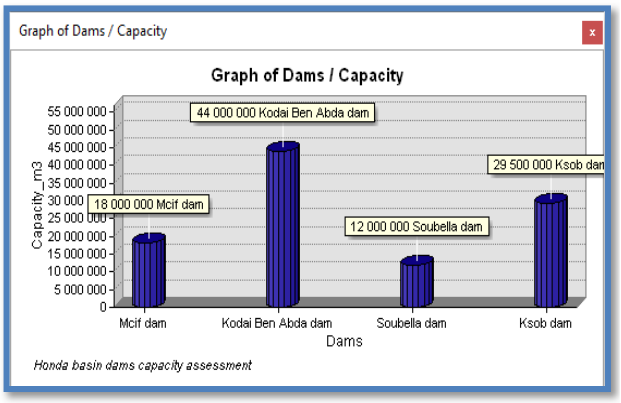

Fig. 11a. Hodna basin dams capacity assessment

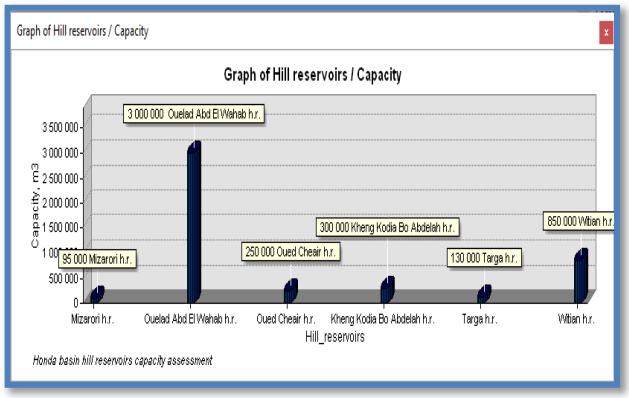

Fig. 11b.Hodna basin hill reservoirs capacity assessment

Therefore, the assessment of the mobilization of Hodna basin water resources was estimated at 108.125000 m^3, which is a lower number per report the potentiality in basin surface water, which is estimated at 288.2 hm^3 (see Figure 12).

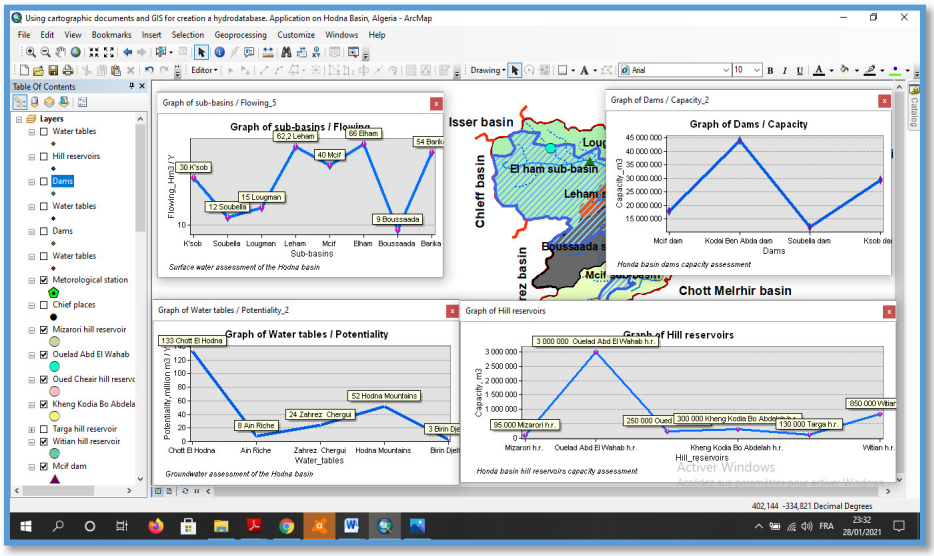

Fig. 12. GDBM - Evaluation and distribution of Hodna watershed water

4. Discussion

In developing regions, including North Africa like Algeria, data scarcity is a strong barrier to strategic environmental and socio-economic assessments (Falchetta et al., 2020) like the case of this study which concerns the establishment of a database for a vital resource: water.

The Hodna watershed is equipped with significant water potential. It is subdivided into eight hydrogeological sub-basins. Most permanent wadis are supported by groundwater during dry periods (BGS., 2019). Among the main wadis that flow in this basin, we have the wadis of El Ham, Soubella, Barika, Bitam, M'cif, Boussaâda, and K'sob. The arrangement of the northern and southern mountainous reliefs organize the Hodna watershed around a closed basin, located at an altitude of 400 m, and which receive the flow of surface and underground water from this region. At the bottom of the basin, Chott El Hodna has an area of 1,150 km^2 (Kebiche., 1994).

The actual water potentials of the Hodna watershed vary from year to year, depending on the amount of annual rainfall. Three quarters of the total flow of the wadis of the Hodna depends on precipitation and whose figure is estimated between 60 and 70% of the total runoff of the Hodna, the rest is the result of small temporary rivers and the runoff which takes on great importance during severe thunderstorms (Ladgham-Chicouche and Zerguine., 2001). The surface water potential (dams and hill reservoirs) in this basin is based on the annual contribution of the flows of the existing wadis in the sub-basins mentioned above.

The problem is much more serious than one might imagine, it is no longer a question of the loss of water capacity, but rather the destabilization of the structure. In reality, the water from the leaks is not lost, it can be collected and reused for agriculture and, if necessary, let it infiltrate to replenish the water table (Kachi., 2016).

The lack of groundwater resources is justified by the low permeability of much of the land in the basin (Achour., 2013). The groundwater resources in the basin region are divided into these eight hydrogeological sub-basins. Each of these sub-basins contains a water table and a deep system of different aquifer levels. The characteristics (area, average altitude, average annual rainfall, average annual temperature, concentration time and flows), length of wadi, annual surface water supply, capacity of dams and hill reservoirs and estimation (Potentiality) of groundwater in these sub-basins requires the comparison of maximum information from various sources.

On the basis of available data and previous studies carried out of this region (Hasbaia., 2012; DRE M'Sila, period 2002/2018; Achour., 2013; ANRH, period 1969/2018) and using new technologies for the treatment of Geographic information, we are trying to assess and estimate the water found in the basin, and develop a database (HydroGeoDataBase) using GIS like the work operated in the River Têt (Southern France) about hydroclimatic response (Ludwig et al., 2003).

A database is implemented in order to create georeferenced maps (Geoffetti et al., 2019). The database exploitation in our case allowed us to extract several thematic maps. Its contribution is certain because it allows any user or consultant of the HydroGeoDataBase to make the desired semantic map or table just by selecting the layers that form the chosen theme. ArcGIS software enables the creation of two- or three-dimensional maps, structural maps defining the geometry of each hydrogeological sub-basin. In the end further investigations are needed to consolidate our findings.

5. Conclusion

The knowledge and the study of the hydrological and physical behavior of the rivers in this Hodna basin are therefore of major importance and make it possible to produce a few models and thematic maps, such as MBDG Geographic Database Models, DTM Digital Terrain Models, and several thematic maps. The main objective of this work is based on the hydrological and geomatics study in this area. The methodology is essentially based on the collection, grouping, and processing of data with ArcGis 10.7 software. After an analysis of hydrological data available from various sources, the hydrometric and pluviometric characteristics of this watershed were determined. In this regard, it should be stressed that the flow of surface waters from the studied perimeter is influenced by the physical characteristics and the meteorological parameters of the region. A hydrological study and exactly on the hydric potentialities on the contribution of Geographic Information Systems (GIS) for the

development of a database within the Hodna watershed, several fundamental points should be noted like the development of several maps with an improvement and an organization of information and rapid decision-making, also the Arc-GIS allows a great user-friendliness at the level of the design and at the level of the use of the application and finally access to the data is simplified, the queries are executed and the results are fed into the statistical calculations and the cartographic representation.

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Author contributions in the paper:

- Dr. Djamel KHOUDOUR: Execution of the investigation and prospecting, sampling, data analysis, maps establishment & redaction.
- Dr. Abdelghani ZEDAM: Write the first manuscript draft & redaction.
- Dr. Sofiane BENSEFIA: Data analysis & redaction.

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11. KEYTERMS AND DEFINITIONS

GIS: Are software used to represent and work with data linked to geographic coordinates.

Hydrology: Earth science which focuses on the water cycle, that is to say the exchanges between the atmosphere, the earth's surface and its subsoil.

Thematic map: Graphic representation of a given theme.