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Monitoring vegetation and surface water dynamics of Wadi Tamanrasset using earth observation data

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I dedicate this work; To my dear parents who supported and encouraged me during these years of study, you really deserve the testimony of my deep gratitude. To my brothers and sisters, To all my family and friends, I owe you, for your sympathy and your continued

NoUra. M

This work is dedicated

TO my dears parents…….DOUADI and HANIA

To those who supported my brothers and sisters IMAD, MARWA, HADIL ,FATIMA ,ABD EL AZZIZ

To my life partner …….NADJIB

To all my relatives, my family and all my friends. ,MARWA, MAAMER ,JAMILA SAIDA , AHMED ,IMAN , JIHAN , SAFA , HODA, WISSAL, SOUNDOUS , RABIA , ZOUBIADA , FARIDA ,SABAH ,FATOM, HADJER ,WIAM, ZINEB

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Table of contents

CHAPTER IV: Results

CHAPTER V: DISCUSSION

Abbreviation

CDRS: Commissariat of agricultural development in the Saharan region.

DEM : Digital Elevation Model.

DVI : Difference Vegetation Index.

EO: Earth Observation.

EOS : Earth Observation System.

ESRI : Environmental System Research Institute.

NDVI : Normalized Difference Vegetation Indice.

NDWI : Normalized Difference Water Index.

NIR : Near Infrared.

OT : Observation de Terre.

SAVI : Soil Adjusted Vegetation Index.

TM : Thematic Mapper.

List of Tables

List of Figures

INTRODUCTION

The Sahara as the largest desert, is characterized by soil and very climatic conditions of strict with spontaneous species survival of flora and fauna. However, this ecosystem remains a living environment with a particular vegetation cover, adapted to harsh desert conditions, characterized by high temperatures and low rainfall (OZENDA, 1983; CHEHMA, 2005).

The algerian sahara is one of the hottest and driest in the world, covers an area of more than two million km² and extends from the Saharan Atlas Mountains to the Malian, Nigerien, and Libyan borders.

From the algerian sahara Tamanrasset region which located in the central sahara, it covers an area of 557906 km^2. The groundwater resources are very limited and are located mainly in the lap of the infero-flow of Wadi (SEKKOUM *et al*., 2012).The complexity of the desert environment and its special nature makes it the focus of research for everyone to understand the ecosystems that contain them.

Environmental monitoring describes the processes and activities that need to take place to characterize and monitor the quality of the environment It is used in the preparation of environmental impact assessments, as well as in many circumstances in which human activities carry a risk of harmful effects on the natural environment. All monitoring strategies and programmers have reasons and justifications, which are often designed to establish the current status of an environment or to establish trends in environmental parameters. In all cases the results of monitoring will be reviewed, statistical analysis and published (MARSTIJEPOVIĆ and WILLIAMS, 2009).At present, environmental monitoring is primarily dependent on the Earth observation data that in turn has facilitated many environmental studies.

Earth observation by satellite enables spatially continuous, regular and repeatable observations over large areas and has become an indispensable tool for global monitoring of natural and anthropogenic patterns, processes and trends (SKIDMORE *et al*., 2015).

Actually, the field of Remote Sensing and Geographical Information system (GIS) has become exciting and desirable with rapidly expanding opportunities and provides vital tools which can be applied in the various levels leading to decision of making toward sustainable socio-economic development and conservation of natural resources. Remote Sensing and GIS has proved a powerful tool for the environmental monitoring in many cases. Satellite remote sensing showed monitoring capability not only at global scale but also at local scale (KUMARSINGH*et al*, 2016).

Watershed knowledge is very important because it is the basic framework and unit of hydrological studies and can be a useful tool for providing an overview of natural risks or the vulnerability of water resources. The problems highlighted today in arid areas are that water resources are poorly exploited and little known by the authorities (BEKHIRA *et al*., 2018).

In southern Algeria, many studies on aquifers and watersheds have been carried out using remote sensing techniques and satellite Earth Observation Systems. We can cite that of BOUAMER & CHARGUI (2018) in Wadi M'ya; and also respectively BOULAHBAL (2012) and MEHALLI (2017) on underground flows in Precambrian fissured shale gneisses in the Tamanrasset region and the Hydrological Characterization of the Wadi Tamanrasset Upstream Watershed, for flood estimation purposes.

The objectives of this study are to monitor the vegetation cover and surface water dynamics of Wadi Tamanrasset using remote sensing data. The region is known to have a significant reduction in vegetation cover and a shortage of water resources, especially groundwater, the climate of this region is different from the rest of the desert areas, and it is a region with a great geological transformation throughout history.

Can those different factors have a role in creating a special environment for this region? How the dynamics of vegetation was cover surface waters in the Tamanrasset Watershed in 2018. It is on progression or regression?

Therefore, the morphological analysis, and the monitoring of vegetation and surface water dynamics can give us a glimpse of the characteristics of this unique ecosystem.

The objective is based on delimit the watershed and determine their morphometric characteristics using the digital elevation model, but the monitoring vegetation and surface water is based on the multispectral satellite images by applying certain indices such as Normalized Differential Vegetation Index and Normalized Difference Water Index.

The first chapter is a review of the literature on remote sensing and vegetation dynamics in wetlands. Is further followed by a description of the region and the study site ; which is also followed by a citation of the materials and methods adopted for the accomplishment of this project. The last chapter will outline the main results with a discussion. Finally a conclusion followed by prospects for future studies.

CHAPTRE I

Literature view on remote sensing and vegetation dynamics in wetlands.

1.1. Algerian Sahara

The Sahara is the largest of the deserts, but also the most expressive and typical for its extreme aridity, that is, the one where desert conditions reach their greatest aridity. In Algeria, it occupies more than 80% of the country's total surface area. The vast majority of this vast territory is occupied by large vacant areas represented by Regs, Erg and salt lakes. Its climate is characterized by low and irregular rainfall, high temperatures, intense light and high evaporation. The situation of the algerian Sahara is strictly dependent on its abiotic characteristics, which determine any survival or spontaneous activity based on the exploitation of the natural resources of these immense desert areas (CHEHMA, 2011).

1.1.1. Water of Algerian Sahara

In Algerian Sahara, the water has a vital character, because the climatic and hydrological contexts are extremely fragile. The spatial and temporal irregularity of the water availability, the impact of the droughts and flooding and the pressure of the demand of water are in continual increasing facing limited resources (SEKKOUM *et al.*, 2013).

1.1.2. Vegetation of Algerian Sahara

The vegetation of the arid zones and particularly that of the Sahara is very sparse, generally nude and lifeless, the trees are as rare as scattered and the herbs appear there only during a very short time of the year, when the conditions become favorable (SCHIFFERS, 1971).

In the Sahara, in spite of very harsh and constraining environmental conditions, there are still some geomorphological formations offering more or less favorable for the survival and proliferation of a spontaneous flora characteristic and well adapted to the climatic hazards of the desert. Outside these areas, which represent less than half of the area, vegetation cover is totally absent (CHEHMA*et al*., 2005).

Depending on its adaptation to drought, the Saharan flora can be divided into several species; ephemeral plants, named "evils", appear only after the rainy season and make their entire vegetative cycle before the soil is dried out, the cycle time is very variable from one species to another and generally takes from one to four months. Thus, the presence of permanent or perennial plants (CHEHMA, 2008).

1.2. Earth Observation System (EOS)

The Earth Observation System (EOS) is one of the primary components of a NASA-initiated concept originally referred to as Mission to Planet Earth (MTPE), which was renamed the Earth Science El1terprise (ESE) during 1998. The ESE is an international earth science program aimed at providing the observations, understanding, and modeling capabilities needed to assess the impacts of natural events and human-induced activities on the earth's environment. The program incorporates both space and ground-based measurement systems to provide the basis for documenting and understanding global change with an initial emphasis on climate change. The program also focuses on the necessary data and information systems to acquire, archive, and distribute the data and information collected about the earth. The intent is to further international understanding of the earth as a system. (LILLESAND&KEIFER, 2015)

1.3. - Geographical Information System (GIS)

The French Photogrammetry and Remote Sensing Society (1989) has defined a GIS as a computer system that allows, from various sources, to gather and organize, manage, analyze and combine, develop and present geographically located information, contributing in particular to the management of space.

A geographic information system is a set of geographically located and structured digital data within a computer processing system comprising functional modules, making it possible to construct, modify, interrogate, and map out the database, Data according to semantic and spatial criteria (GILLET, 2000).

1.3.1. - Roles of GIS

According to Ashok (2008) the roles of GIS are:

-Abstraction: Modeling the database by defining the objects, their attributes and their relations;

-Acquisition: GIS data supply, it is necessary on the one hand to define the shape of the geographical objects and on the other hand their attributes and relations;

-Archiving: Transfer of data from the workspace to the repository (hard disk);

-Analysis: Answer to the questions asked;

-Display: Production of cards automatically.

1.3.2. Remote sensing and GIS

The remote sensing space, based on ground-based measurements and combined with geographical information systems, is now making a decisive contribution to the various environmental, health and land-use planning (LABED *et al*, 2009).

1.3.2.1. Remote sensing

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation.

In many respects, remote sensing can be thought of as a reading process. Using various sensors, we remotely collect data that may be analyzed to obtain information about the objects, areas, or phenomena being investigated (LILLESAND&KEIFER, 2015).

The human eye however is limited to a small part of the total electromagnetic spectrum i.e. approximately 400 to 700 nm. In remote sensing various kinds of tools and devices are used to make electromagnetic radiation outside this range visible to the human eye, especially the near infrared, middle infrared, thermal infrared and microwaves. Remote sensing now plays an important role in a wide range of environmental disciplines such as geography, geology, zoology, agriculture, forestry, botany, meteorology, oceanography and civil engineering (JONG & VAN DER MEER, 2004).

1.3.2.1.1. Applications of Remote Sensing

There are probably hundreds of applications - these are typical:

- Meteorology: Study of atmospheric temperature, pressure, evaporation, and wind strength.
- Oceanography: Measuring sea surface temperature, mapping ocean currents, and wave energy spectra and depth sounding of coastal and ocean depths.
- Glaciology: Measuring ice cap volumes, ice stream velocity, and sea ice distribution. (Glacial)
- Geology: Identification of rock type, mapping faults and structure.
- Geodesy: Measuring the figure of the Earth and its gravity field.
- Topography and cartography: Improving digital elevation models.
- Agriculture: Monitoring the biomass of land vegetation
- Forestry: monitoring the health of crops, mapping soil moisture
- Botany: forecasting crop yields.
- Hydrology: Assessing water resources from snow, rainfall and underground aquifers.
- Disaster warning: Monitoring of floods and landslides, monitoring volcanic activity, assessing damage zones from natural disasters.
- Planning applications: Mapping ecological zones, monitoring deforestation, monitoring urban land use. (ABDULRAHMAN,2010).

1.3.2.1.2. Principles of remote sensing

The Remote Sensing is basically a multi-disciplinary science which includes a combination of various disciplines such as optics, spectroscopy, photography, computer, electronics and telecommunication, satellite launching etc. All these technologies are integrated to act as one complete system in itself, known as Remote Sensing System (AGGARWAL; 2003).

There are a number of stages in a Remote Sensing process, and each of them is important for successful operation:(fig.01)

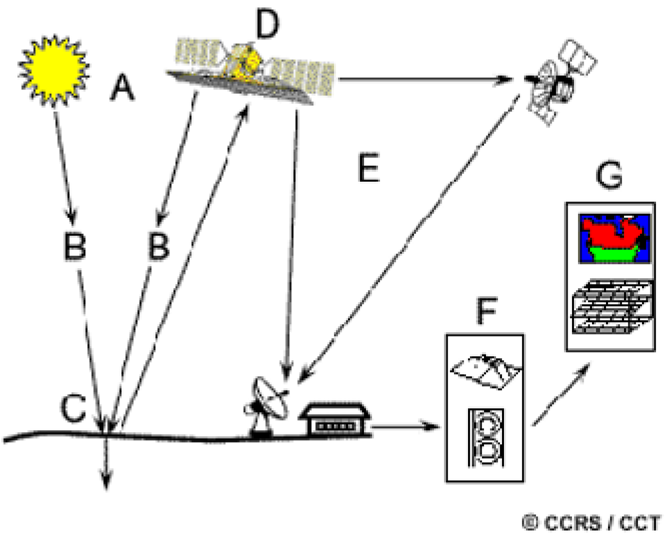

Figure 1: principles of Remote sensing (CCT, 2001)

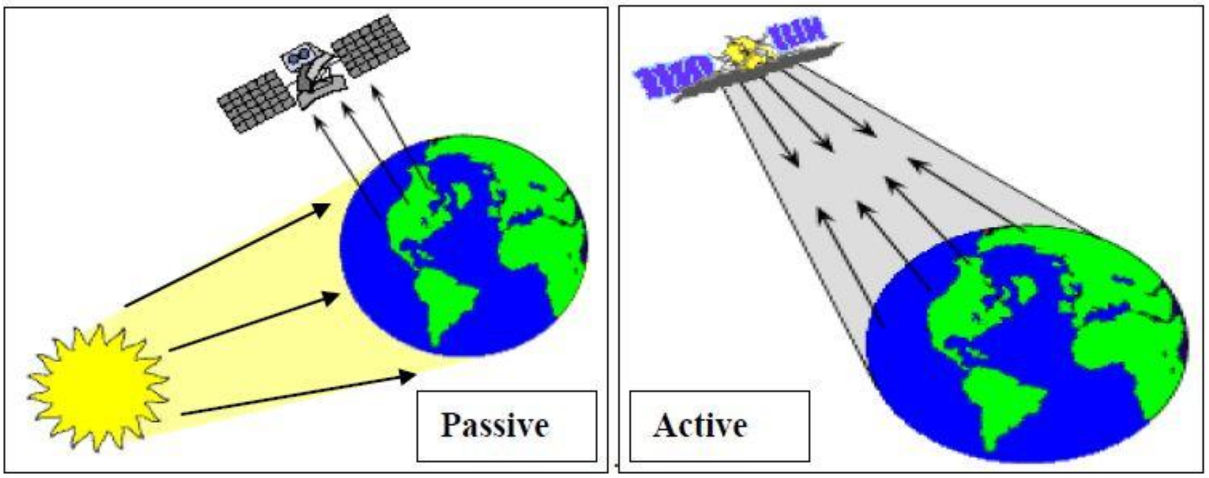

Figure 2: Passive and active remote sensing (ABDULRAHMAN, 2010)

- ✓ **Energy Source or Illumination**: The first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.
- ✓ **Radiation and the Atmosphere**: As the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.
- ✓ **Interaction with the Target**: Once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.
- ✓ **Recording of Energy by the Sensor**: After the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

- ✓ **Transmission, Reception, and Processing**: The energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed.
- ✓ **Interpretation and Analysis**: The processed image is interpreted, visually and/or digitally or electronically, to extract information about the target, which was illuminated.
- ✓ **Application**: The final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

1.3.2.1.3. Types of Remote Sensing

The sun is a source of energy or radiation, which provides a very convenient source of energy for remote sensing. The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then reemitted, as it is for thermal infrared wavelengths.

There are two main types of remote sensing: Passive remote sensing and Active remote sensing.(fig.02)

1.3.2.1.3.1. Passive remote sensing

Passive sensors detect natural radiation that is emitted or reflected by the object or surrounding area being observed. Reflected sunlight is the most common source of radiation measured by passive sensors. Examples of passive remote sensors include film photography, infrared, and radiometers.

1.3.2.1.3.2. Active remote sensing

In other ways, emits energy in order to scan objects and areas whereupon a sensor then detects and measures the radiation that is reflected or backscattered from the target. RADAR is an example of active remote sensing where the time delay between emission and return is measured, establishing the location, height, speeds and direction of an object (ABDULRAHMAN ; 2010).

1.3.2.1.4. Remote Sensing Platforms

Imaging in remote sensing can be carried out from both satellite and aircraft platforms. In many ways their sensors have similar characteristics although differences in their altitude and stability can lead to very different image properties. There are essentially two main categories of satellites: satellites at geostationary altitudes above the Earth's surface that are generally associated with weather and climate studies, and those which orbit much closer to the earth’s surface and that are generally used for earth surface and oceanographic observations. Usually, the low earth orbiting satellites are in a sun-synchronous orbit, in that their orbital plan processes around the earth at the same rate that the sun appears to move across the earth's surface .In this mean earth satellite acquires data at about this ame local time on each orbit (RICHARDS &XIUPING, 2005).

1.3.2.1.5. Remote sensing satellites

Satellites are one of the most extensive forms of remote sensing. As of 2016 there were over 400 EO satellites in orbit, and at least 400 more are expected to be launched by 2025. Satellites collect data via a number of sensor types. Including optical sensors, which derive information about the Earth from reflected sunlight, and radar sensors, which transmit and receive microwave pulses to assess, for example, the texture of the surface (NASA, 2017). The capabilities of satellites can be understood with reference to resolution. There are four main types.

1.3.2.2.Spectral Differentiation

Remote sensing depends on observed spectral differences in the energy reflected or emitted from features of interest. Expressed in everyday terms, one might say that we look for differences in the "colors" of objects, even though remote sensing is often conducted outside the visible spectrum, where "colors," in the usual meaning of the word, do not exist. This principle is the basis of multispectral remote sensing, the science of observing features at varied wavelengths in an effort to derive information about these features and their distributions. The term spectral signature has been used to refer to the spectral response of a feature, as observed over a range of wavelengths (PARKER &WOLFF, 1965).

1.3.2.3.-Radiometric Differentiation

Examination of any image acquired by remote sensing ultimately depends on detection of differences in the brightness of objects and the features. The scene itself must have sufficient contrast in bright nesses, and the remote sensing instrument must be capable of recording this contrast, before information can be derived from the image. As a result, the sensitivity of the instrument and the existing contrast in the scene between objects and their backgrounds are always issues of significance in remote sensing investigations.

1.3.2.4. Spatial Differentiation

Every sensor is limited in respect to the size of the smallest area that can be separately recorded as an entity on an image. This minimum area determines the spatial detail - the fineness of the patterns - on the image. These minimal areal units, known as pixels ("picture elements"), are the smallest areal units identifiable on the image. Our ability to record spatial detail is influenced primarily by the choice of sensor and the altitude at which it is used to record images of the Earth. Note that landscapes vary greatly in their spatial complexity; some may be represented clearly at coarse levels of detail, whereas others are so complex that the finest level of detail is required to record their essential characteristic.

1.3.2.1.5.3.4. Temporal Dimension

Although a single image can easily demonstrate the value of remotely sensed imagery, its effectiveness is best demonstrated through the use of many images of the same region acquired over time. Although practitioners of remote sensing have a long history of exploiting the temporal dimension of aerial imagery, through the use of sequential aerial photography (using thearchives of photography preserved over the years since aerial photography was first acquired in a systematic manner), the full value of the temporal dimension was realized later, when satellite systems could systematically observe the same regions on a repetitive basis. These later sequences, acquired by the same platforms using the same instruments under comparable conditions, have offered the ability more fully exploit the temporal dimension of remotely sensed data (CAMPBELL &RANDOLPH, 2011).

1.2. 3-Types and Classes of Remote Sensors and Sensing Data

Herbert J. Kramer in his book displays a great variety of sensor types that need an ordering scheme for a better understanding and overview by the reader. There are many ways of sensor classifications for instance by:

- The type of application (field of research or operation such as: meteorology, atmospheric research, solid Earth, climatology, biosphere, etc.)
- The type of primary observation targets (oceans, land, coastal regions, ice sheets, or atmosphere.
- The observed frequency range (UV, optical, infrared, microwave, etc.), the type of sensing mechanism (passive or active source),
- The type of instrument (imager, altimeter, sounder, spectrometer, radiometer, etc.)
- The type of measurement precision (resolutions) etc. (Kramer, 1996).

1.4. Monitoring surface water by remote sensing (water indices)

Remote sensing technology offers effective ways to observe surface water dynamics. Compared to traditional in situ measurements, remote sensing is much more efficient, because of its ability to, continuously monitor earth surface at multiple scales. Remote sensing datasets provide spatially explicit and temporally frequent observational data of a number of physical attributes about the earth surface that can be appropriately leveraged to map the extent of water bodies at regional or even global scale, and to monitor their dynamics at regular and frequent time intervals (CHANG *et al*.,2018).

1.5. Remote Sensing Vegetation Index

In many cases of vegetation remote sensing studies, vegetation index has been used as a primary source of information related to the biophysical characteristics of vegetation over large geographic area (EIDENSHINK, 1992; LOVELAND *et al*, 1991; TOWNSHEND & JUSTICE, 1986). Vegetation index, derived from remote sensing data, is used as a single measure of such canopy characteristics as biomass, productivity, leaf area index, photosynthetically active radiation, or canopy closure (Larsson, 1993). This technique of vegetation index was developed from the unique spectral characteristics of green vegetation in visible and near infrared wavelengths. Green vegetation has relatively low reflectance in visible wavelength and high reflectance in near-infrared spectrum (0.7 – 1.3 micrometers) whiles other surface types, such as bare soil and water, have similar reflectance in both spectrums. In addition, the spectral reflectance of green vegetation in this spectrum is very sensitive to the amount of chlorophyll content and canopy thickness (HOFFER, 1978). Healthy and fully developed vegetation canopy tends to have less reflectance at red spectrum and higher reflectance in near-infrared spectrum as compared to under-developed canopy condition.

CHAPTRE II

Study area presentation

2.1.Hoggar mountains

The Hoggar covers an area of about 556000 km^2. It is a massif formed of crystalline and crystallophyllian rocks whose vertiginous summits exceed 3000 meters of altitude. At its center, the Tahat (3003 m) which dominates all Atakor, is the culminating point of Algeria. Its capital Tamanrasset (1400 m altitude) is located 2000 km south of Algiers. The large area, the variety of geological formations and the excellent quality of outcrops make the Hoggar a world of geological research unique in the world (KHEDIMI, 2014).

2.1.1 Geology of Hoggar

The Hoggar is a tabular mass, made up of crystalline rocks, at the center of which have pierced volcanoes which have left many slags in the vicinity. The most remarkable of these volcanoes are Ilaman and Tahat (rising to 2800 and 3000 m respectively), Adrian, and Akarakar. All are composed of masses of rhyolite, and they sometimes take singular forms. This set constitutes Atakor, which is based on gneisses, schists and micascists(LHOTE, 1932).

2.1.2.Structural Subdivisions of Hoggar

The structure of the Hoggar is characterized by the occurrence of large lithospheric (4°50’ and 8°30’) sub-meridian shears and major dextral NNE and senestral NNW detours which give it a fragmented structure whose interpretation has evolved time. Three major structural subdivisions have been proposed.

2.1.2.1. First Subdivision

M LELUBRE (1952) identifies two organic cycles separated by a clear major discordance:

2.1.2.1.1. Basic Suggarian Cycle

The basic Suggarian Cycle consisting of two superimposed polyhedral and strongly metamorphic gneiss ensembles of Paleoproterozoic age. The lower gneissic ensemble dominated by orthogneiss and rare meta-sediment (Arechchoum series) and the upper sedimentary meta-dominated gneissic ensemble (Aegere or Aleksod series).

2.1.2.1.2. Pharusian cycle

The Pharusian cycle at the summit is also composed of two monocyclic and less metamorphic volcanosedimentary complexes of Neoproterozoic age. On his 1/500000 geological map, M LELUBRE distinguishes two large blocks separated by the 4°50’ accident; the Suggarian block in the East and the Pharusian in the West.

2.1.2.2. Second Subdivision

BERTRAND and CABY (1978) subdivided the Hoggar into three (03) large structural domains separated by major N-S shear. These domains have totally different tectono metamorphic, geochemical and magmatic histories. It is West to East of (Fig 03):

- Western Hoggar(Lelubre 1952;Gravelle, 1969;Caby, 1970).
- Central polycyclic Hoggar (Bertrand, 1974)
- Oriental-Ténéré Hoggar.

2.1.2.2.1. Western Hoggar or Pharusian Chain

Limited West by the West African craton, and to the East by the submeridian accident 4°50'

In Western Hoggar, pan-African orogeny is the most complete. It is interpreted as a complete Wilson cycle (BLACK*et al.*, 1979, CABY*ET al.*, 1981).

The western Hoggar consists of two twigs, an eastern branch and a western branch separated by the granulitic mole of In Ouzzal, which is made up of Archean formations, structured and metamorphosed with Eburnean.

The western branch includes the Inouzzal-Iforas, Kidal-Tirek, Tassendjanet and Ahnetterranes.

The eastern branch consists of two main units, previously assimilated to two distinct orogenic cycles: Pharusian I and Pharusian II, corresponding respectively to the terranes of Iskel and In Teidini.

2.1.2.2.2. Hoggar central (polycyclic)

It is an Archean and Eburnian basement that has been reactivated to the Pan-African, extended to the southeast by the Aïr.

Its current configuration corresponds to the juxtaposition of four terranes that have the same geological characteristics, designated by the acronym LATEA (Laouni, Azrou-n-fad, Téfest and Aééré-Aleksod), and an oriental block (Assodé terrane). -Issalene), separated by the youngopiumoliteterrane of Serouénout

2.1.2.2.3. Hoggar Oriental

The eastern Hoggar is east of the accident 8°30', it includes from east to west four separate terranes: Barghot (Aïr), Djanet, Edembo and Aouzegueur.

2.2 - Geographical situation of Tamanrasset

The Tamanrasset Wilaya is located in the extreme south of the country; it is border with two neighboring countries namely Mali and Niger and sharing the boundaries with Adrar, Ghardaia, Ouargla and Illizi. It is positioned between the longitudinal parallels 4° and 7° and between 22° and 24° latitude,(Fig 04)

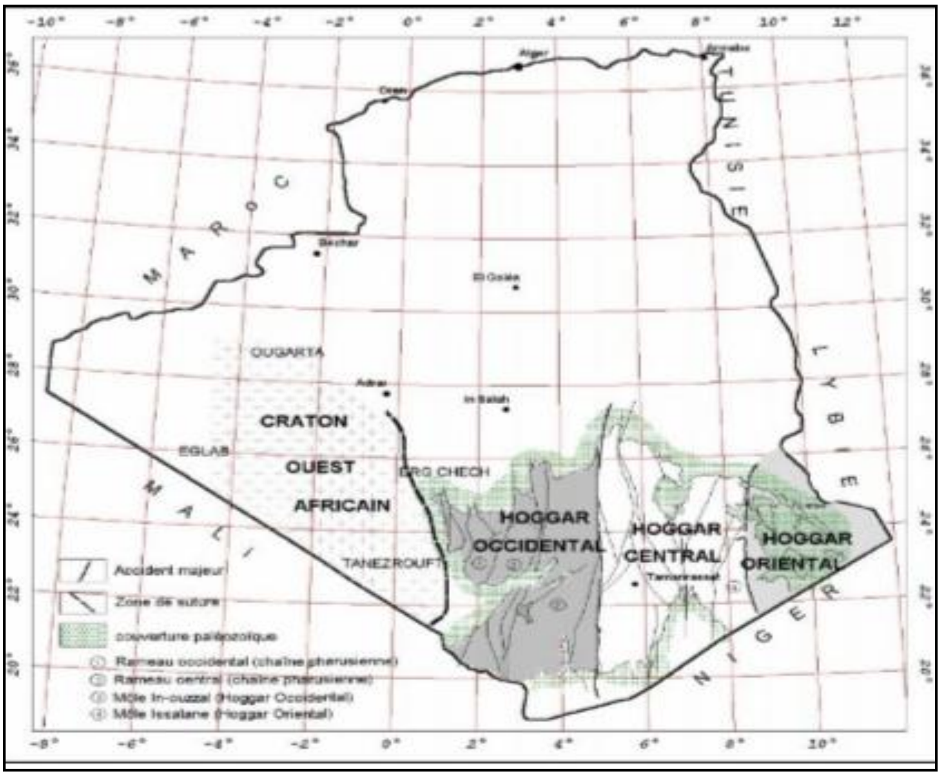

Figure 3: Schematic diagram of Hoggar (BETRAND & CABY, 1978)

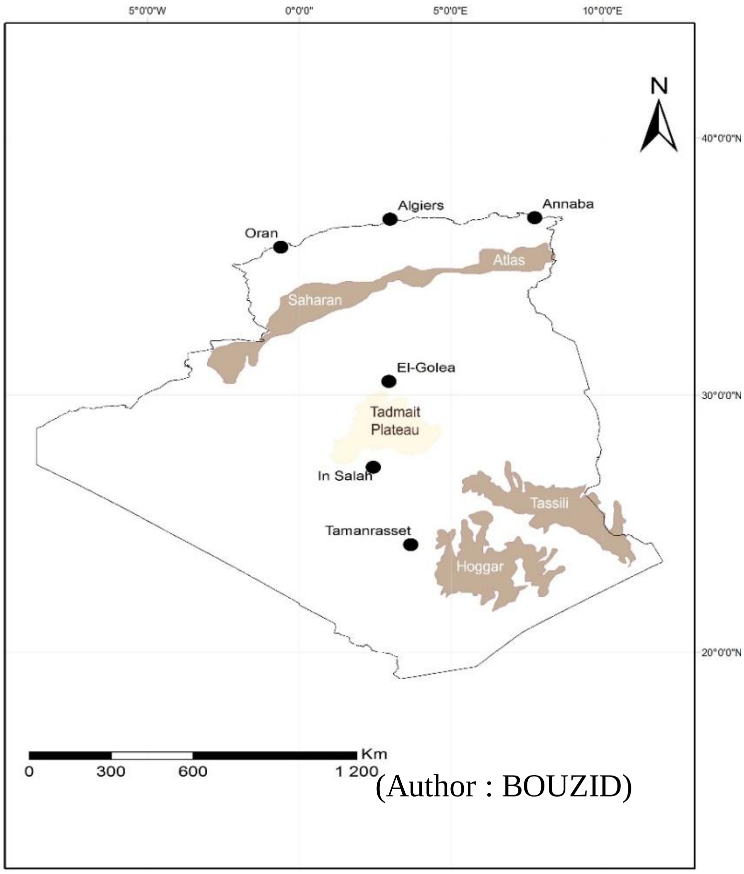

Figure 4: Location of Tamanrasset

2.3. Geology and relief of the study area:

The Tamanrasset region is characterized by two main periods of soils, a Precambrian basement more than 600 million years old, and a cover that originated from the Paleozoic (HAMDINE, 2001).

In terms of terrain, several mountain systems stand out(D.P.A.T., 1994;HAMDINE, 2001;KAIDI, 2007):

- Atakor: central core of the Ahaggar mountain system, culminating at 3003 m with Mount Tahat;
- The Anahef, located east of the Atakor, is formed by a series of hills oriented North, North-West to South, South-East opening to the North on the basin of Serouamont and South on the Ténéré;
- The Tafedest, to the north with a maximum altitude of 2400 m appearing as a fragment of planet sunk into the earth's crust.

The mountains of Moydir: it is the extension towards the West of TassiliN'Ajjer, It culminates with Iftissene at 1 680m**.**

2.4. Hydrographic Network

Water availability in the Tamanrasset region is represented by natural, permanent, semi-permanent water points or by underground waters. The scarcity of water in this region is associated with high temperatures and constant hot and dry winds that result in difficult living conditions for both wildlife and humans and their live stock(HAMDINE, 2001).

The wadis almost all originate in the central Hoggar, which is the area of water distribution. Two very large quaternary wadis, the Igharghar wadi and the Tamanrasset wadi, drain the waters of the West and the North (OUELD EL-HADJ, 2004).

2.5. Climatic characteristics of the study area

Among the climatic factors characterizing the region of Tamanrasset, the rainfall and temperatures are detailed in what follows. Just after, a synthesis of climate data is used to characterize the climate of the study area.

The Hoggar region is characterized by a Saharan-type climate, with changes due to altitude and tropical influences.

The climate in Tamanrasset is dry, winters are harsh. The average annual temperature is 22 ° C. The precipitation does not exceed on average 50 mm at Tamanrasset (1400 m alt.) But can reach 380mm, a value observed during the period (1985/2006), on the highest zones (2700m alt.) (BOULAHBAL, 2012). Evaporation is very high and averages 4187 mm / year.

2.5.1. Climate synthesis

The different climatic factors do not act independently of one another (DAJOZ, 1985). It is therefore necessary to study the impact of combination of these factors on the medium.

To characterize the climate of the study area and specify its position at the Mediterranean scale, the ombrothermal diagram of GAUSSEN (1953) and the EMBERGER (1955) Rainfall Climagram are used.

For this work, two culminating stations of our study basin were taken into consideration. Their data being collected, series of tests, analyzes and treatment were applied to them.

2.5.1.1. Station of Tamanrasset

Tamanrasset meteorological station is located at Tamanrasset aerodrome (Latitude: 22° 48’.Latitude 22° 48’'N, Longitude: 05° 26' E and Altitude: 1362 m), will provide observation and meteorological service in steady state (H-24). The data set adopted in this work is from 1996 to 2018.

2.5.1.2. Station Assekrem

The Assekrem main meteorological station at 2710 m altitude on the summit of the Assekrem Atakor mountainous massif, its geographical coordinates are Latitude: 23° 16' N and Longitude: 05° 38' E, she will ensure the observation meteorological steady state (H-24). It should be noted that this station is part of the global network for monitoring global climate change (Global Atmosphere Watch Center).

2.5.1.3. Gaussen Ombrothermal Diagram

The GAUSSEN Ombrothermal Diagram is a graphical method that allows defining the dry and wet periods of the year. It is based on the formula P = 2T °C.

When temperatures rise above the precipitation curve, the corresponding period is water deficient, and when the precipitation curve passes above

From that of the temperatures, the corresponding period is wet.

The determination of this period is of paramount importance for irrigation water needs

The Fig 05 shows us that the region of Tamanrasset is characterized by a dry period spanning all the months of the year for the period (1996 - 2018).

Rains are rare and irregular in the Tamanrasset region. The most rainy month during the period (1996 - 2018), is the month of August (20.5 mm).

The Fig 06 shows us that the region of Assekrem is characterized by a dry period spanning all the most months of the year for the period (2008 - 2018).except the period of August to September is characterized by humid period.

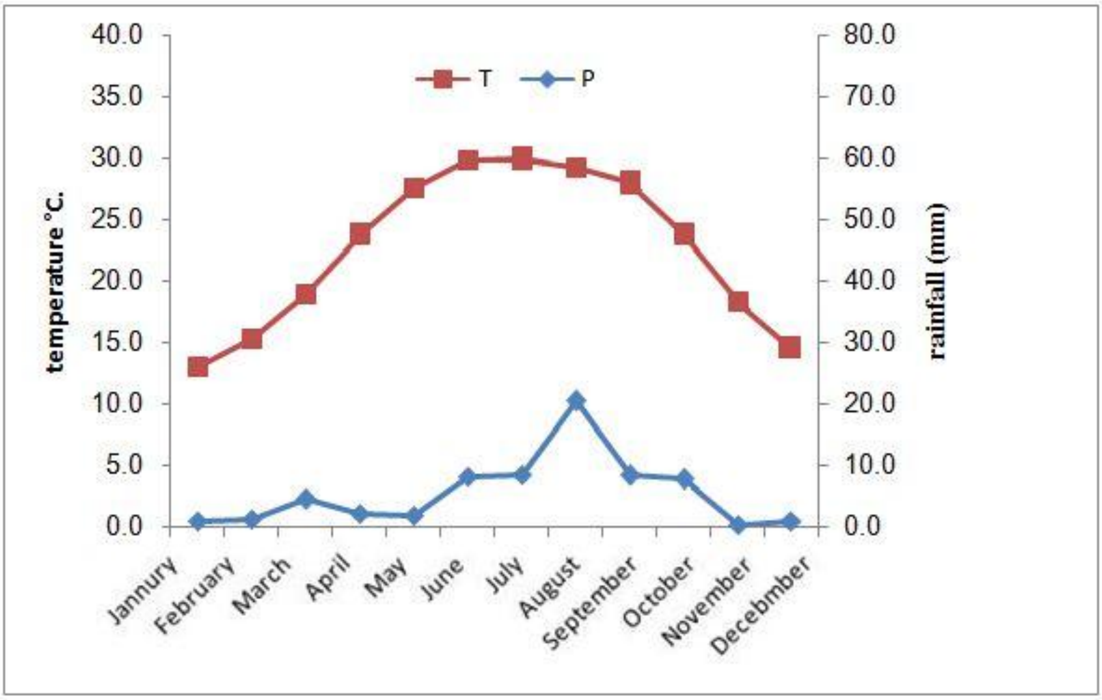

Figure 5: Bagnouls and Gaussen Ombrothema Diagram of Tamanrasset (1996-2018)

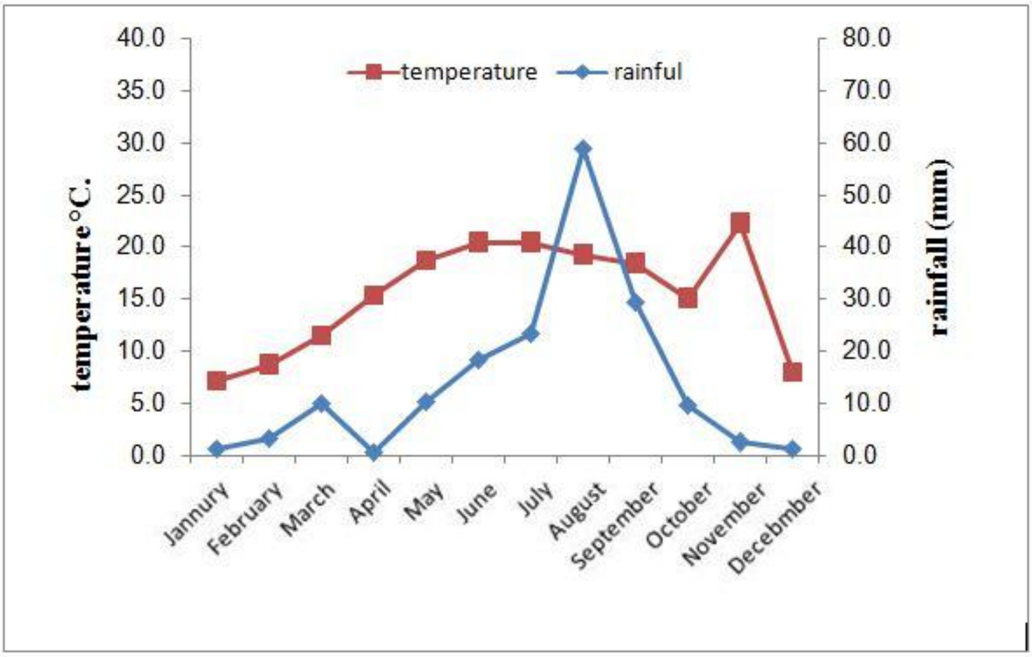

Figure 6: Bagnouls and Gaussen Ombrothermic diagram of Assekrem (2009-2018)

2.5.1.4. Emberger Climagram and bioclimatic stages

The Emberger climagram is used to classify the different types of climate in bioclimatic stages (DAJOZ, 1971). The location of a given region in a bioclimatic stage is based on the study of temperature and precipitation variations (DAJOZ, 1971). This is ensured by calculating the rainfall quotient Q_3 given by the following formula:

$$Q_3 = 3.43 \frac{P}{(M-m)}$$

Q_3: Stewart rain water quotient
P: average annual precipitation in mm
M: is the average of the maximum hottest month in °C
m: is the average of the minimum of the coldest month in °C

The value of the quarantine rainfall of Emberger calculated for the region of Tamanrasseton the period (1996-2018) is 6.49 with a minimum temperature range of about 5.15 °C. From Figure07 Tamanrasset that is classified as a hyper-arid desert that characterized by Saharan bioclimate with mild winter, and a dry period that last throughout the year.

While Assekrem its value of the quarantine rainfall of Emberger calculated on the period (2009-2018) is 27.36 with a minimum temperature range of about 3 °C.It is classified as a arid desert.

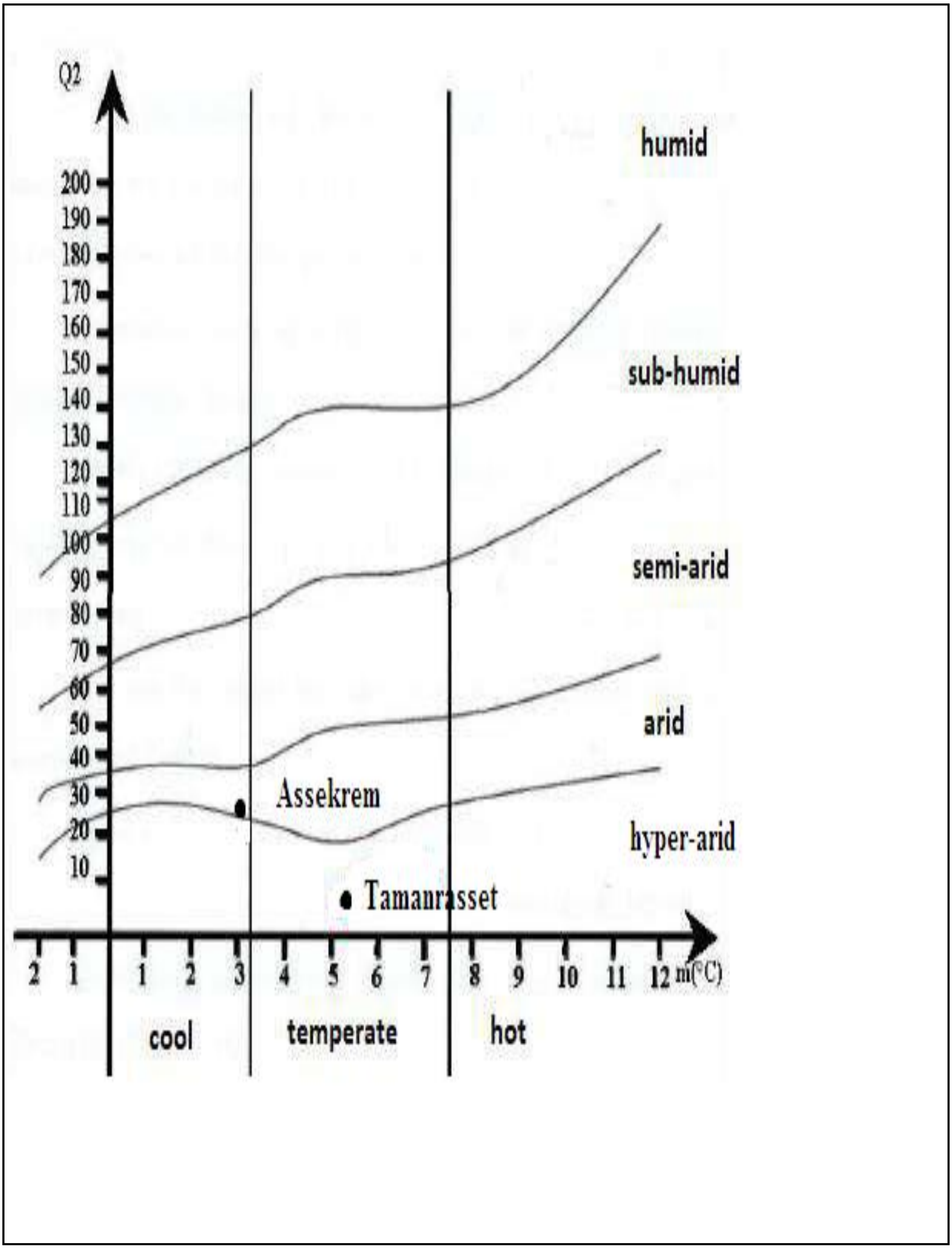

Figure 7: Bioclimatic stages of Assekrem and Tamanrasset

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2.6. Bibliographic data on the flora and fauna of Tamanrasset region:

This part includes the various studies that were done, first, on the flora then on the wildlife of the Tamanrasset region

2.6.1. Flora of the Tamanrasset region

The flora of the Hoggar Massif is estimated at some 300 species (OZENDA, 1983). It includes species specific to the Sahara, to which are added Mediterranean and tropical elements. The cohabitation of such different origins has been maintained thanks to the remarkable adaptation developed by these plants since the first geological eras (HAMDINE, 2001).

The distribution of the spontaneous flora of Tamanrasset varies according to the different climatic zones (OZENDA, 1983). Schematically, vegetation ranges from plains in low altitudes (about 500 m) where the most important pastures, at the high mountains of Atakor (3000 m) where the vegetation grows on plateaus but also on the flanks of the massifs (HAMDINE, 2001).

Indeed, according to the altitude, there are 3 types of vegetation:

•Vegetation of low and medium altitudes (600 to 1400 m) subservient to wadis beds, wide spreading areas as well as near water points. This is the domain of *Acacias*, *Tamarisks* and *Palms* of the desert;

•a vegetation of medium and high altitudes (1500 to 2500 m), of tropical stock, it is progressive dominated by the perennial species, subservient to the valleys, gorges, beds of oueds, peneplains, ravenelles and basements of the granite massifs, represented by Wild olive, *Sumac*, Sahara *Myrtle*, *Antinea Lavender*, wormwood, etc .;

•high mountain vegetation (2500 to 3000 m), occupying rocky basaltic plateaus, scree and mountain slopes. It is composed of*Armoise* herbe white, felty *Germander*, *Ephedra*, *Clematis*, cabbage, etc. (HAMDINE, 2001 WACHER *et al*; 2005).

Animal adaptation to desert environments is still less perfect than plant adaptation to the Sahara (BAMAHHAMED ;2011 citer par ILLIASSOU, 2004).The number of plant species that a desert can shelter per unit area is relatively small, compared to that of other environments on the planet.

There is, however, in the desert a surprising variety of invertebrate animals, fish, amphibians, reptiles, birds and mammals**.**

2.7. Wadi Tamanrasset

The wadi Tamanrasset is born on the South face of Atakor, in the region of Assekrem, towards 2700 m of altitude, it descends according to a direction SSW. He receives practically no tributaries of his left bank and very little of his right. The profile is fairly regular, but in the details of many small accidents disrupts its course, the latter are due to the presence of recent volcanic flows and more or less eroded crystalline thresholds it crosses in small gorges sometimes very narrow. Upstream of these crystalline thresholds the wadi sometimes spreads and drills small alluvial plains that it currently digs (TARENGAL *et al*., 2015).

2.7.1. Hydrogeology of the watershed

In terms of water resources, the crystallophyllian and magmatic countries of the Ahaggar supply their water needs mainly through wadi-related infer flux systems, which are renewed by occasional floods. The most favorable aquifer horizons are located in the valleys and present on three superimposed levels, distinguishing from top to bottom;

• The superficial alluvium which shelters the infero-flux aquifers fed mainly by the floods.

•The altered layer of the underlying bedrock.

•Affected crack network pedestal fed by infiltration of water across both levels previous.

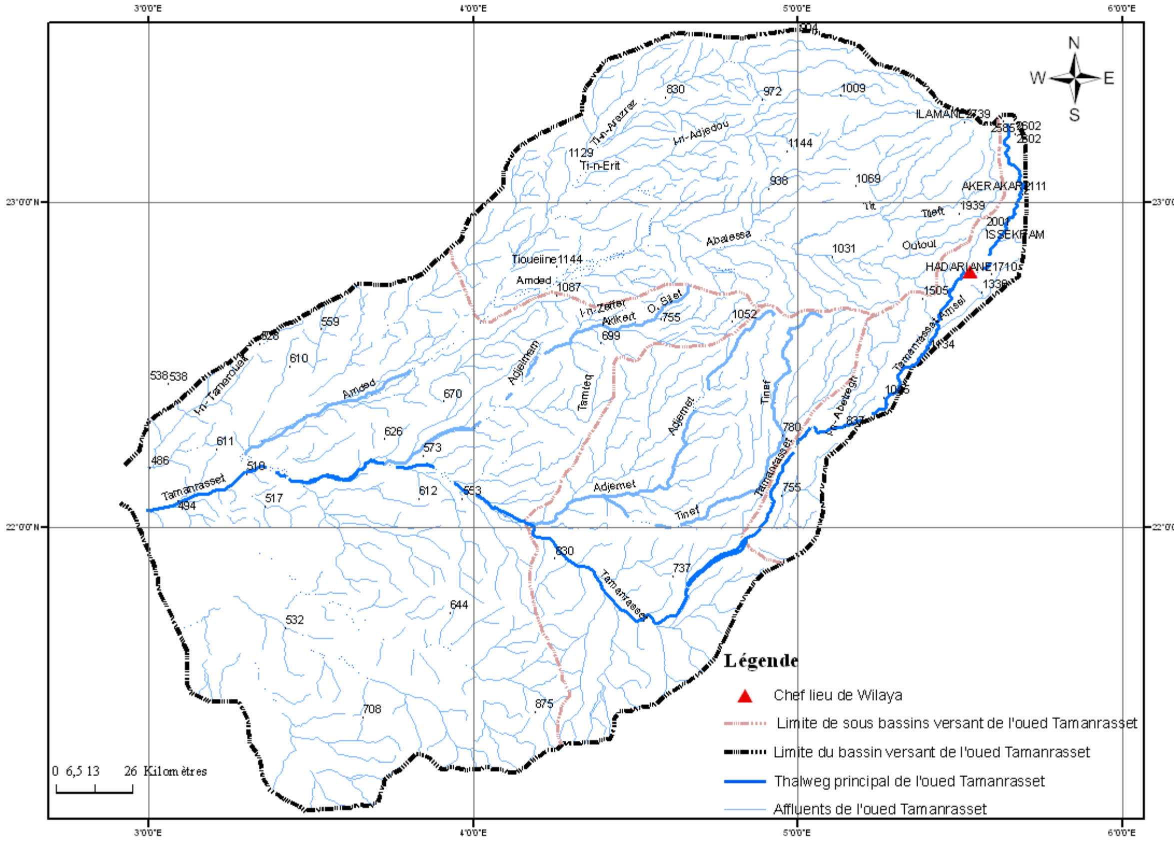

Figure 08: Wadi Tamanrasset catchment (BOULAHBAL.2012)

The Wadi Tamanrasset is located on the territory of the Wilaya of Tamanrasset located in the extreme,south-east of Algeria. The watershed covers an area of 48915 Km²; we limit ourselves in this work to a very small part constituting the most active section of the Wadi

Tamanrasset and which extends from the Assekrem (2800 m) in the ATAKOR chain to the level of the town of Tamanrasset (1358 m).

CHAPTRE III

Materials & methods

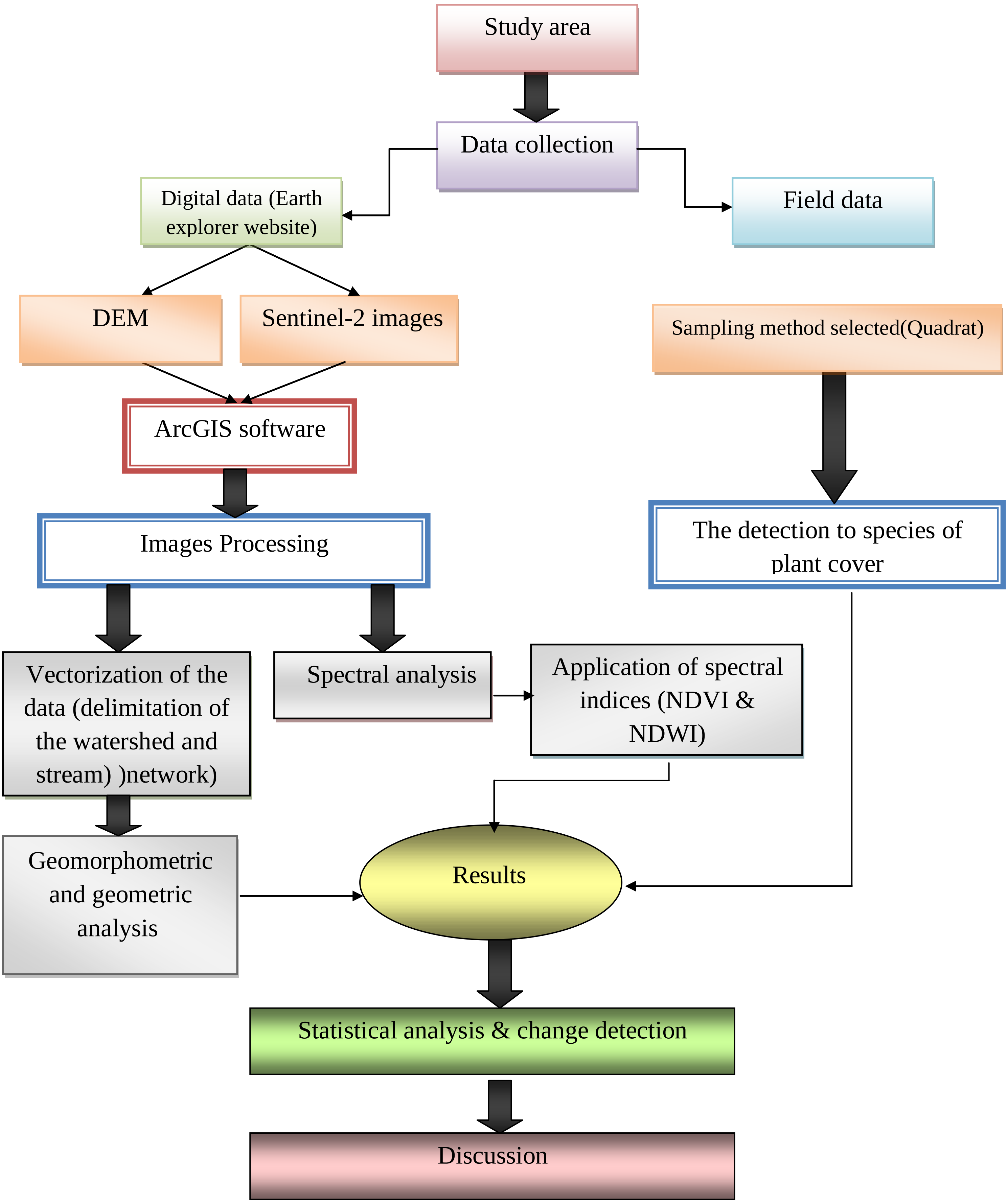

Figure 09: flowchart of the general methodology

The analyses were performed in area which covers the Wadi Tamanrasset, we limit in this work to only a very small part of large basin, and this latter is a part of the great basin of the Sahara, more precisely of the Tanezrouft basin. The area show different land covers and climatic conditions in the year. Three Sentinel-2A images of three different periods and DEM were collected for identifying differences states in land covers of study area by the change detection study on water dynamics and evolution of vegetation covers and it's related with geometric characteristics and compositional aspects of Wadi Tamanrasset during the different periods.

The Most work has been done by geographic information system software ArcMap 10.4, ArcGIS Spatial Analyst analyzes maps and measured data like elevation, rainfall, etc. by dividing geographic space into a matrix of square cells that store numbers (pixel).

3.1. - Delineating Watershed and identifying stream networks

A watershed is an upslope area that contributes water flow as concentrated drainage. This area can be delineated from a digital elevation model (DEM) using the Hydrology toolset from the Spatial Analyst toolbox.

3.1.1. Materials used

We used tow tools:

3.1.1.1. Digital Elevation Model (DEM)

A digital elevation model (DEM) may be defined as any numeric or digital representation of the elevations of all or part of a planetary surface, given as a function of geographic location (O'Callaghan & Mark., 1984).

Digital Elevation Models (DEMs) in its most generic term implies elevation of the terrain devoid of vegetation and manmade features. It represents the elevation of the earth's surface in the form of a digital image where each pixel1 contains an elevation value of the center point of the pixel; DEMs are a primary input to any modeling or process quantification involving the earth's topography (SUGANTHI& SRINIVASAN, 2010).

3.1.1.2. ArcMap

GIS tasks can be broadly divided into two categories. One includes mapmaking, editing, and spatial analysis; the other includes database design and data management.

ArcMap is an application for displaying maps and investigating them. For analyzing maps to answer geographic questions and producing maps that make analysis persuasive. The ArcMap application window consists of a map display for viewing spatial data, a table of contents for listing the layers shown in the display, and a variety of toolbars for working with the data (ORMSBY et al, 2004). It can be downloaded from the ESRI Web site.

3.1.2. -Method

Digital Elevation Models (DEMs) contribute to geomorphological and hydrological applications. In this study, we evaluated the DEM based on the spatial extent and resolution of the 12.5 m.

- The following steps from the ESRI websiteprovide a workflow to create a watershed and identifying stream networks using the Hydrology toolset from the Spatial Analyst toolbox and convert the raster results to watershed bounding polygon:

3.1.2.1- Run the Fill tool

The Fill tool fills sinks to remove imperfections from the DEM. The Sink (Spatial Analyst) tool can be used to identify the sinks and their depths prior to using the Fill tool.

3.1.2.2- Run the Flow Direction tool

The Flow Direction tool determines the direction of flow from each cell to its steepest downslope neighbor. The direction of flow is determined by the direction of steepest descent, or maximum drop, from each cell.

3.1.2.3- Run the Flow Accumulation tool

The Flow Accumulation tool calculates the accumulated flow to each cell, as determined by the accumulated weight of all cells that flow into each downslope cell.

3.1.2.4 - Identifying stream networks

Stream networks can be delineated from a digital elevation model (DEM) using the output from the Flow Accumulation function. Flow accumulation in its simplest form is the number of upslope cells that flow into each cell. By applying a threshold value to the results of the Flow Accumulation function using the Con tool in geoprocessing, a stream network can be delineated.

The stream network can be further analyzed using the Stream Order, Stream Link, and Stream to Feature functions, for ordering (ranking) the streams, assigning unique IDs to stream links, or creating a feature dataset.

3.1.2.4.1 -Conditional evaluation with Con

The Con tool allows you to control the output value for each cell based on whether the cell value is evaluated as true or false in a specified conditional statement.

3.1.2.4.2 -Stream ordering

This instruction assigns a numerical order to segments of a raster representing branches of a linear network Stream ordering is a method of assigning a numeric order to links in a stream network with the Stream Order tool. This order is a method for identifying and classifying types of streams based on their number of tributaries. Some characteristics of streams can be inferred by simply knowing their order.

3.1.2.4.3 -Stream links

The Stream Link function allows you to assign unique values to each of the links in a raster linear network between intersections. This is most useful as input to the Watershed function to quickly create watersheds based on stream junctions. It can also be useful for attaching related attribute information to individual segments of a stream.

3.1.2.4.4 -Vectorizing a stream network

A raster linear network can be accurately converted to features data with the Stream to Feature tool, representing the linear network using the Stream to Feature function. The vectorization algorithm is designed primarily for vectorization of raster stream networks or any other raster representing a raster linear network for which directionality is known.

The Stream to Feature algorithm is optimized to use a direction raster to aid in vectorizing intersecting and adjacent cells.

3.1.2.5 - Run the Snap Pour Point tool

The Snap Pour Point tool is used to locate the pour points to cells of high accumulated flow. Cells that are not NoData (cells with values) are considered pour points and are snapped if a raster input is used, while a point feature input specifies the locations of cells to be snapped.

Pour points are points at which water flows out of an area, usually the outlet or re-entrant locations from the flow accumulation. The Snap Pour Point tool snaps these points to the cell of highest flow accumulation within a specified distance.

3.1.2.6 - Run the Watershed tool

The watershed tool determines the contributing area above a set of cells in a raster, from watershed delineated in raster format; we converted this to a shapefile with the basins as individual polygons by Raster To Polygon tool in ArcGIS.

3.2 -Morphometric Characterization of a Watershed

Morphometric analysis is a set of procedures that characterize the geometric and compositional aspects of environmental systems, serving as indicators of the related form, structural arrangement and interaction between aspects and the network of fluvial channels in a watershed in situations and values that exacerbate hydrological and geomorphological issues HORTON (1945).

Evaluating the morphometric characteristics of any basin depends mainly on quality of the data and the performed measurement technique. Morphometric analysis is an important factor for studying and understanding the development of any river basin(BURROUGH*etal*, 2012).

The morphometric analysis is carried out quantitatively using ArcGIS 10.4 Using drainage network map all measurements, like linear aspects such as stream length, main stream length, area of the watershed, circular area of the watershed, and diameter of the watershed were calculated. With the help of Conversion tools in the ArcToolbox, the data is converted in to raster to vector form.

Hydrology tools were used for creation of drainage basin, delineation of sub-watersheds, flow direction, Stream order and stream intersection points. After this process, Bifurcation ratio, form factor, elongation ration, drainage density, drainage frequency, stream frequency and drainage texture were analyzed. The drainage basin analysis was carried out quantitatively aspect wise such as linear aspects and aerial aspects. In the linear aspects, stream order, stream length, bifurcation ratio, mean length, stream length ratio, and mean length ratio were analyzed. In the basin geometry factors like drainage density, stream frequency, texture ratio, constant of channel maintenance and the length of the overland flow were carried out. The method of calculation and the procedure involved in estimating each parameter is briefly described.

The hydrological behavior of a watershed is influenced by the following morphometric factors:

3.2.1 -Linear parameter

We used the flowing parameter:

3.2.1.1 -Hierarchical order (stream order (U))

The stream ordering is the establishing the classification of a drainage flow in the whole set of the watershed in which it is located. In our study we selected the Strahler classification for stream ordering using ArcGIS.

3.2.1.2 - Number of stream order (N_u)

Sum of all channels of the basin (HERTON, 1945; STRAHLER, 1964):

$$N_u = N_1 + N_2 + \ldots N_n$$

3.2.1.3 - Stream length (L_u)

The stream length was computed on the basis of the law proposed by (Horton, 1945), as following:

$$L_u = L_1 + L_2 + \ldots L_n$$

3.2.1.4 - Length of the main river (L_r):

Higher-order channel.

3.1.2.5 - Bifurcation ratio (Rb)

Bifurcation ratio is related to the branching pattern of a drainage network and is defined as the ratio between the total numbers of stream segments of one order to that of the next higher order in a drainage basin (SCHUMN, 1956).

$$R_b = \frac{N}{N+1}$$

N: the total numbers of stream segments of one order.

N+1: the next higher order.

$$Rb_m = \frac{Rb_N + Rb_{N+1} + \cdots + Rb_{N+n}}{N_0 - 1}$$

Rb_m: the mean bifurcation ratio
Rb_N: the bifurcation ratio between the two first orders.
No: the total number of the orders.

3.2.2 -Areal parameter

3.2.2.1 - Drainage areaA (km^2)

Entire area drained by the set river system. The surface of the watershed can be determined a better by the techniques of digitization (we used ArcGIS 10.4 software) (SCHUMN, 1956).

3.2.2.2 - Perimeter (P) (km)

Perimeter is the most commonly used length feature. The perimeter can be measured indirectly using the GIS software (we used ArcGIS 10.4)(SCHUMN, 1956).

3.2.2.3 - Basin length (Lb) (km)

Distance measured in a straight line between the outlet and the highest point located along the perimeter (from outlet to farthest point on basin boundary)(SCHUMN, 1956).

3.2.2.4 - The Stream frequency (Fs)

The Stream frequency is defined as the total number of stream segments of all orders per unit area (HORTON, 1932).

$$Fs = \frac{N_u}{A}$$

F: The Stream frequency (km^{-2}).
N_u: number of streams.
A: area of the basin (km^2).

3.2.2.5 - Drainage density (D_d):

The drainage density is the stream length per unit area in a region (STRAHLER, 1952).

$$D_d = \sum \frac{L_u}{A}$$

D_d: drainage density (km / km^2).
Li: length of stream (km).
A: catchment area (km^2).

3.2.2.6 -The Drainage texture (D_t)

The Drainage texture is defined as the total number of stream segments of all orders per perimeter of the area (HORTON, 1945).

$$D_t = \frac{N_u}{P}$$

D_t: the Drainage texture.
N_u: total number of stream.
P: perimeter of watershed.

3.2.2.7 -Length of overland flow (L_g):

It is one the most important independent variables affecting hydrological and physiographical development of a drainage basin. It is the length of water over the ground before it gets concentrated into definite stream channels and is equal to half of drainage density (HORTON, 1945).

$$L_g = \frac{1}{D*2}$$

L_g: Length of overland flow.
D_d: Drainage density

3.2.2.8 -Basin form (F_f):

Form factor is defined as the ratio of basin area to the square of the basin length (HORTON, 1932)**.** Its formula as following:

$$R_f = \frac{A}{Lb^2}$$

R_f: Form factor
A: Area of the basin (km2)
Lb^2: Square of basin length

3.2.2.9 -Elongation ratio (Re):

The elongation ratio is defined as the ratio between the diameter of the circle of the same area as the drainage basin and the maximum length of the basin (SCHUMN, 1956).It is derived by the following formula:

$$R_e = \frac{(2\sqrt{(A/\pi)})}{Lb}$$

R_e: elongation ratio
A: Area of the basin (km^2)
Lb: basin length

3.2.2.10 -Circulatory ratio (R_c)

Circulatory ratio (R_c) Circularity ratio is defined as the ratio of the area of the basin to the area of a circle having the same circumference as the perimeter of the basin (MILLER 1953).It is derived by the following formula:

$$R_c = \frac{4*\pi*A}{P^2}$$

Rc_c: Circularity ratio;
P^2: Square of the perimeter (km)

3.2.2.11 -Shape Factor (B_s)

Shape Factor (B_s), it is the ratio of the square of the basin length (Lb) to area (A) of the basin (HORTON, 1945):

$$B_s = \frac{Lb^2}{A}$$

B_s: Shape Factor
A: Area of the basin (km^2)
Lb^2: Square of basin length

3.2.2.12 -Coefficient of compactness

It is defined as the basin perimeter divided by the circumference of a circle to the same area of the basin.

$$C_c = 0.28 \frac{P}{\sqrt{A}}$$

C_c: Compactness Coefficient.
P: Perimeter of watershed.
A: Area of the basin (km^2)

3.2.3 -Relief parameter

When conducting the morphometric analysis of the drainage basin, we must analyze the relief aspects because it is a key factor in the water resources studies, direction of stream flow analysis in study area, and the following aspects were analysed in this research:

3.2.3.1 -Basin Relief (H)

Most meteorological and hydrological factors are function of altitude; it is interesting to study the hypsometry of the watershed by altitude range (different elevations in watershed). It is determined by arcGIS.

3.2.3.2 -Total basin relief (H)

The calculation is just the difference between the height of basin outlet and maximum height of basin (STRAHLER).

$$H = Z - z$$

3.2.3.3 -Relief Ratio

Relief Ratio is the ratio of basin relief to the horizontal distance on which relief was measured (SCHUMM, 1956).

$$Rh_l = \frac{H}{Lb}$$

H: Total basin relief.
Lb: length of watershed.

3.2.3.4 - Relative Relief (Rh_p)

Relative Relief (Rh_p) is the ratio of relief (H) to the perimeter of basin. It is an important morphometric variable used for the general estimation of morphological characteristics of terrain.

$$Rh_p = \frac{H}{p}\ 100$$

Rh_p Relative Relief
H: the total reliefs
P: perimeter of basin

3.2.3.5 - Ruggedness number (R_n):

Ruggedness number (Rn) is the product of drainage density (D_d) and basin relief (H) (STRAHLER, 1957;MELTON, 1958).

$$R_n = D_d * \frac{H}{1000}\ MR_n = \frac{H}{A^{0.5}}$$

H: total basin relief.
D_d: drainage density.
A: area of watershed.

3.2.3.6 - Slope

The slope is the angle of inclination of the local surface relative to the horizontal plane.It is determined by ArcGIS.

3.3 - Spectral Indices application

Two indices used in this research, Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI).

3.3.1 -Definition and principle of the indices that use them

In this part, two indices are used:

3.3.1.1 - Normalized Differential Vegetation Index (NDVI):

The Normalized Difference Vegetation Index (NDVI)is suitable for monitoring drought, estimating healthy status of vegetation, crop growth conditions and crop yields (SINGH *et al*, 2003). NDVI is a standardized index that can be used to generate an image showing vegetation cover (relative biomass). This index is based on the contrast of the characteristics of two channels of a multispectral raster dataset: the absorption of chlorophyllian pigment in the red channel and the high reflectivity of plant material in the near infrared (NIR) channel

3.3.1.2 - Normalized Difference Water Index (NDWI)

The Normalized Difference Water Index (NDWI) is a new method that has been developed to delineate open water features and enhance theirpresence in remotely-sensed digital imagery. The NDWI makes use of reflected near-infrared radiation and visible green light to enhance the presence of such features while eliminating the presence of soil and terrestrial vegetation features(MCFEETERS, 2007).

3.3.2 - Materials used

Satellite images to satellite sentinel-2, ArcMap 10.4

3.3.2.1 - Satellite sentinel-2

The Sentinel-2 mission provides for a combination of two satellites Sentinel-2A and Sentinel-2B equipped with identical Multispectral Instruments (MSI) capable of acquiring data in 13 bands(Table 01) at different spatial resolutions (between 10m and 60m)(EMANUELE et *al* 2016).

Table1: Sentinel-2 spectral bands characteristics

Sentinel-2 bands	Central wavelength (µm)	Resolution (m)
Band 1 – Coastal aerosol	0.443	60
Band 2 – Blue	0.490	10
Band 3 – Green	0.560	10
Band 4 – Red	0.665	10
Band 5 – Vegetation red edge	0.705	20
Band 6 – Vegetation red edge	0.740	20
Band 7 – Vegetation red edge	0.783	20
Band 8 – NIR	0.842	10
Band 8A – Vegetation red edge	0.865	20
Band 9 – Water vapour	0.945	60
Band 10 – SWIR – Cirrius	1.375	60
Band 11 – SWIR	1.610	20
Band 12 – SWIR	2.190	20

(GORDANA. K& UGURAVDAN, 2017)

3.3.3 –Methods

The methods used in this section are based on the following use of ArcGIS to Image processing and change detection.

3.3.3.1 - Image processing using ArcGIS

Image processing is done during the year 2018; it is based on pixel precision to collect information on surface water and vegetation dynamics in Wadi Tamanrasset during three different periods:

- First period: before precipitation in 02-08-2018 for vegetation detection and for water detection.
- The second period: after precipitation in 12-08-2018 for water detection.
- The third period: within two months after the precipitation (response time)for monitoring the evolution of vegetation cover.

In our work we used the Sentinel-2 images have a spatial resolution between 10m and 60m, we used 04 spectral bands which have a spatial resolution of 10m for calculate the two indices that use them. The indices used one for vegetation detection and the other for water detection by processing satellite images as following:

Table 2: Spectral bands used for calculate the indices

Index	Band	Formula
The Normalized Difference Water Index	03- Green 08- NIR	$NDWI=\frac{GREEN-NIR}{GREEN+NIR}$
The Normalized Difference Vegetation Index	04- Red 08- NIR	$NDVI=\frac{NIR-RED}{NIR+RED}$

3.3.3.2 - Change detection

Change detection is an important application of remote sensing technology. It is a technology that ensures that specific characteristics evolve over a certain period of time. It provides the spatial distribution of characteristics and qualitative and quantitative information on their evolution. The quantitative analysis and identification of the characteristics and processes of surface change is carried out from the different periods of remote sensing data. These are the type, distribution and quantity of changes, i.e. land surface types, boundary changes and trends before and after changes (ZHANG, 2008).

Change detection is a technique for determining changes in the particular characteristics of an object over a specific time interval. Its main objective is to provide quantitative and qualitative information on gaps and their spatial distribution, including the category, quantity and areas of change that have occurred (ZHANG, 2008).

After classification, two main classes are identified (water mass and vegetation cover), represented by statistical data. This showed a fluctuation in plant cover and surface water. From these data, change detection is analyzed at the obtained variables to try to extract the relationships between vegetation, surface waters and morphometric data of the study area.

3.4 - Field data study

Remote sensing provides quantitative information, geographic data and spatial distributions. This will make it easier for us to understand the dynamics within ecosystems. Its use remains limited so that it does not provide qualitative information during studies. There is a continuing need for field data that will allow us to understand spatial trends and distributions, as well as their associations and relationships across the study area.

In this study, a field survey was conducted to collect qualitative rather than quantitative information on plant species present in the study area (Wadi Tamanrasset Watershed). It's important to know plant species in order to characterize their environment (climate, geology, soil characteristics, etc.). Our aim through the qualitative data collection is simply to confirm the results of the processing of the images obtained.

3.4.1 - Material used

The delimitation is always materialized by a rigid frame or a stretched rope.

3.4.2 -Method

Sampling was carried out by a CDARS staff during the optimal vegetation development period. The sampling method used is the quadrats, the most common sampling unit that delineates an area from which to estimate vegetation cover, count listed plants or species. The inventory of plant species was carried out in 10x10m sampling units on three levels; each level has 03 stations, the total of the sections (09 quadrats) covering an area of 1 Km^2 over 200 ha of the selected area (Fig.10). In each frame, we estimated the existing plant species.

This allows, to use more quadrats for a vegetation survey, which increases the accuracy of the estimates, the number of samples depend on the size of the site, their nature, heterogeneity and diversity or the statistical population.

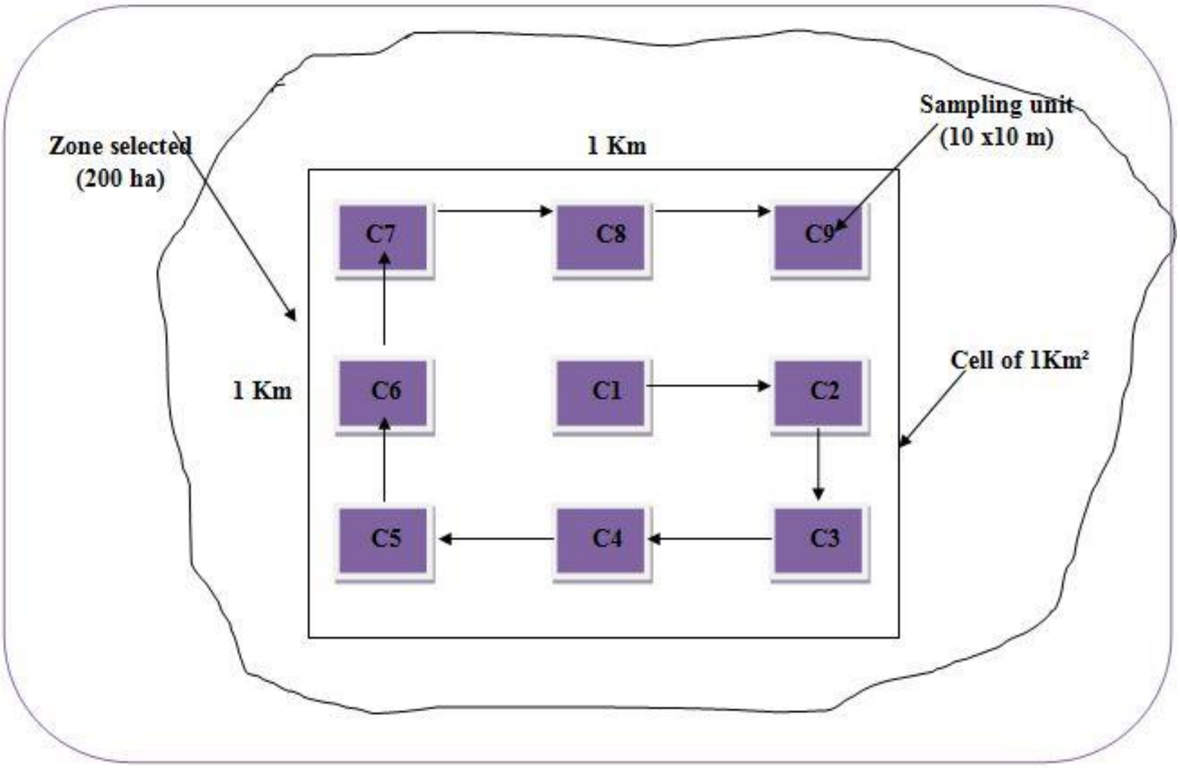

Figure 10: sampling device at 03 levels

CHAPTRE IV

Results

The study carried out has been divided into four sections, the first section deals with delineation of watershed; along with identify the stream order in the study area using DEM (12.5m) in arsis, the second section deals with the various linear and shape morphometric parameters (area, perimeter and length, relief parameters of watershed and drainage network with its characteristics) and the third section deals with the indices application for monitoring vegetation and surface water dynamics, along with comparison in change detections of land cover of study area, and finally the fourth section deals with field data study.

4.1 -Delineating Watershed and identifying stream networks

In order to delimiting the watershed we have to do the following basic steps:

4.1.1 -Two basic steps used

The basic results of the steps are the direction of flow and water accumulation to delineate the hydrographic network and the hydrographic network; based on digital elevation models using ArcGIS hydrological tools.

This standard procedure for extracting coded information from the flow, flow direction and accumulation network matrices represents the starting point for the further refinement of the watershed delimitation and the determination of geomorphometric data from the watershed and the extraction of the fluvial network.

4.1.1.1 -Flow direction result

The flow direction principle is based on eight valid output directions in relation to eight adjacent cells in which flow could occur as follows:

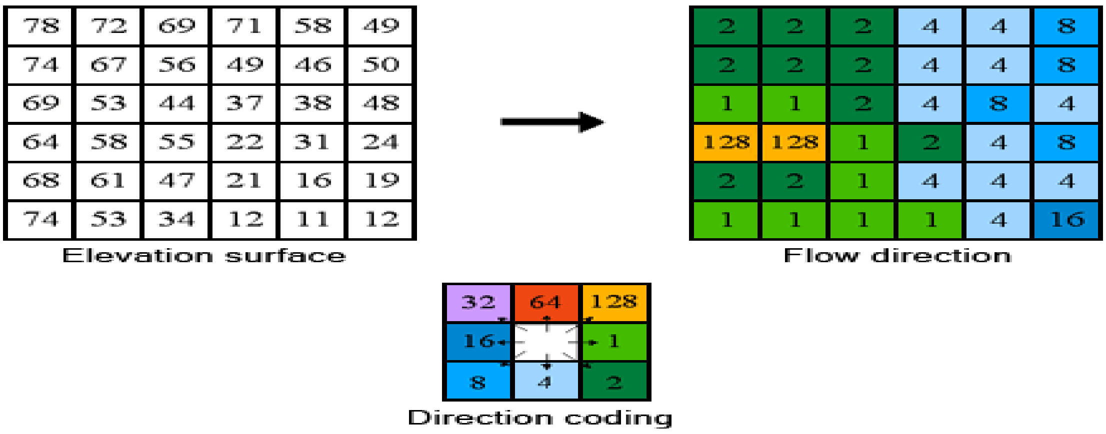

Figure11: the flow diriction principle

Obtained by ESRI website

Meaning of the numbers:

64: North, **128:** Northeast, **1**: East, **2**: Southeast, **4**: South, **8:** Southwest,

16: West, **32**: Northwest

The calculated water flow direction obtained after applying flow direction tool is shown in (Fig 12).

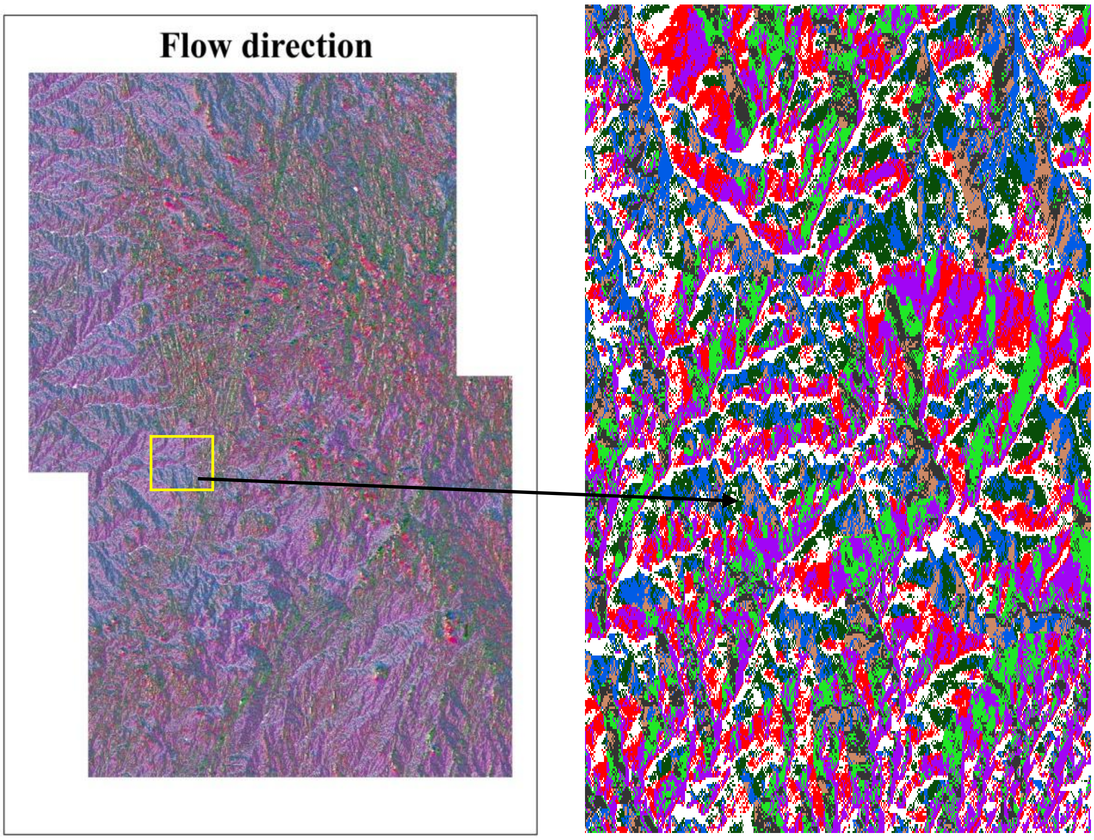

Figure12: the flow direction results

The eastern direction (1) is represented by a black color; the southeastern direction (2) is represented by a light green, the southern direction (4) is represented by a magenta color, the southwest (8) is in red, the west (16) in white, the northwest (32) is represented by a dark green color, the north (64) is in blue and the northeast (128) is represented by a brown color.

4.1.1.2 -Flow Accumulation

The Flow Accumulation tool calculates the cumulative flow as a cumulative weighting of all the cells flowing in each downhill cell of the output raster. In the figure below, the image at the top left shows the flow direction of each cell, and the image at the top right shows the number of cells that flow in each cell (Fig. 13).

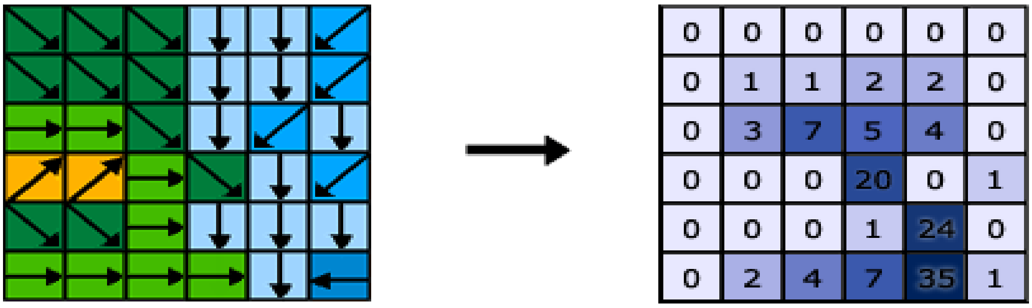

Figure13: flow accumulation principle

Obtained by ESRI website

Figure 14: flow accumulation results

High flow accumulation cells are concentrated flow areas that are used to identify flow channels; while cells without flow accumulation are high local topographic areas. The values along the cells that appear to form a flow network will have much higher values than the surrounding cells. As shown by the result of the accumulation of the following flow rate:

In the next flow accumulation output, the cells in white pixels have a very high value compared to those in black pixels. These cells with high pixel values form the watershed network of the basin.

From these basic phases, the identification of water systems and the delineation of watersheds are realized to obtain the following results:

4.1.2 -Watershed limits

The delineated watershed represents, in principle, the geographical unit on which the analysis of the hydrological cycle and its effects is based. This watershed is part of 1.04% of the greater Tamanrasset Wadi basin, which has a total area of approximately 48,000 km^2 and is located exactly between latitudes 22°46'00", 23°16'00" N and longitudes 5°30'00", 5°43'30" E (Figure 15). The shape of the watershed is sinuous and is based on cells of the MNE grid (different elevations in the cells).

Geomorphological indexes and numerical analysis are always based on the hydrographic network that provided information on the dynamical evolution of surface waters. We have therefore determined the order of the waterways in this watershed.

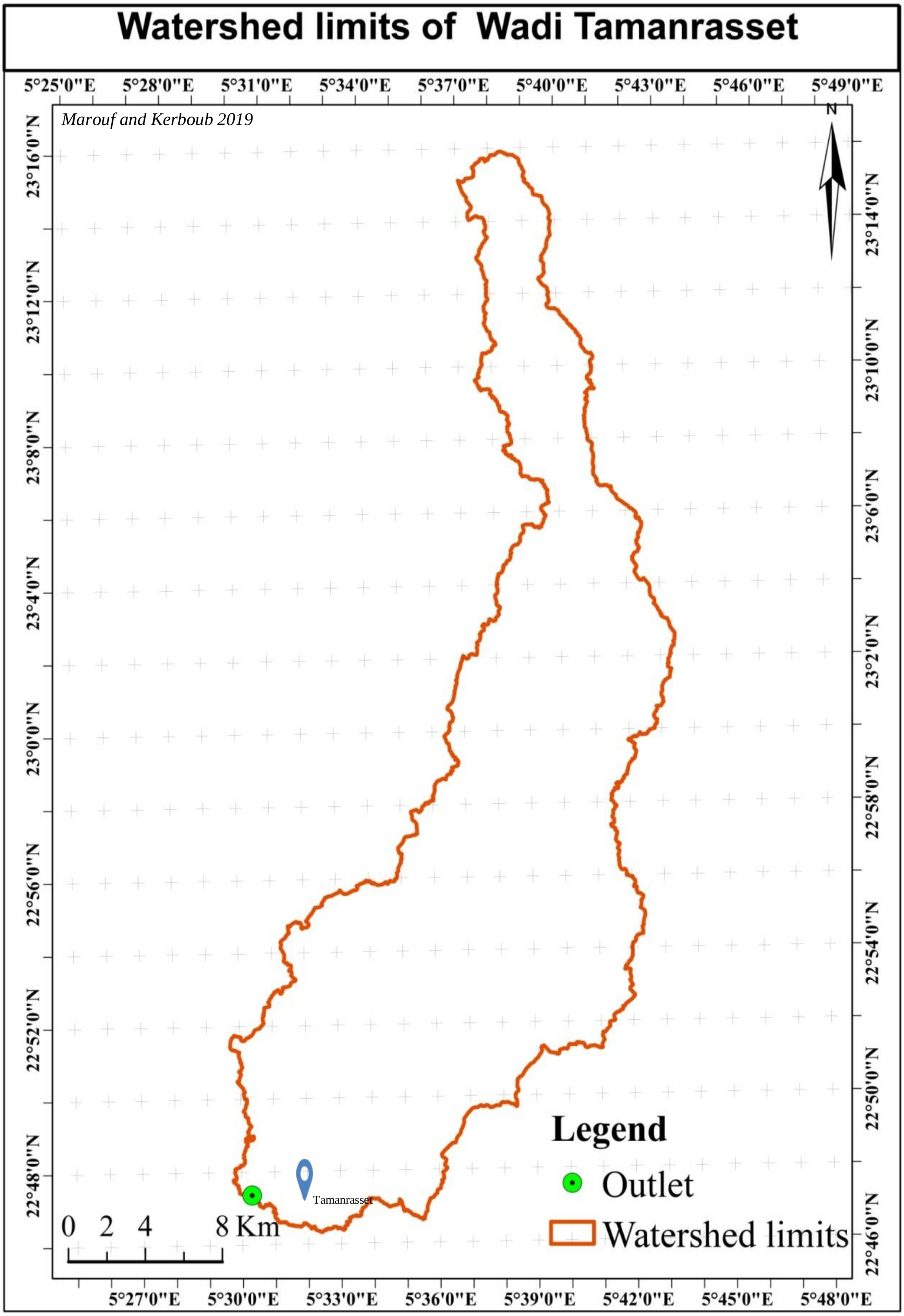

Figure 15: watershed limits map of Wadi Tamanrasset

4.1.3 -Identifying stream networks

The first step in the watershed analysis is the designation of watercourse orders, we have chosen the method proposed by STRAHLER (1957) for assigning orders to the watercourse network. This technique is based on measuring the degree of branching of watercourses in a watershed. Order is a method of identifying and classifying stream types according to their number of tributaries (assigning a numerical order to links in a stream system).

The principle of the Strahler method is as follows: all links without tributaries are assigned an order of 1 and are called first order, and the order of flows increases when flows of the same order cross each other. Therefore, the intersection of two first-order links will create a second-order link; the intersection of two second-order links will create a third-order link, and so forth. The intersection of two links of different orders will not lead to an increase in flow (the intersection of a first-order and second-order link will not create a third-order link but will keep the order of the highest located link, etc.).

The resulting drainage pattern shown in Figure 15, which is characterized by irregular branching of tributaries in many directions. The characteristics of the watercourses determined were used to deduce the parameters of the Wadi Tamanrasset catchment.

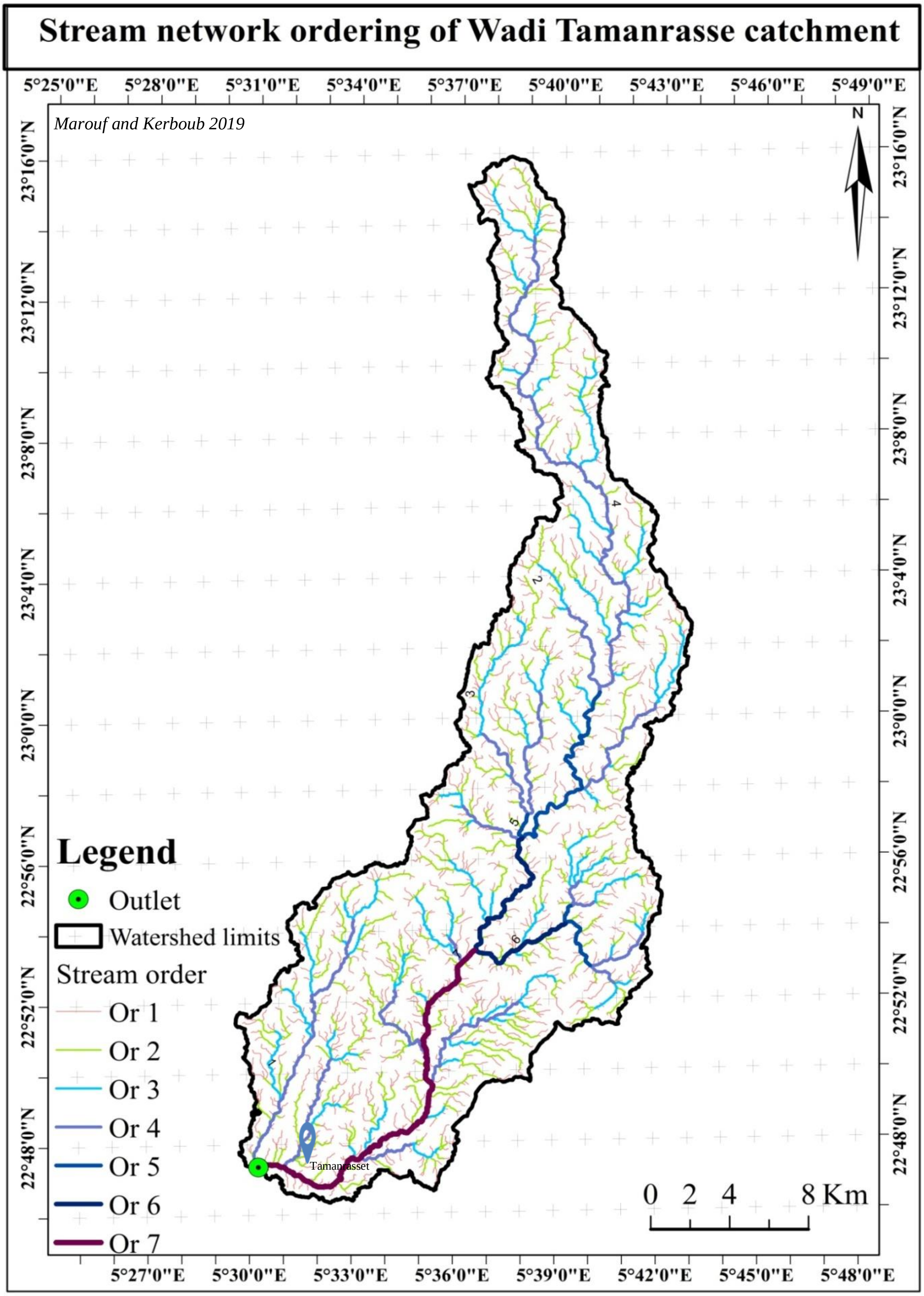

Figure 16: Stream network map of wadi Tamanrasset watershed

4.2 - Morphometric characterization of a watershed

Drainage basin or watershed analysis based on morphometric parameters is very important for watershed planning. Morphometric analysis of watershed is the best method to identify the relationship of various aspects in the study area.

4.2.1 - Linear parameter

Linear aspect of the drainage basin includes a description of stream ordering, stream length ratio and bifurcation ratio.

4.2.1.1 - Hierarchical order of the stream network and its characteristics

The establishment of a numbering system for each section of the stream flow in the hydrological network branch depends on its importance. This is the most important parameter for drainage basin analysis. In this study area, total number of streams found is 2217, it is noted that first order streams are highest in number while highest order has the lowest number, shown in following table:

Table 3: the different stream orders and its number and lenght.

Stream order	Number	Length (km)
Order 1	1727	621.768841
Order 2	386	303.7257
Order 3	81	156.734494
Order 4	15	115.63781
Order 5	5	18.9094126
Order 6	2	14.6876633
Order 7	1	22.2163136
Total	2217	1253.68023

The table represents the number and length of the different hydrological orders of the watershed studied, so that the order (1) is all the non-tributary waterways that number 1727, the order (2) includes all the channels resulting from the confluence of two rivers of the same order (1) that their number is 386 waterways, all the confluences between two rivers of the same order (2) give the rivers of the order (3) that its number reaches on the 81 rivers, the order (4) includes all the channels resulting from the confluence of two rivers of the same order (3) and the number of rivers of the order (4) is 15, and so on until the level (7).

4.2.1.2 -Bifurcation Ratio:

The Bifurcation ratio looks at the relationship between streams of different orders which denoting the ratio between the number of streams of one order and those of the next higher order in a drainage network. The bifurcation ratio results were shown in the following table:

Table 4: Bifurcation ration results

Order	Or ½	Or 2/3	Or 3/4	Or 4/5	Or 5/6	Or 6/7	Average Rb
Rb	4.47	4.77	5.4	3	2.5	2	3.69

Lower bifurcation ratio values are the characteristics of structurally less disturbed watersheds without any distortion in drainage pattern (NAG, 1998). The value of mean bifurcation ratio of watershed studied is 3.69 indicating structural control in drainage development in this area and this value shows that is the watershed of Wadi Tamanrasset has a mountainous drainage.

4.2.2 - Areal parameter

The areal parameter was represented as following:

4.2.2.1 -Measured dimensions of Wadi Tamanrasset watershed

The attribute data of the Wadi Tamanrasset watershed was obtained by ArcGis software so that the vectorization of the identified areas makes it possible to determine the different dimensions of the study area that are:

The surface of the watershed which was determined by the techniques of digitization was estimated at 498 km² and its perimeter was estimated at 177.1 Km; and the length of the main river of this watershed reaches of the 82.203 km, It extends from the altitude of 2746 m in Assekrem territory to the outlet of the watershed which is existed in the city of Tamanrasset (1394 m of the altitude). The length of watershed was measured in a straight line between the outlet and the highest point located along the perimeter; it is estimated at 54.53 km.

After summarizing some of the major results on dimensions of Wadi Tamanrasset catchment, we were examinees its geometric characteristics by clearly formulas, It is generally traded in all morphometric analyzes.

4.2.2.2 - Stream frequency (Fs)

Generally high stream frequency is related to impermeable surface material, sparse vegetation, high relief and low infiltration capacity of the region. The stream frequency in the watershed has been estimated at 4.45 km ^{2}, so the study revealed that the Wadi Tamanrasset watershed have high stream frequency because of the fact that it falls in the active zone of Wadi Tamanrasset.

The higher values, indicating denser network, found along the hilly regions, where the first order and second order streams are well-developed with large in number of streams (the presence of ridges on both sides of the Wadi, results highest stream frequency), shown in figure 17.

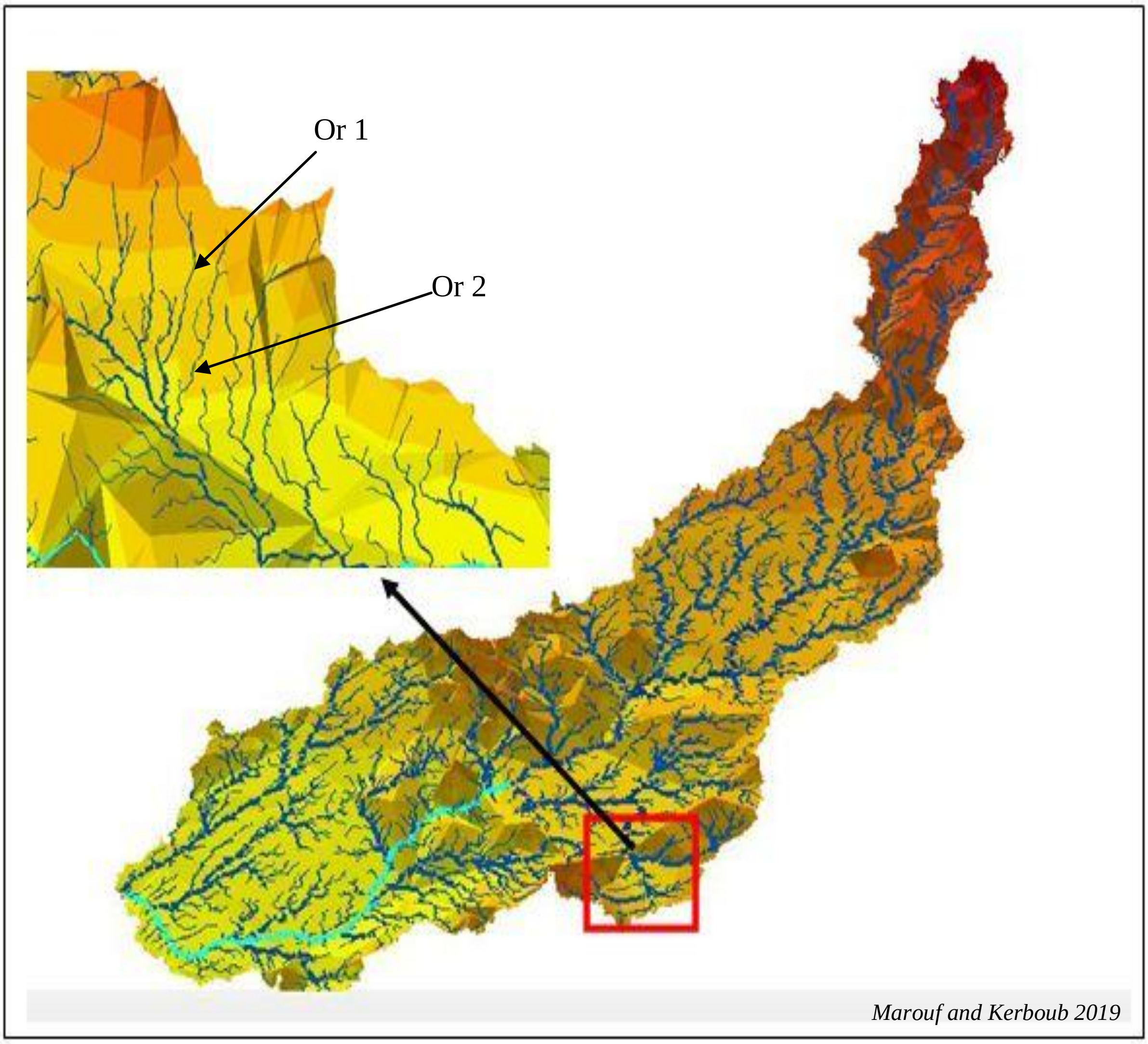

Figure 17: Frequency drainage in the Wadi Tamanrasset Watershed

4.2.2.3 - Drainage density (Dd):

The drainage density as the frequency drainage, that it is an essential element of drainage morphometriy to study the surface water dynamics, runoff potential, infiltration capacity of the land, climatic condition and vegetation cover of the basin.

Drainage density in the watershed is 2.52 km/km².It has been observed that low drainage density is found to be associated with regions having highly permeable subsoil material under dense vegetative cover, and where relief is low while as high values of drainage density are noted for the regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief (NAG, 1998). Because the drainage density of this watershed is less than 04, we say that the fundamental factor of decreased drainage density is the low rainfall and steep slope in the mountainous areas (figure 16), as this watershed has a High mountainous terrain and impermeable surface, also is having low and sparse vegetation cover.

4.2.2.4 - Drainage texture (D_t)

The drainage texture depends upon a number of factors, the first of which is stage of development and other natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity and relief (SMITH, 1950). The drainage texture has been classified to into five classes as following:

Table 5: The drainage texture classes

Value of Dt	<2	2-4	4-6	6-8	8<
Classes	very coarse	coarse	modera te	fine	very fine

We found that the watershed studied had a very fine drainage texture, its estimated value being 12.52; this is a very high value.

The drainage texture of the basin reflects the slow evolution of the watercourses because is closely related to the prevailing geological formation in the area (Rocky area) and also the low precipitation at the Tamanrasset region level.

4.2.2.5 - Length of overland flow (L_g):

Further the length of overland flow has a inversely relationship with the slope of watercourses, its higher values indicate to slower runoff process on account of the gentle slopes and the flow paths length, but its low values indicate to quicker runoff process because of the steep slopes and the short flow paths.

We observed that the value of length of overland flow in Wadi Tamanrasset watershed is very low (0.19); indicating that this region has steep slopes and at the precipitation results a very fast water runoff and do not take much time to reach the watershed outlet, especially since it is defined that the land cover of this area is impermeable, it is a rocky zone, as the previous morphometric analyzes prove.

4.2.2.6 - Shape parameters of watershed

The shapes of a watersheds influence to a large degree its hydrological responses and especially the flow regime during floods and the distribution of the vegetation cover at the level of this geographic unit, it gives us an initial image on stream network speed resulting from a rain. The shape parameters values calculated is shown in the table below:

Table 6: The shape parameter results of watershed

Parameter	Ff	Re	Rc	Bs	Cc
Value	0.167	0.461	0.199	5.970	2.222

From these all findings we conclude that the shape of this watershed is of elongated form, therefore, the values obtained refer respectively to:

- ✓ For the basin form parameter, the value was estimated at 0.167, and this value is used as a quantitative expression of the shape of basin form. All the basin form values which is lower of 1 indicating the form factor is more elongated.
- ✓ The value of elongation ratio (Re) generally varies from 0.6 to 1.0 associated with a wide variety of climate and geology. Values close to 1.0 are typical of regions of very low relief whereas, that from 0.6 to 0.8 are associated with high relief and steep ground slope (DAR. et *al*, 2013). So this elongation ratio value of Wadi Tamanrasset watershed indicates that the study area has a relief and steep ground slope.
- ✓ The value of circulatory ratio (Rc) reaches at 0.199 which shows that the watershed is elongated. Just like previous results.
- ✓ We find that there is an inversely relationship between the Shape Factor parameter and the basin form parameter. The high values of the shape factor refer to the elongated shape of the basin while the high values of the basin form parameter (Ff) mean the opposite. We find the value of shape factor is 5.970 and this value is logical for the previous result that is equal to 0.1.
- ✓ The coefficient of compactness defined as the ratio of the perimeter of the basin to that of a circle of the same surface, so its value is:

1.5<**Cc**<1.8: Basin of elongated shape.

1.0<**Cc**<1.15: Basin of circular form.

The value of this index (2.222) indicates that the watershed form is completely elongated and far from the circular shape.

4.2.3 - Relief parameter

In addition to that the study of terrain plays a large role in morphometric analysis; it is also a necessary factor in detection denudation conditions of the watershed from direction of streamflow analysis. The hypsometry study of the watershed shown in the figure 18:

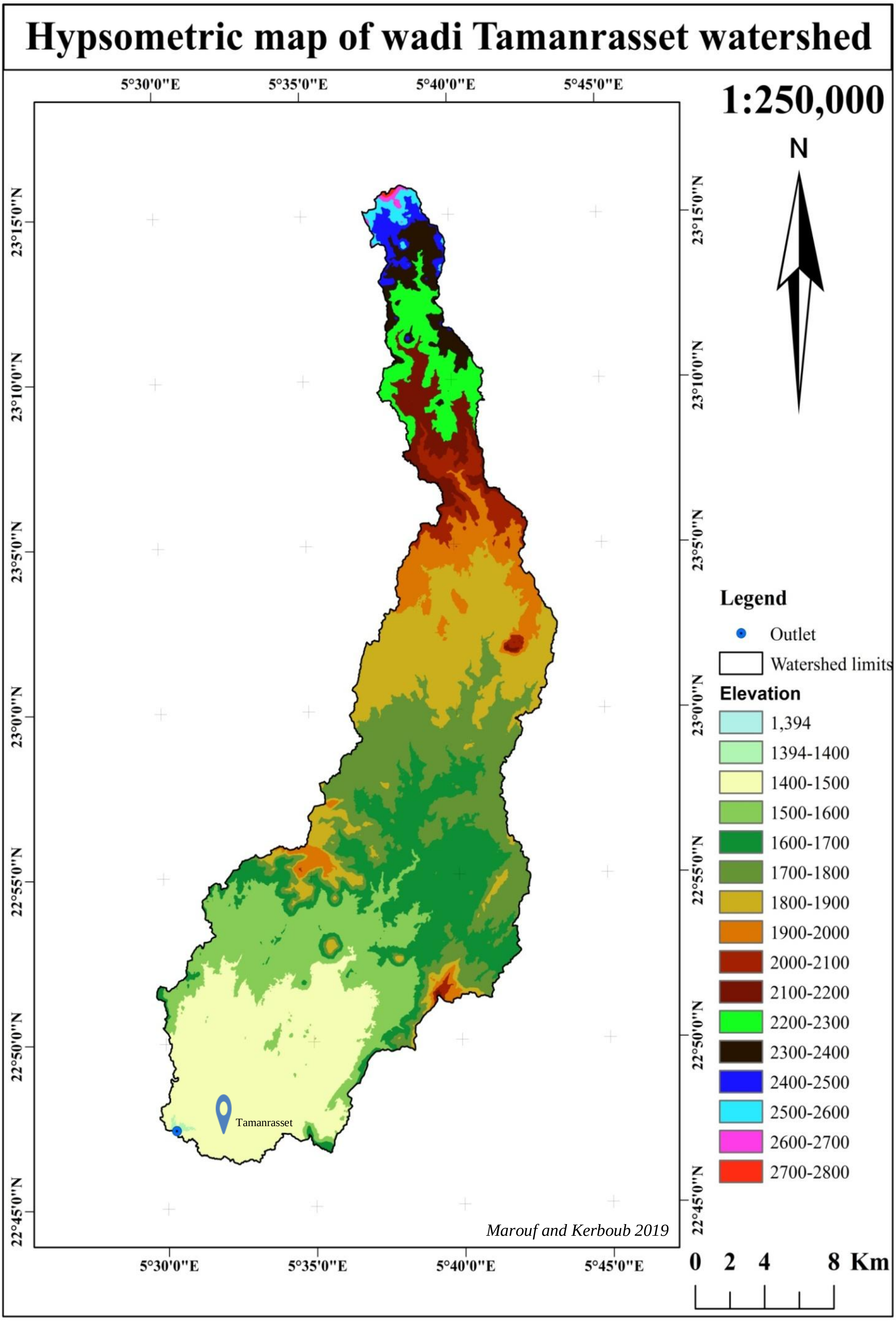

Figure18: Hypsometric map of Wadi Tamanrasset watershed

The hypsometric map indicates the distribution of basin area relative to height (the distribution of altitudes within the watershed). From this map, we observed when we headed from the watershed outlet to highest elevation in this latter, the surface decreases and the relief increases, but when we headed from the highest elevation of the watershed towards its outlet, the relief decreases but the surface increases (when the area proportion is highest, height proportion is lowest). So, the majority of basin area lies at low elevations of this watershed, this variation can be due to climatic (precipitation) and geological conditions of the area, so that the precipitation causes the eroded of the plateau gradually, so the uplands will be eroded and valleys will widen. As this happens, the area of the basin at low relief (valleys) increases whiles the area of the basin at high relief decreases (mountains or plateau surfaces).

From this map we can be extracted some characteristic altitudes and some indices for Wadi Tamanrasset watershed.

4.2.3.1 - Distribution of altitudes and surface area which occupied

Generally, the important altitudes occupied a low area proportions and when the area proportion increases, the relief decreases until reaching the outlet of watershed. See the table below:

Table 7: Distribution of the total area according th slices of altitude

Elevation	Surface (km²)
1394-1400	0.544012
1400-1500	96.8126
1500-1600	65.686259
1600-1700	74.103062
1700-1800	81.544547
1800-1900	73.971822
1900-2000	28.874614
2000-2100	14.164918
2100-2200	17.20825
2200-2300	21.800076
2300-2400	13.070899
2400-2500	6.048496
2500-2600	3.157855
2600-2700	0.769569
2700-2800	0.228081

The extreme altitudes of the watershed, such as minimum and maximum, are obtained from the map or by arcGIS. The maximum altitude is the elevation of the highest point of the watershed (2746 m), while the minimum altitude is the elevation of the lowest point, this being generally the outlet section of the watershed (1394 m). These values help to calculate the some indices of watershed.

4.2.3.2 - The reliefs parameter

The indexes which calculated are shown in table below:

Table 8: The different calculated parameter of the reliefs

Parameter	H	Rhl	Rhp	Rn
Value	1352	24.79	763.43	60.58

- ✓ High value of relief ratio is the characteristics of the hilly region, indicating that the Wadi Tamanrasset watershed is a mountainous area par excellence.
- ✓ The watersheds having higher relative relief have higher runoff potential, so this watershed is vulnerable to flooding and the erosion process.
- ✓ Generally, the ruggedness number is linked with the steep slope, so all results is indicating that the studied watershed represents a mountainous area and having the important slopes.

4.2.3.3 - Slopes of watershed

- ✓ The slopes of a watershed influence radically the value of the time of concentration and, directly, the runoff generated by a rainfall. The slopes of Wadi Tamanrasset watershed are shown in fig.19:

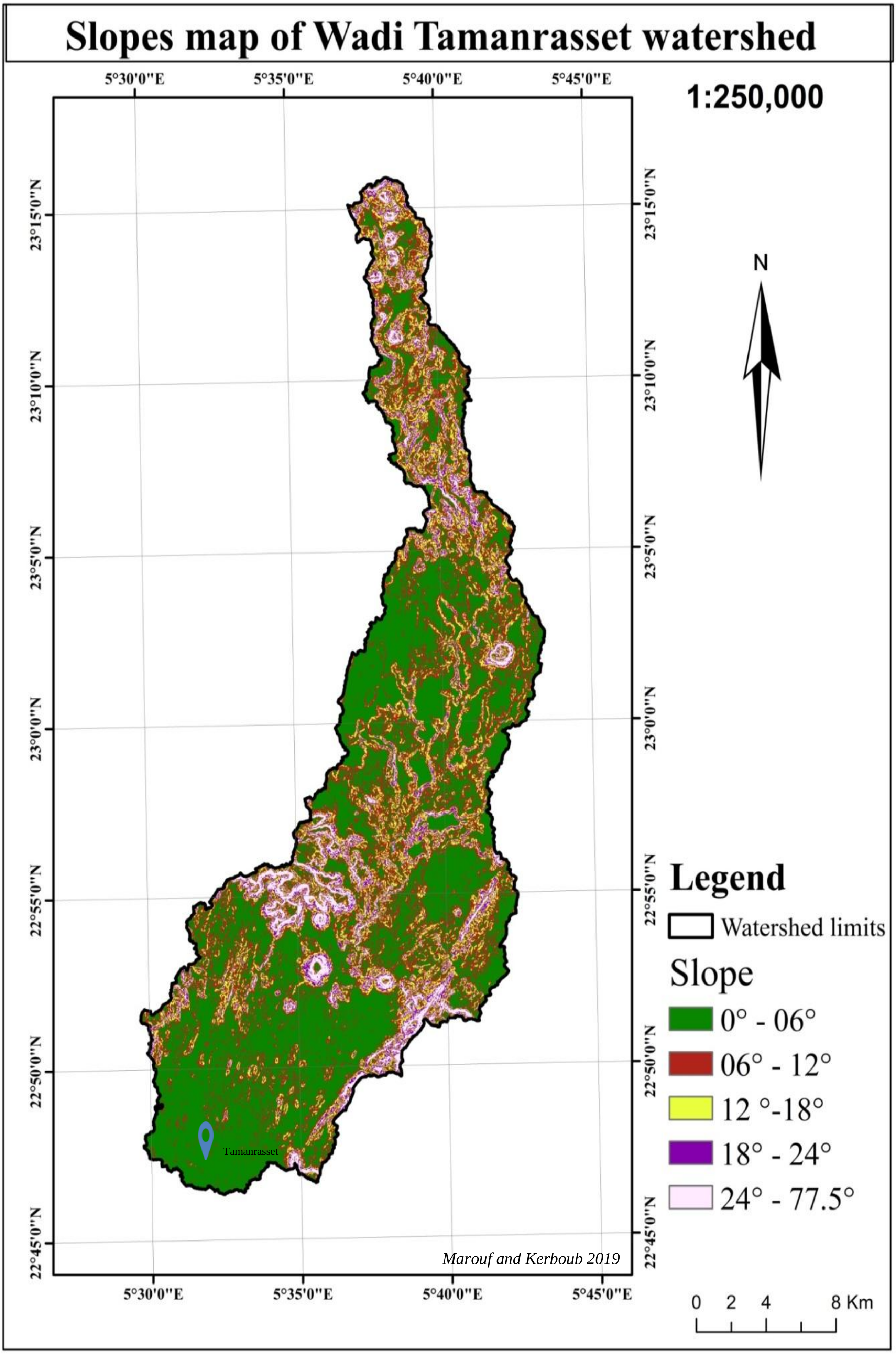

Figure19: Slope map of Wadi Tamanrasset watershed

From the hypsometric and slopes map and table of surface occupation by slopes and elevation it has been observed that there is a correlation relation between the surfaces occupied by the relief and by the slopes, it is logically because the mountainous regions contains a significant proportion of the slopes. as the elevations, the important slopes occupied a low area proportions. See the table below:

Table 9: Distribution of total area according to slices of slope

Slopes	Surface (Km)
0° - 06°	249.884185
06° - 12°	127.110144
12° - 18°	63.779631
18° - 24 °	33.04709
24° - 77.5°	24.144135

The waters run off the more in the large slopes, so in the mountains more floods than in plain which having the slopes much lower that are why this region is more vulnerable to flooding.

Note: The last interval was maximized to become more representative in the map.

4.3. - Spectral Indices application

The spectral indices are used to highlight specific features on the landscape, such as vegetation, water. We used the most common spectral indices which are the modified normalized difference water index (NDWI) and the normalized difference vegetation index (NDVI), for estimating the change detection and dynamics of the surface water and vegetation cover during a different periods.

4.3.1 - The Normalized Difference Water Index (NDWI)

When we calculated the NDWI, we fended that the topographic and cloud shadows in the mountainous area are showing in the obtained results.

At the application NDWI, we used the unsupervised classification and the basis of its work depends on the fact that any kind of items in the scene are made up of units of images with values close to each other. For compared between results of two periods, we presented the results by stretch values classification along a color ramp (to get more clear results). After that we presented the same results by the grouping values into classes in order to we can be quantified this results.

4.3.1.1 - Results presented by stretch values classification along a color ramp

The obtained results were at in two different periods, the first period before precipitation in 02-08-2018 and the second period after precipitation in 12-08-2018. The results are showing in figure 20 and 21:

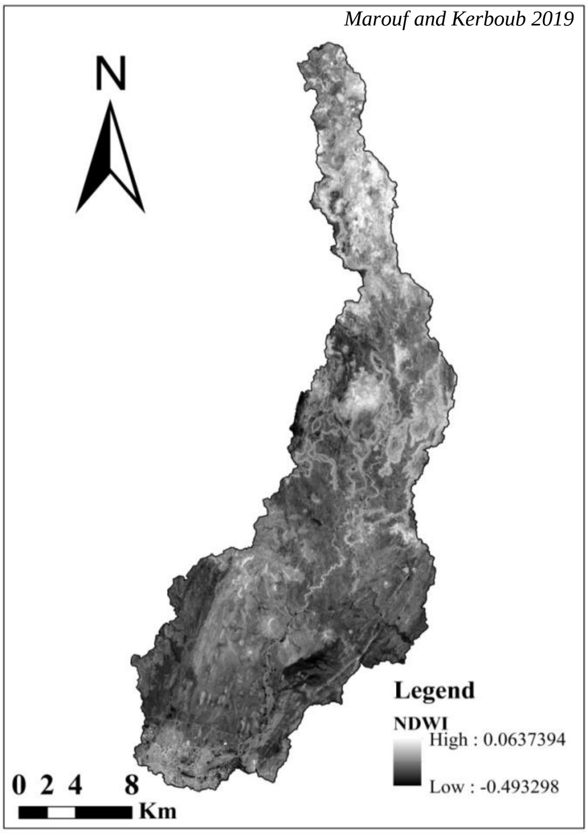

Figure 20: NDWI image in first period (02-08-2018)

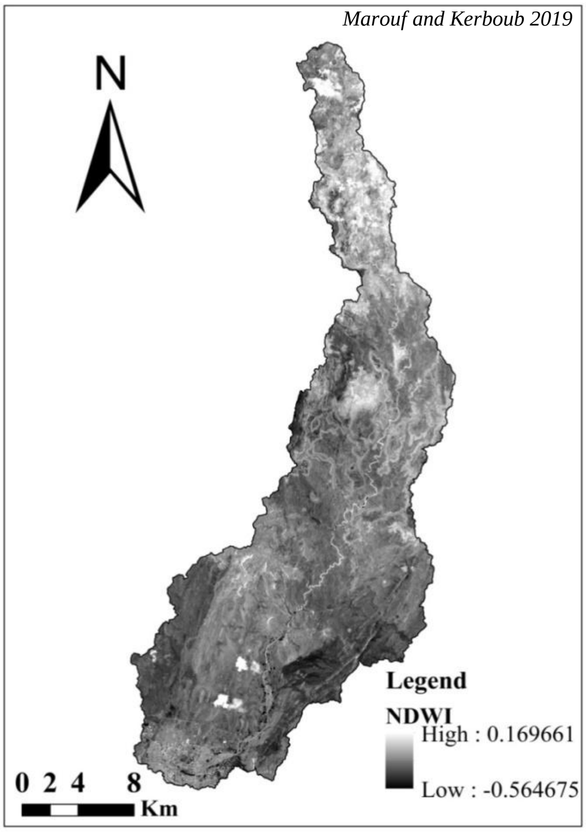

Figure 21: NDWI image in second period (12-08-2018)

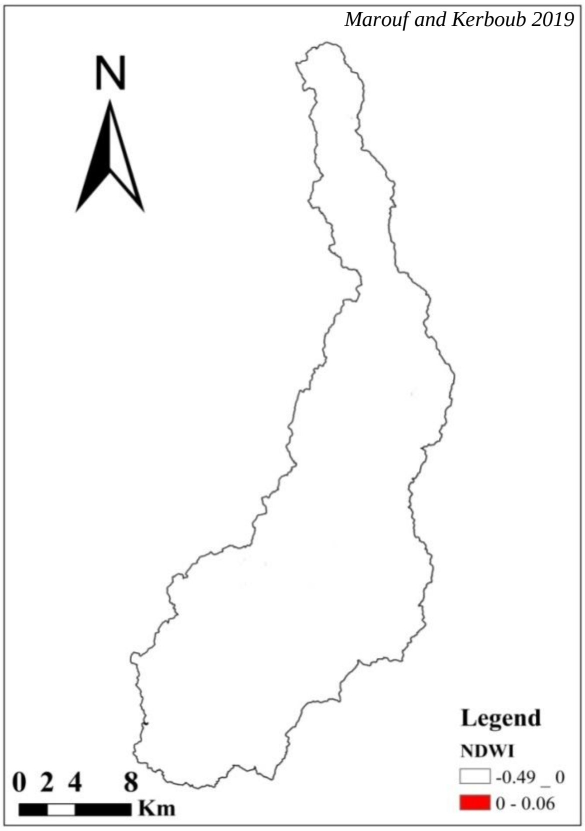

Figure 22: NDWI classes in first period (02-08-2018)

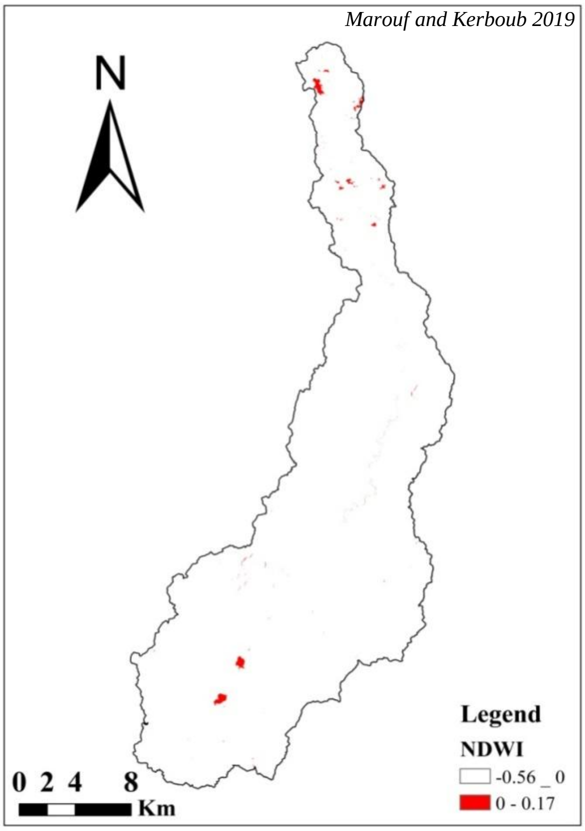

Figure 23: NDWI classes in second period (12-08-2018)

The values scales of NDWI are typically from -1 to 1 where positive values represent surface water and (with more proportion of water closer to 1) and negative values represent water absence (Dry land).

From the two figures, we observes that resultant values scale approximately from -0.49 to 0.06 in the first figure and the resultant values scale approximately from -0.56 to 0.17, so the maximal value of NDWI is indicating the important surface water in study area.In any case, these values remain low, of course, that is logical because we are in a desert region.

Between the two periods there is a difference in the extreme values (minimal and maximal), which indicating the increase of the surface water after the precipitation.

4.3.1.2 -Results of NDWI by grouping values into classes

The results represents in the figures above:

We classified the results of NDWI just into two classes to we can quantified the surface water according the its proportion of the surface, so that the negative values means the absence of water and the positive values means the presence of water, this classification is more logically because the study area not having a height proportion of surface water (dry area).For example the decrease proportion of water in first figure, didn't allow it to be a representative value in the image despite its presence. See the figure 22 and 23.

4.3.2 - Normalized Difference Vegetation Index (NDVI)

The application principle of NDVI as the NDWI principle, we used also the unsupervised classification, for compared between results of two periods, we presented the results by stretch values classification along a color ramp (to get more clear results). After that we presented the same results by the grouping values into classes in order to we can be quantified this results.

4.3.2.1 - Results presented by stretch values classification along a color ramp

The obtained results of NDVI were at in two different periods (between them approximately two month), the first period before precipitation in 02-08-2018 and the second period after 45 day from the precipitation (response time in order to get a best developing of the vegetation cover) this period was in 26-09-2018. The results are showing in the following figures:

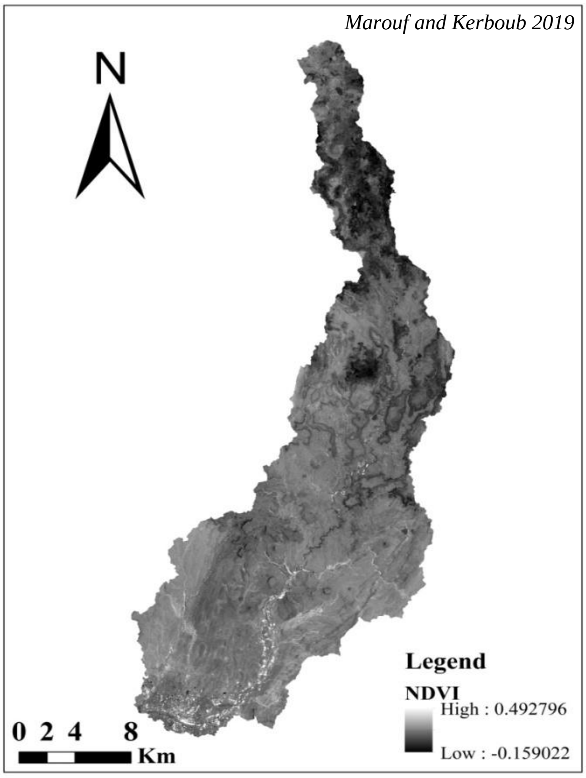

Figure25: NDVI image in first period (02-08-2018)

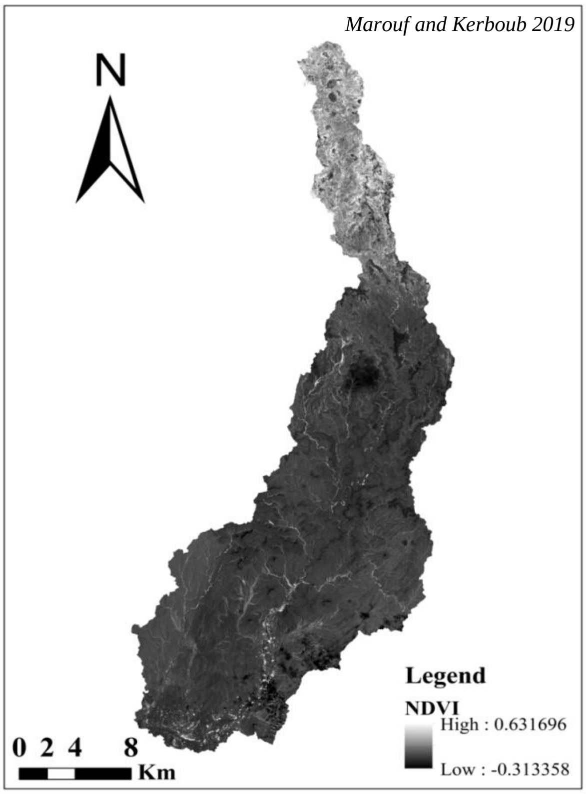

Figure26: NDVI image in second period (26-09-2018)

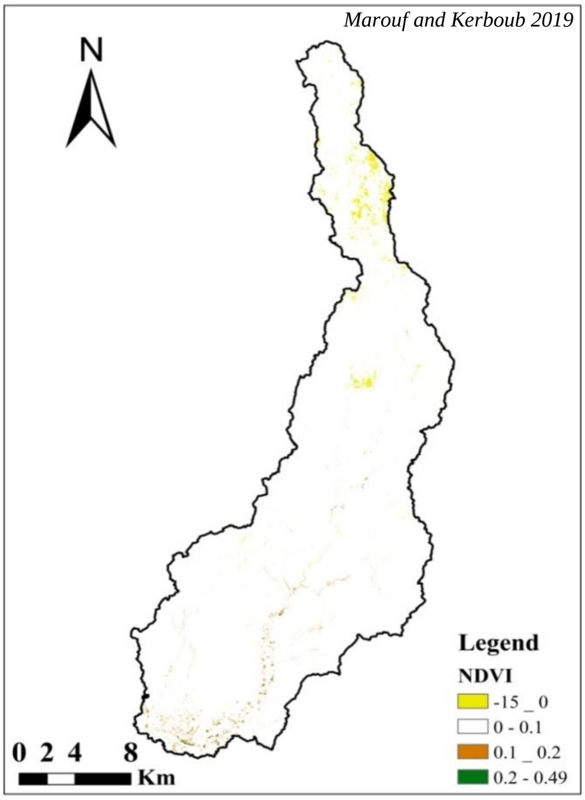

Figure 27: The NDVI classes in first period (02-08-2018)

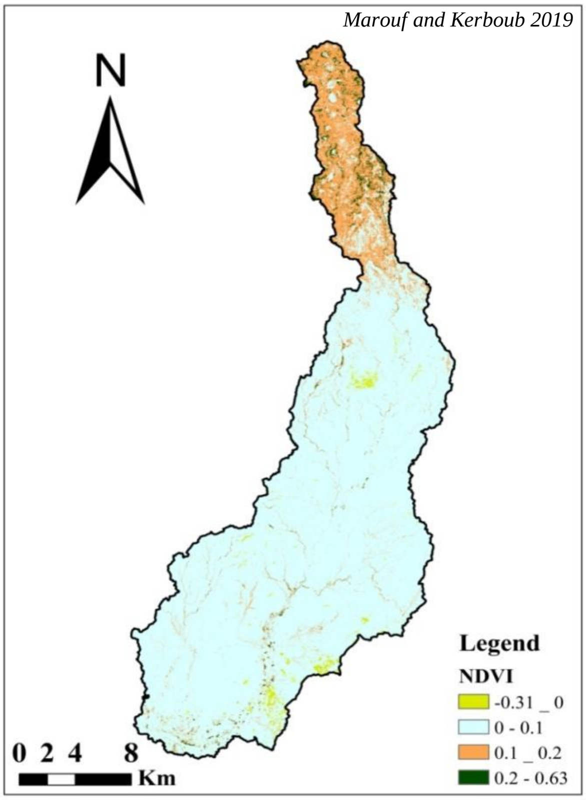

Figure 28: The NDVI in second period (26-09-2018)

The obtained value scales of NDVI are also from -1 to 1 where positive values represent vegetation cover and (with the high density of vegetation cover is closer to 1) and negative values represent vegetation absence (bare ground).

From the two figures, we observes that resultant value scales of NDVI from -0.16 to 0.49 in the first figure, and the resultant value scales from -0.31 to 0.63 in the second figure, so the maximal value of NDVI is indicating the important vegetation cover in the study area.

Between the first period and the second period there is a difference in the extreme values (minimal and maximal), which indicating the increase of the vegetation cover because the humidity factor increases after the precipitation.

4.3.2.2 - Results of NDWI presented by grouping values into classes

The results of NDVI were classified into four classes in order to quantify the vegetation cover according the proportion of the surface as we had doing with the NDWI index. The results of NDVI classification represents in following figures:

From the last figures, the classification of results NDVI index during the two different periods was grouping into four classes, there is a negative values and positive values represents the vegetation cover density which distributing according the surface of Wadi Tamanrasset watershed. The signification of those values scales is showing in the table below:

Table 10: Classes of NDVI index

Value of the NDVI	Class
Negative values	No- vegetation
0 – 0.1	Very low vegetation
0.1 – 0.2	Low vegetation
0.2 – 0.63	moderately strong density

Geminately from the obtained NDVI index results we have:

- ✓ During the dry periods, the distribution of vegetation which having an important density is in the downstream of the watershed.
- ✓ After precipitation (humid periods), the distribution of vegetation which having an important density is in the upstream of the study area, also it existed in the downstream by the low proportion. In this periods

4.3.3 Statistical analysis and change detection

The monitoring vegetation and surface water dynamics in Wadi Tamanrasset catchment by remote sensing technique had based on the change detection application for ascertaining the changes in surface area which is occupied by the vegetation cover and the surface water during the different determined periods. For ascertaining the changes in studied surface area we must use the quantitative data for observed and to quantified the proportion of the changes.

4.3.3.1 - The change detection of the NDWI index

The quantitative data of surface area changes of watershed was represented according the obtained statistical information by arcGIS shown the increase soil occupation by surface water after the precipitation, so that the surface of water was covering 0.15 km² in 498 km² ofwatershed before the precipitation, but its surface had increasing after the precipitation until reached to 2.1 km² in the total surface area of the watershed (498 km²). See the following table:

Table 11: The occupied surface by each class of NDVI index in study area

	Surface (km²)	
	Class 01	**Class 02**
Period 01	497.98	0.015
Period 02	495.90	2.097

4.3.3.2 - The change detection of the NDVI index

The changes detection of NDVI index was represented by the areal data which was obtained from arcGis, we had measured the surface of each class of vegetation cover in the study area, and the results are represented in the table:

Table 12: The occupied surface by each class of NDVI index in study area

	Surface (km²)	
Class	Period 01	Period 02
1	5.33	5.029
2	490.01	426.75
3	2.27	58.68
4	0.37	7.51

There is the increase in the surface of vegetation cover after the precipitation, especially the last class which represents the high density of vegetation cover.

4.4. The results of field data

The knowing the species of plants is an important parameter to studying environmental characteristics (climate, geology, soil characteristics...), and it is a qualitative indicator complete the information that we getting from the remote sensing, and this latter mostly provide a relative data on variables to be studied. So that always we need field data, which enhance our understanding about patterns and spatial distributions, their associations and relationships at the study area level. The results of field survey are showing in the following table:

Table 13: The group of vegetation existing in Tamanrasset watershed

Plants	Description	Habitat
Acacia ehrenbergiana Fabaceae	tall shrub or small tree	drought-tolerant species and can survive in areas with a rainfall range of between 50 and 400 millimetres perannum
Urgineanocti flora Batt. &Trab. Hyacinthaceae	plant growing from a bulb or corm or rhizome or tuber. Bulbous plant having showy white to reddish flowers.	After the rains, in rocky terrain and hamada.
*Panicum turgidum*Forsk Poaceae	Perennial herbaceous plant	the wadi beds.
Aristida pungens Desf. Poaceae	tall perennial plant with deep roots and long leaves	a plant of the dunes, present in the Sahara.Extremely drought-resistant
Calligonum comosum L'Hérit. Polygonaceae	Shrubs plant .	in wadis beds, regs and alluvium
Tamarix aphylla (L.) Karst. Tamaricaceae	is an evergreen tree	In watercourses in arid areas
Randonia qfricana Coss. Resedaceae	. Deciduous sub-shrub (high: 50-100 cm), with spiny branches.	watercourses and regs
Citrulus colocynthis Cucurbitaceae	Perennial plant	in sandy,arid soils and watercourses.
Artemisia herba_alba Cucurbitaceae	Artemisia herba-alba is a short shrub .is a chamaeophyte that grows to 20–40 cm.	Watercourses

Acacia tortillis sp. Fabaceae	"miracle" tree of circum-Saharian region	in the aridand semi-arid regions of Africa .sandy and loamy soils.

CHAPTER V

Discussion

The complexity of the Tamanrasset region required us to make a complete study in terms of water surface and vegetation cover monitoring with the focused on the morphometric analysis of the Wadi Tamanrasset watershed, which has a profound impacts on the watershed hydrology and so also impacts on the vegetation cover. We tried to link the results between them and its compare with previous researches on the region:

5.1. In terms the morphometric analysis

STRAHLER (1964) mentioned the important of morphometric analysis, so said that the quantitative analysis of morphometric parameters have to be of immense utility in river basin evaluation, watershed prioritization for soil and water conservation and natural resources management at watershed level. Morphometric analysis of a watershed provides a quantitative description of the drainage system which is an important aspect of the characterization of watersheds.

Within this perspective, our focused was primarily on the morphometric analysis of Wadi Tamanrasset watershed and from which we derived valuable information about study area. The significations of the obtained results of morphometric analysis were as following:

We found variation in order of stream network is largely due to physiographic and structural conditions of the region, the total number of streams in study area found 2217, classified to 07 orders and each one is different from the other at level of length, number, texture and its distribution area. From our study, the estimated 3.69% of the bifurcation ratio shows that is the watershed of Wadi Tamanrasset has a mountainous drainage; the stream frequency is high (4.45 km $^{-2}$) because that it falls in the active zone of Wadi Tamanrasset and indicating also it's found along the hilly regions.

NAG (1998) mentioned that the drainage density is found to be associated with regions having highly permeable subsoil material under dense vegetative cover, and where relief is low while as high values of drainage density are noted for the regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief. But this study area, the fundamental factor of decreased drainage density is the low rainfall and steep slope in the mountainous areas as this watershed has a high mountainous terrain and very low surface permeability, also is having low and sparse vegetation cover.

What confirms that decline of drainage density is the low rainfall and steep slope in the mountainous is a said of BRIEDGE (1993) that the northern part of the catchment area consists of basaltic plateaus covering most of the Assekrem at 2000 m altitude, while The South is formed by the alternation of granitic formations attributed to the Pharusian. Also, BOUAMER and CHARGUI (2018) mentioned in their search for Wadi M'ya, which its upstream is located in a part of the central Sahara, that the region has seen a low rate of rainfall in recent years, Where they classified the most drought years of the region in the years 2005, 2010, 2016 and 2018, these years are more connected to the "dry period", this means that what NAG said does not correspond to the case of Wadi Tamanrasset watershed, because Wadi Tamanrasset is a specially complex region. so, this denies that the decline of this ratio is due to the permeable soil material, also the basin has a very fine drainage texture (12.52), so it reflects the slow evolution of the watercourses (limit development) because is closely related to the prevailing geological formation in the area (Rocky area) and also the low precipitation at the Tamanrasset region level.

5.2- In terms the shape of Wadi Tamanrasset watershed,

we get that the watershed is having a elongated form, where the values obtained : 0.167, 0.461, 0.199, 5.970, 2.222 represents respectively the parameters, basin form , elongation ratio, Shape Factor, circulatory ratio and coefficient of compactness, so that all values parameters, indicate the watershed is a elongated shape, and this is showing that this watershed is a mountainous area having a high relief and the important slopes, so this watershed is vulnerable to flooding and the erosion process.

5.2. In terms the monitoring the vegetation cover and its relation with a surface water dynamic of this area

From our results, we noticed a correlation between the increase of surface water and ephemera vegetations so that we recorded the area of surface water before precipitation by 2.64 km², while after rain which fed watercourses, we recorded an increase in the covered area by 63.55 km, where the total area of vegetation covered of 66.19 km after precipitation; the increase in this latter is therefore related to the increase of surface water, but we doesn't denied the impacts of lithologic factors on the vegetation cover and also the surface water; Monod in 1954 confirmed that on the other hand, in the mountains of high altitude, including the Hoggar hosting the highest peak in the Sahara, the drop in temperature with altitude leads to a decrease in aridity. With altitude, the vegetation thus ceases to be contracted and concentrated in the Wadi bed and gradually spreads to Regs and rocky plateaus. Also, according to (BOULAHBAL, 2012), the vegetation, almost absent, but it is concentrated in and near the big Wadi, it is mainly composed of shrubs, herbaceous plants of acacias, colocynth of the desert and sometimes of tamarix, which having an indirectly related with the surface water, as the vegetation increased in the upstream of the basin more than the downstream, this may be due to the difference in the climate between the two regions so that the more the rise by 100 m, the temperature drops by 1 ° and the rainfall increases by 1 mm so the rate of rain can be higher above the bottom resulting in the emergence of ephemera plants in the upstream of the watershed (having directly related with the surface water).

But it is worth mentioning that the rate of water increase was very low, where its surface was before the rain estimated at 0.015 km² and after the precipitation has become 2,097 km², as we previously mentioned that BOUAMER and CHARGUI (2018) reported that the 2018 was a dry period (low precipitation).

This information which was obtained by some researches, indicates that the distribution and density of vegetation cover are impacted by the federation of two factors together (lithologic and hydrologic factors), so that concentrate plants always be in the runoff, according LE HOUÉROU (1997) in the arid plains of the central Sahara, perennial vegetation is confined to runoff or the presence of groundwater.

After monitoring the surface water dynamic in watershed of Tamanrasset by remote sensing of two different periods, we observed that a low precipitation that led to the runoff of water though its low proportion, due the steep slopes in this area.

According to (MEHALII; 2017), the month of February is the least rainy month l in this region. On the other hand, the months of August and September record the highest values. This increases the probability of flood specially, in the Assekrem region; we indicated that there is a Runoff at the watershed level in 2018 even though the frequency of rainfall is very low.

So that at the Tamanrasset region level, the precipitation is on the summer, we indicated that there are a Runoff at the watershed level in 2018 though the low proportion of precipitation, but it causing to runoff until the outlet of watershed, the outlet of watershed is within the city making it vulnerable to flooding.

The increase in the percentage of surface water has resulted in an increase in the density of the vegetation cover, mostly concentrated in the upstream (arid), with a medium increase in the vegetation cover density in the downstream (hyper-arid).We assumed that the increase in vegetation cover represents a ephemeral species, so that, according to the field study we have done in Wadi Tamanrasset during the optimal development of vegetation cover, we found there are an important species of vegetation cover were representing ephemeral plant. Some researchers mentioned the general characteristics of this species of between it:

LAARBI (2003) mentioned that as soon as the water conditions are favorable, they perform their life cycle until the its flowering and fruiting before drying out of the soil. Also Wolfgang and Dieter (2010) mentioned that the life cycle can be short, it is two to three weeks. OZENDA (1991) and CHEHMA (2005) mentioned that these plants often constitute, after periods of rainfall, a continuous carpet useful for grazing.

So, we suppose considered the plants that emerged after the rainfall, they represent the ephemeral vegetation. And the low changes in the vegetation cover in the downstream of watershed indicate that the most plants were founding in this slice, represents the perennial plants. The inequality of distribution between ephemera and perennials is also due to adaptation to drought (OZENDA, 1983).

5.3. In terms the field data

Most of the plants that were found after conducting the field survey, were mentioned by CHAHMA (2006) as living in the valleys, and they are: *Panicum turgidumForsk ,Calligonum comosum L'Hérit.,Tamarix aphylla (L.) Karst,Randonia Africana Coss,* and *Citrulus colocynthis*. QUEZEL (1954) also mentioned that the vegetation observed in the Hoggar landscape is natural and confined in wadi beds and the rock gardens bordering them.

Generally, we observed the vegetation cover in Tamanrasset is a low; this scarcity is directly linked to the climatic and climatic conditions that are binding on plant survival. OZENDA (1954) mentioned that the soils encountered in this region show little or very little evolved, due to in sufficient moisture, and MONOD (1957) also, mentioned that they are azonal soils, rough, with little or no differentiated profiles.

CONCLUSION

The region of Tamanrasset is part of the Algerian Sahara, it is characterized by a particular landscape with mountains of different geological nature and complex tectonics.

The synthesis of the climate data on the Tamanrasset region allows us to distinguish that the region is characterized by a hyper arid climate, the annual temperature average is 22 °C and rainfall does not exceed 50mm at 1400m altitude and can reach 380 mm at elevation of 2700m, while the region of Assekrem characterized by arid climate.

The drainage basin system of Tamanrasset is exceptionally dense, making it virtually impossible to count all watercourses especially their primary or secondary tributaries. Most of these watercourses originate in the highest parts of the Atakor and diverge in all directions. Their trace begins in the mountainous regions, with a well-marked bed and a steep slope, and often ends up crossing the flattened surfaces of the regs where they become difficult to identify in their downstream courtyard.

Remote sensing and GIS are integral to each other. The development of Remote Sensing is of no use, without the development of GIS and vice versa. Remote Sensing has the capability of providing large amount of data of the whole earth and also very frequently. GIS has the capabilities of analyzing a large amount of data within no time. These voluminous data would have become use less without the development of GIS analysis processes. The methods of remote sensing are a very effective and rapid support to high light the geological formations and to specify the limits of different geographic formations of a given region. The knowledge of the field of the study area confirms the results and above all, it allows extrapolating the data to areas not yet visited. It is therefore a very effective tool for regional mapping.

The methods of remote sensing are a very effective and rapid support to high light the geological formations and to specify the limits of different geographic formations of a given region. The knowledge of the field of the study area confirms the results and above all, it allows extrapolating the data to areas not yet visited. It is therefore a very effective tool for regional mapping.

Monitoring vegetation and surface water dynamics of Wadi Tamanrasset by technology of remote sensing and Earth Observation data using the software of Gis give a lot of information about the watershed like its limit, the flow network, slope and the elevation of the basin terrain. And its morphometric characteristic also show the dynamics of covert vegetal and surface water and this by application of some spectral indices. We can easily translate the information which has been processed into quantitative data to facilitate their analysis and classification according to detection of change at their level.

The Tamanrasset watershed cover 498 km² and its perimeter was estimated at 177.1 Km .It has morphometric characteristics that favor runoff during periods even if they were low rain. Rain fall is low and appears as thunderstorms from May to September, It is noted that these storms give rise to significant floods.

During this period the temperatures each their maximum threshold, which results in very high evaporation values, this makes it decrease the possibility to recharge the aquifers in the bed of the Wadi where the impermeable land cover (rocky area), but the bed of Wadi having the sediments which are deposited also have a good permeability.

We obtained results that show the important overall changes of the Watershed with increase of water surfaces and of vegetation cover, the proportion cover vegetal in first period (02-08-2018) cover in area 2.64 km² while in the second period (12-08-2018) cover in area 66.19 km^2. For water surface proportion, we found that the first period (02-08-2018) cover 0.02 km² and 2.1 km² in the second period (12-08-2018).This evolution depends on the studied conditions in the region, that's mean, the vegetation dynamic in Wadi Tamanrasset during 2018 was according the precipitation and runoff, but its growth was confined to the valley level only, because it contains a considerable soil compared to other pools, which are mostly rocky areas.

Our study Contributed in monitoring vegetation and surface water dynamics of Wadi Tamanrasset by technology of remote sensing and Earth Observation data in give a small idea about the cover vegetal and surface dynamic in the watershed of Tamanrasset. Any environmental system study requires a long period to understand complexity and monitor its changes, the results of our study was relative and not absolute because it was conducted within one year only (2018).

The fact that Tamanrasset is a unique region is a combination of historical, lithological, climatic and environmental factors that are very different from other desert areas, we indicates that the quantitative or qualitative description of drainage basins is more difficult. Although drainage networks may be classified according to the geometry of their branches and quantitatively described by orders, lengths, areas, and densities, this all done by remote sensing, within this perspective, the remote sensing has proven to be a powerful tool for has proven to be a powerful tool for watershed analysis and management. It can be used to do another study of monitoring of this ecosystem in long period and many years to give us more information about the characteristic of this Wadi also knowing what are the impact factors.

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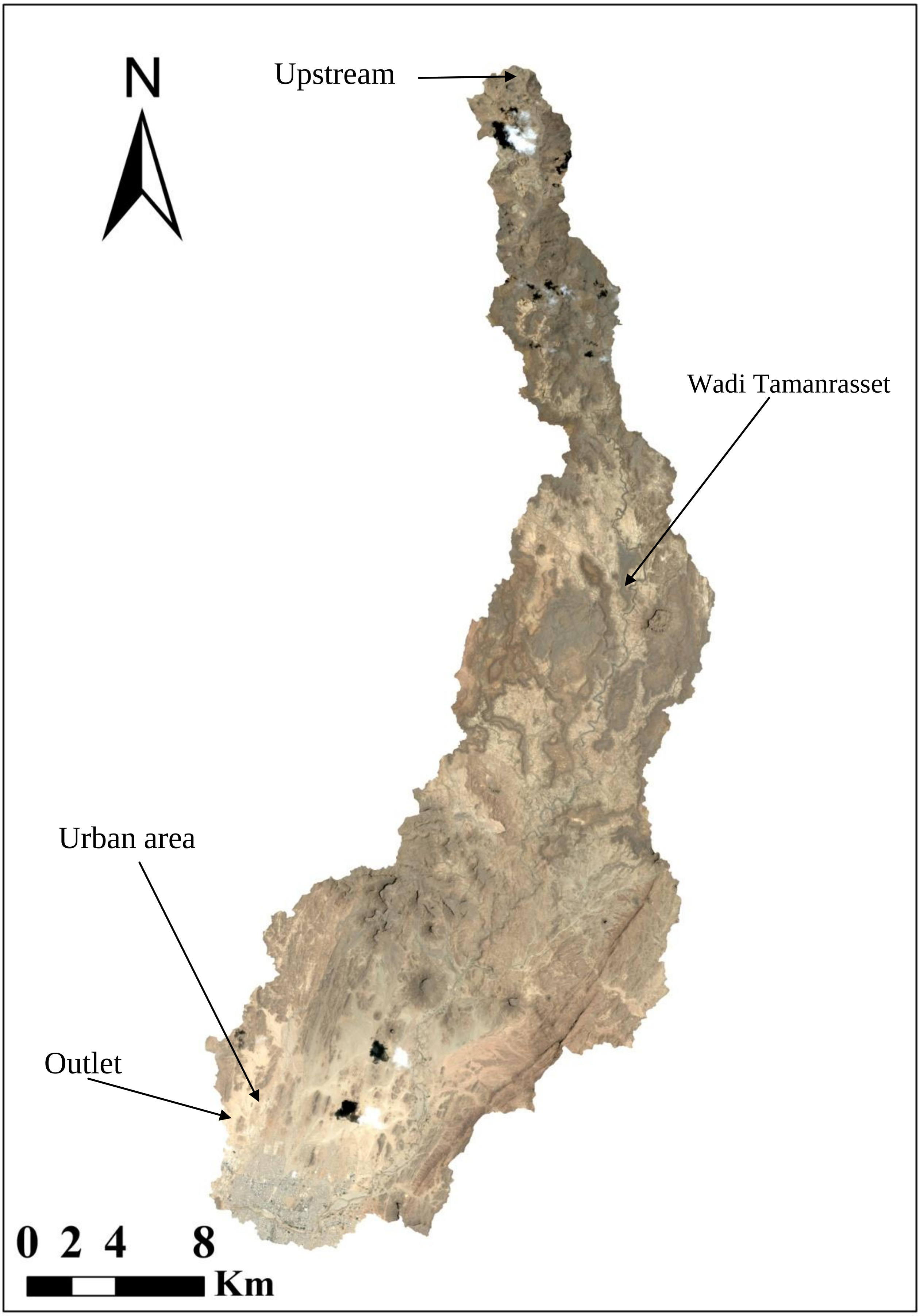
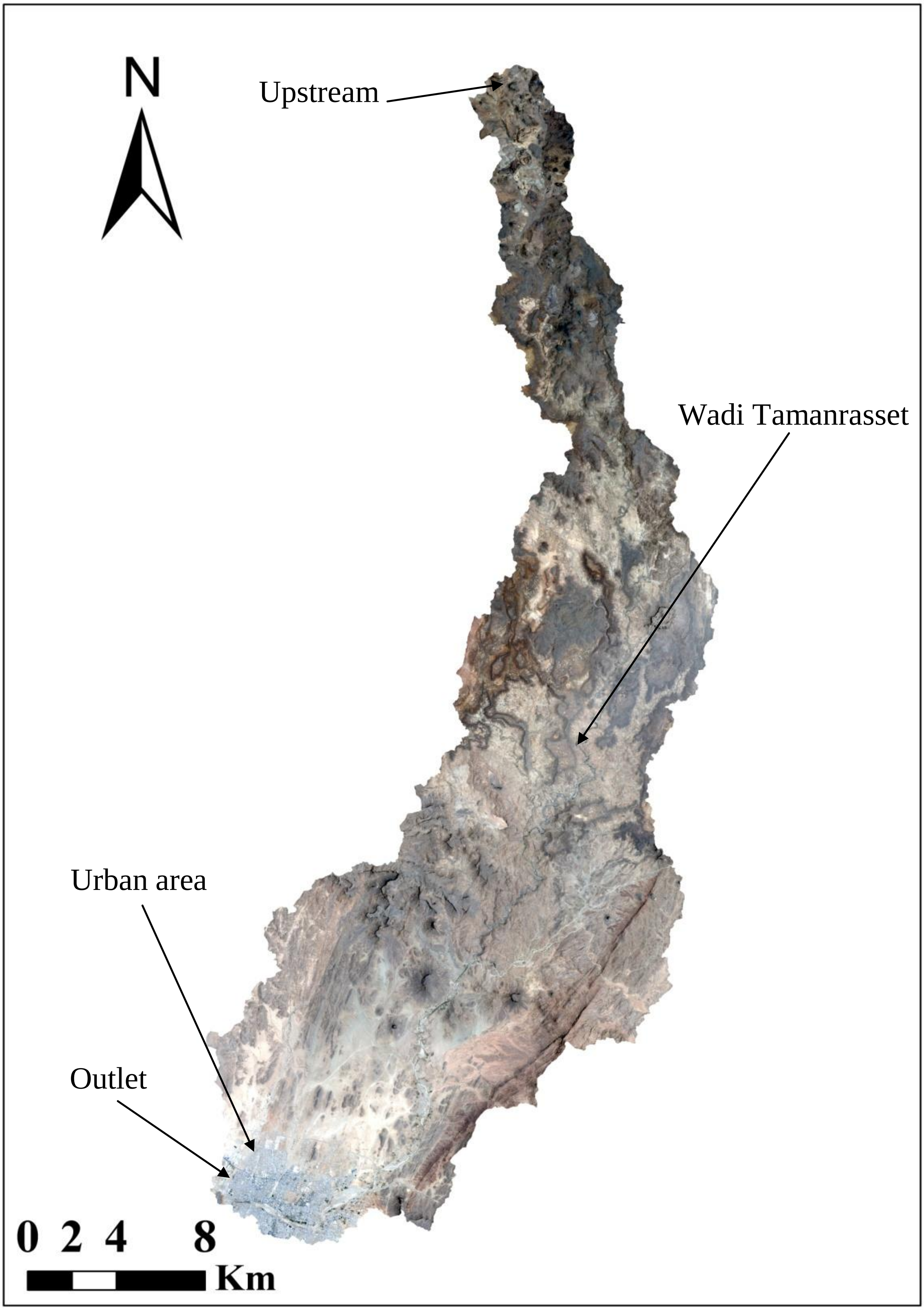
ANNEX

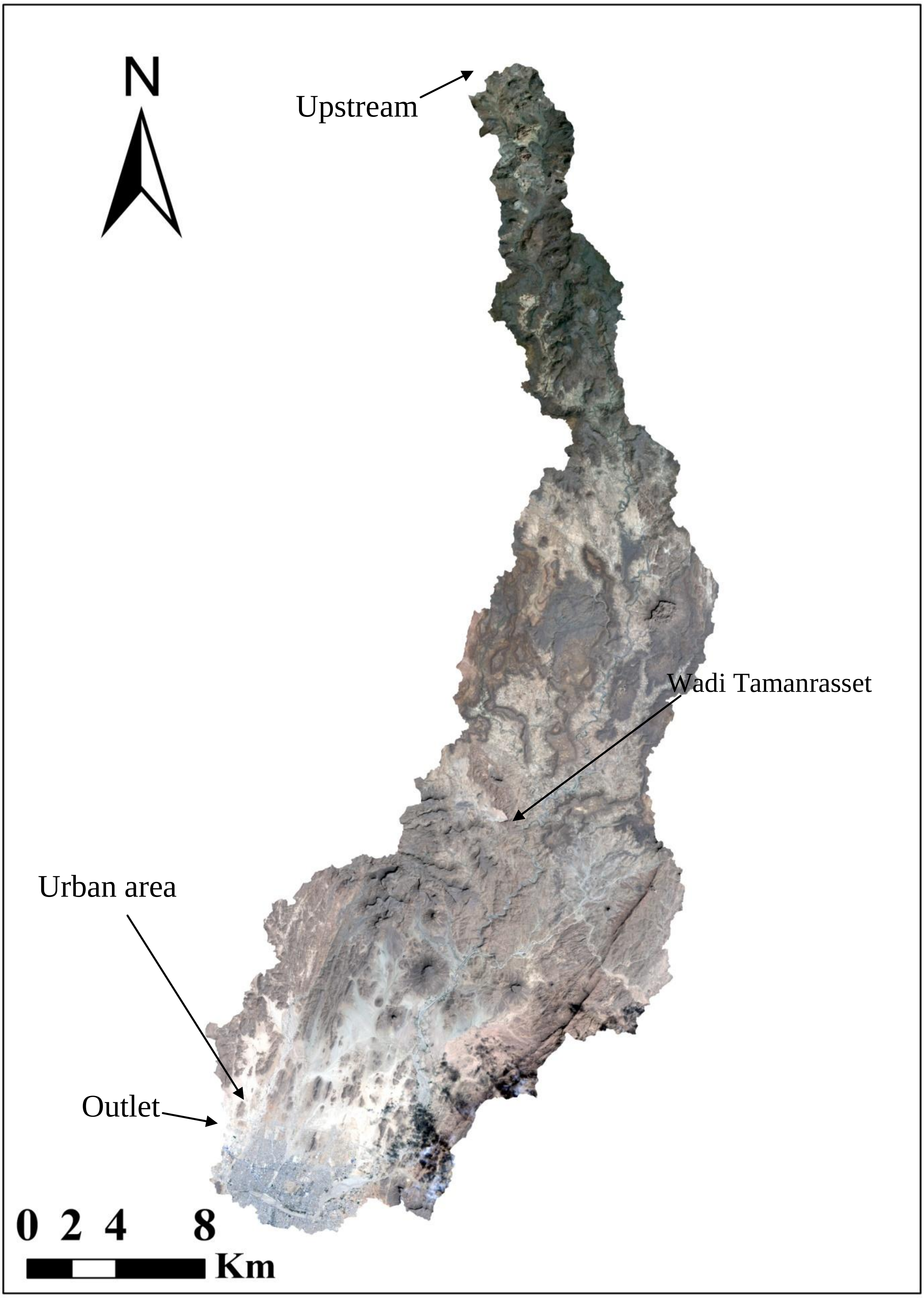
Annex 01: Image of Wadi Tamanrasset watershed in first period (02-08-2018)



Annex 02: Image of Wadi Tamanrasset watershed in second period (12-08-2018)



Annex 03: Image of Wadi Tamanrasset watershed in third period (26-09-2018)



Monitoring vegetation and surface water dynamic of Wadi Tamanrasset using earth observation data.

Abstract

Remote sensing data are primary sources extensively used for change detection in recent decades. In this research the site sellected is Wadi Tamanrasset (extreme south-east of Algeria). The results of our study show that watershed cover 498 km² and its perimeter was estimated at 177.1 Km, this Watershed has morphometric characteristics that favor runoff during periods of short rain and we found that the cover vegetal in first period cover 2.64 km² (early August 2018) while in the second period cover 66.19km^2(September 2018). For water surface, we found that the first period (early August)cover 0.02 km² and 2.1km² in the second period (mid-August). That's mean high dynamic progression of vegetation whilthe surface water dynamic in low progression.

Key words: Wadi Tamanrasset, remote sensing, change detection, NDVI, NDWI, morphometric characteristics.

Suivi dynamique de la végétation et des eaux de surface à Wadi Tamanrasset en utilisant les données d'observation de la Terre

Résumé :

Les données de télédétection sont des sources primordiales, largement utilisées pour la détection des changements au cours des dernières décennies. Wadi Tamanrasset (extrême sud-est de l'Algérie) fait partie des sites de recherche. Les résultats de notre étude montrent que le bassin versant couvre 498 km² et que son périmètre a été estimé à 177,1 Km. Ce bassin hydrographique présente des caractéristiques morphométriques qui favorisent le ruissellement lors de périodes de faibles pluies. Nous avons constaté aussi que la végétation couvre 2,64 km² en première période (début aout 2018) et 66,19 km2 en seconde période (fin septembre 2018). Pour ce qui de la surface de l'eau, elle couvre 0,02 km² en première période (début aout 2018) et 2,1 km² pendant la seconde période (la mi-aout 2018). C'est la forte progression de la végétation avec une faibleévolution pourla dynamique de l'eau de surface.

Mots clés: Wadi Tamanrasset, télédétection, détection de changement, NDVI, NDWI, caractéristiques morphométriques.

متابعة الغطاء النباتي وديناميكية المياه السطحية في وادي تمنراست باستخدام بيانات مراقبة الأرض

ملخص:

بيانات الاستشعار عن بعد هي المصادر الأولية المستخدمة على نطاق واسع لاكتشاف التغيير في العقود الأخيرة. في هذا البحث،الموقع الذي تم اختياره هو وادي تمنراست (أقصى الجنوب الشرقي للجزائر). تظهر نتائج دراستنا أن مستجمعات المياه تغطي مساحة 498 كم² ومحيطها يقدرب-177.1 كم ،لهذه المجرى المائي خصائص مورفومترية التي تفضل الجريان السطحي خلال فترات الأمطار القصيرة .ووجدنا أن الغطاء النباتي في الفترة الأولى يحتل مساحة 2.64كم² (بداية أوت 2018) بينما في الثانية فترة تغطية مساحة 66.19 كم² (أواخر سبتمبر 2018). بالنسبة لسطح الماء، وجدنا أن الفترة الأولى (بداية شهرأوت 2018) تغطي 0.02 كم² و2.1 كم²في الفترة الثانية (منتصف شهر أوت). هذا يعني تقدما ديناميكي عالي للنباتات بينما ديناميكية المياه السطحية بتقدم منخفض.

الكلمات المفتاحية: وادي تمنراست ، الاستشعار عن بعد،اكتشاف التغيير،الغطاء النباتي ،المياه السطحية ،الخصائص المورفومترية