

Application of the Racine Gumbel and CUSUM Laws in Water Resource Management: Case of the Tit Zil Spring (Guigou Plain - Morocco)

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Abstract: This study aims to provide a spatial diagnosis of the state of water resources in the Guigou plain, by monitoring the quantitative evolution of precipitation since the 1970s. This study is based on two key indicators to determine the evolution of the flow of Tit Zil source, as well as the flow of the Guigou River at the Ait Khabbash hydrological station, located approximately 11km from Tit Zil source. The results are obtained through field works which manifest a great fall back of water resources. This fall back is due to many factors, natural factors legislated on drought mankind over exploitation since in the 80th. As well as, the changing mode of exploitation leads to emergence of conflicts between tribes.

Keywords: Water Resources, Natural Factors, Exploitation, Tit Zil Source, Morocco.

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I. INTRODUCTION

Water is a natural resource essential to the various components of the ecosystem. Indeed, it is a determining factor in the development of territories depending on its abundance or scarcity. It is highly sensitive and experiences rapid spatio-temporal variability, which can lead to negative effects on all environmental elements. The Tit Zil spring is among the springs that are subject to climatic influences, including its scarcity of rainfall, which has been accompanied by excessive exploitation of water reservoirs to meet the needs of agriculture and livestock. This is evidenced by the change in the source flow rate from 500 l/s in the 1970s to about 20 l/s in the 2010s.

II. MATERIALS AND METHODS

It should also be noted that the hydrological data acquired by the Sebou hydraulic agency were used to identify the hydrological behavior of the rivers Guigou. Indeed, these data provide an important basis for our study, given the relationship between the Tit Zil source and the flow of the rivers Guigou. The methodological approach used was also based on a data analysis method (Gumbel and Cusum law), in order to determine and understand the interannual variability of the hydro-rainfall regime.

III. STUDY AREA

The Guigou Plain is an intramontane plain, located in the central Middle Atlas where it covers an area of approximately 175km². This plain has an average altitude of 1500m; it is limited by the Folded Middle Atlas (8450km²) to the Southeast and the Tabular Middle Atlas or Middle Atlas Causse (4750km²) to the North-west (Fig. 1).

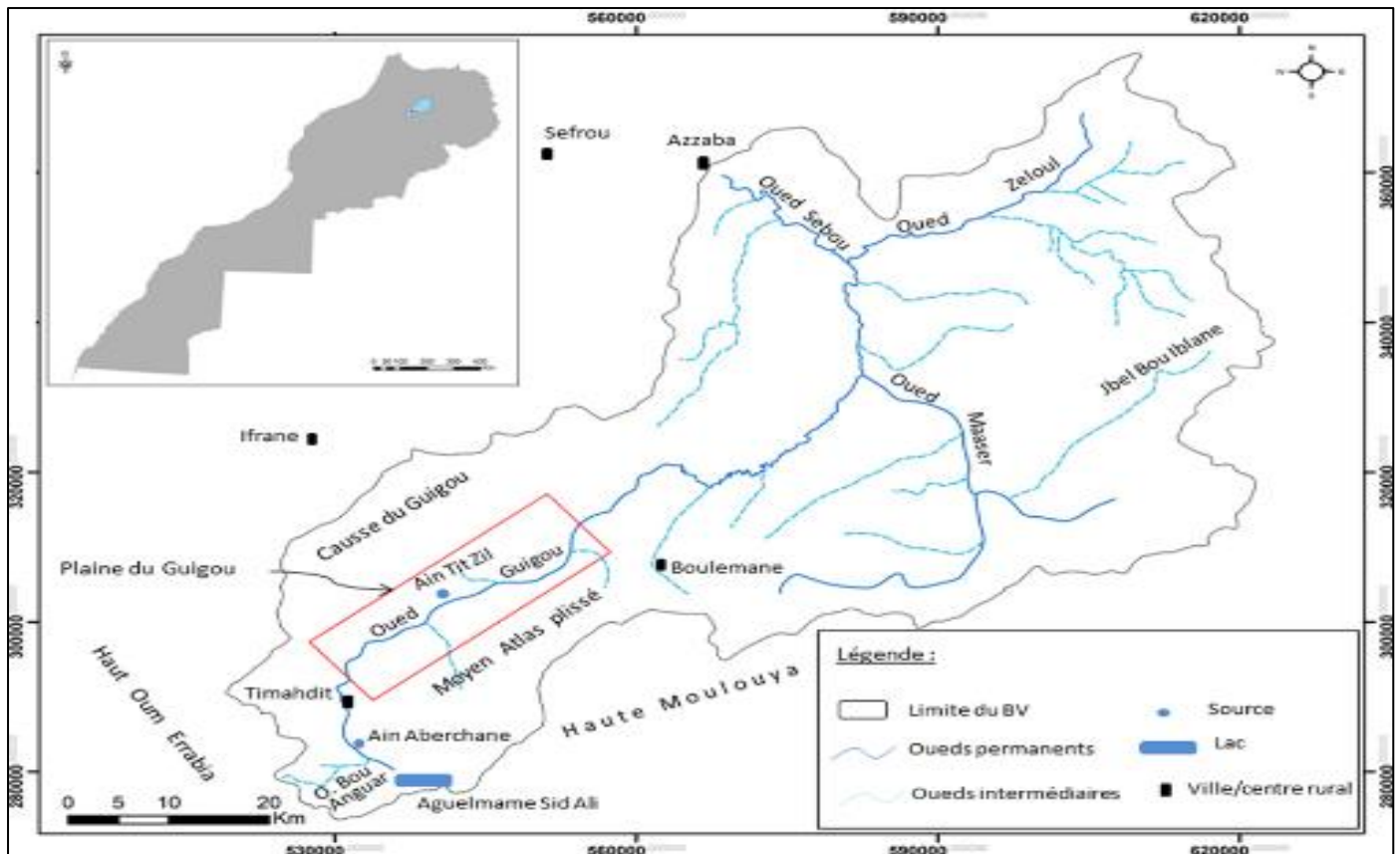


Fig 1: Geographical Location of the Guigou Plain.

It is located in the center of a vast group of reliefs directed from the SW to the NE, with an average altitude of 1600m, crossing the main valley. The NW of the plain with a predominantly tabular shape (1700-2000m) is made up of causses and ranges (Tabular Middle Atlas) and the SW is mountainous (2000-2400m) comprising high massifs and regions (Folded Middle Atlas).

Geologically, the study area is part of the North-Middle Atlas (ANMA) fault domain (fig. 2). It is located in a transition area between two structurally different units: the Tabular Middle Atlas and the Folded Middle Atlas. It is developed in the Liassic limestone formations and the Cretaceous marls and limestones (MARTIN J. 1981) with dominant fissure permeability.

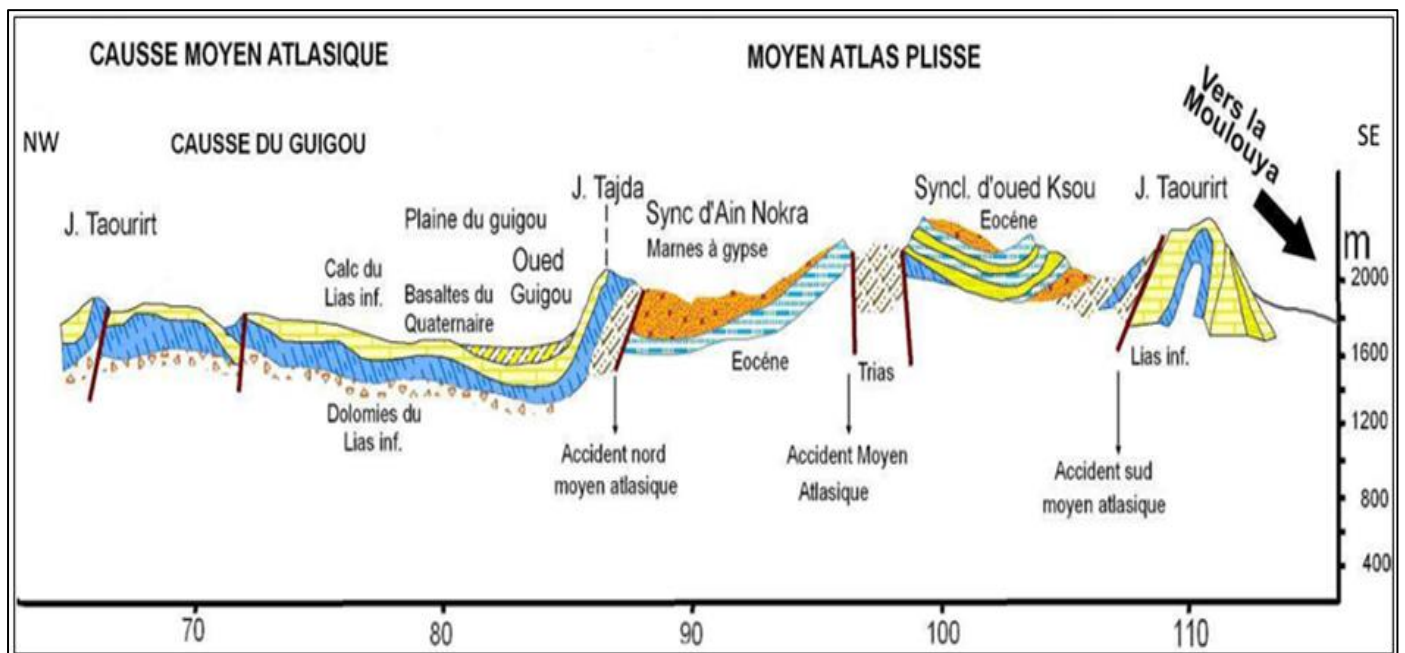


Fig 2: Geological Section of the Northern Middle Atlas (Atlas of the Sebou Basin, 1970).

These basalt outpourings, which occupy the majority of the Guigou plain, give it a monotonous and dark appearance.

From a geomorphological point of view, the Guigou plain extends over approximately 40km in length and 5km in width. It forms an elongated basin with a SW-NE orientation, surrounded by more or less steep escarpments with a very complex structure.

The Guigou plain, and by its geographical location occupies an important place in this mountain range. The general landscape is completely bare, with the exception of a few firm-nuclei and small vegetated areas at the banks of the main river. The surrounding mountains - which belong to the two communes, Guigou and Timahdit - are covered with various forest species of which the holm oak, Thuja and cedar occupy a significant portion.

IV. WATER RESOURCES IN THE GUIGOU PLAIN: A CONTINUOUS DECLINE

➤ *The Study Area Contains a Huge Water Reservoir, Which Allows the Appearance of Important Water Sources.*

A. State of Water Resources and Management Methods in the Guigou Plain

In the study area, three types of water resources can be distinguished: Rivers Guigou, Tit Zil source, Groundwater.

The nature of economic activity is based mainly on agriculture and livestock, and every disturbance in its quantity causes negative changes at the socio-economic level.

➤ Rivers Guigou

The Oued Guigou is supplied mainly by the permanent springs of Fom Kheneg upstream of the watershed and essentially by the Aghbalou Aberchane source, and by the springs of Tit Zil in the middle watershed, with a flow rate which varies between 300 and 650l/s. the drainage density is relatively low (1,3km/km²).

Table 1: Morphometric Characteristics of the Rivers Guigou.

Watershed	Surface (km ²)	Drainage density (km/km ²)	Length of the main wadi (km)	Average slope of the wadi (%)	Gravelius compactness index
Rivers Guigou	1200	1,3	76	0,9	1,46

Despite the contributions from the Aberchane and Tit Zil springs, the specific module at the Ait Khabbache station is very low (1l/s/km²), which indicates a hydrological drought

strongly influenced by the lithology which facilitates losses by infiltration at the expense of runoff.

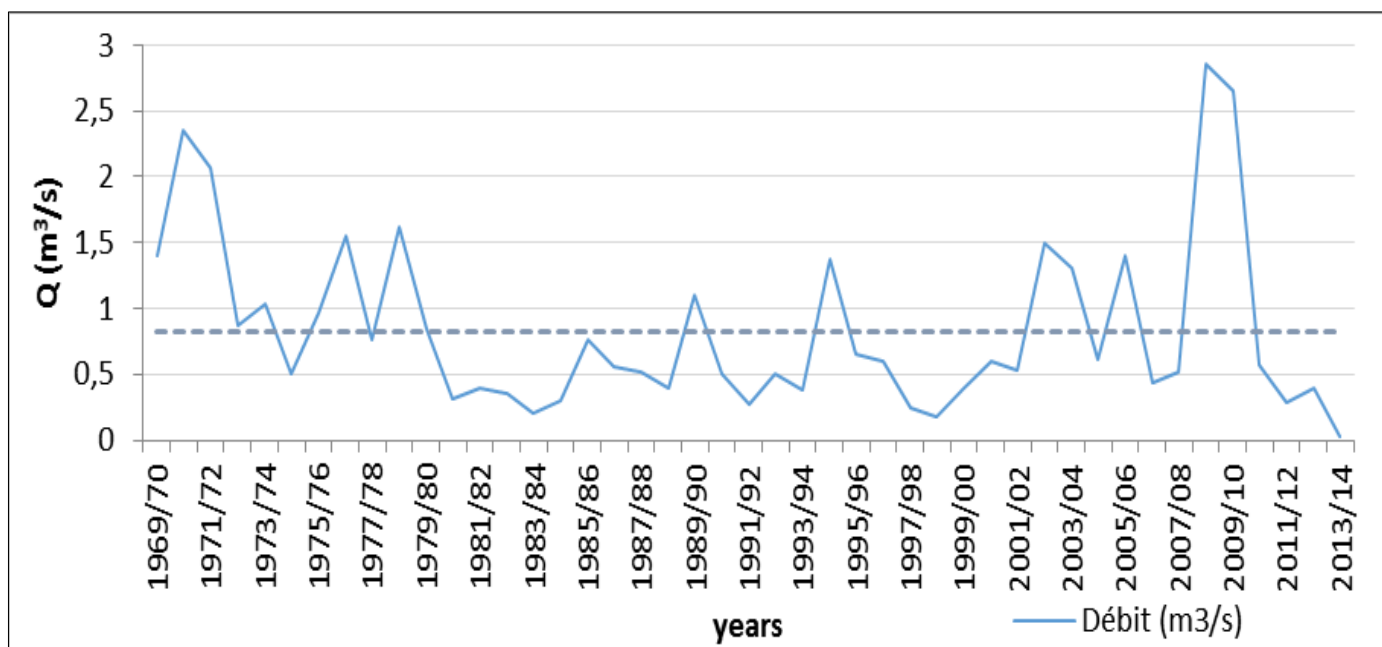


Fig 3: Geological Section of the Northern Middle Atlas (Atlas of the Sebou Basin, 1970).

In the studied chronicle (1969 – 2014), the maximum-recorded flow reached 2.85m³/s in 2008/2009, and the minimum was recorded at 0.03m³/s in 2013/2014. The average annual module does not exceed 0.8m³/s, which signifies the fragility of water resources in the studied area.

The statistical study of annual flows constitutes one of the important stages in each hydrological study; it mainly involves adjusting annual water inputs to a given law.

A. Application of the Racine Gumbel Law

It is also called the doubly exponential law or the law of "extreme values". Considering samples of size "n" of independent random variable, and a value "u" of the variant whose probability of not exceeding is F(u), the probability that all the values of a sample are less than u is $[1-(1-F(u))]^n$.

We write it:

$$F(x) = \frac{1-s}{2} + se^{-e^{-u}}$$

With

$$u = \frac{x-x_0}{s} \text{ et } s=1$$

With The sign of s.

If f(x) is the frequency at non-overshoot and when x varies from $-\infty$ to $+\infty$, f(x) increases from zero to 1.

X0 is the position or mode parameter

S is the positive or negative non-zero scale parameter.

The density function is represented by an asymmetric bell curve with inflection points at u.

In this study, the flow rates were adjusted to the RacineGumbel law in order to determine characteristic frequencies that are very useful for understanding the hydrodynamic functioning of the rivers Guigou.

The results of the adjustments (fig. 4) show an irregular distribution of the water flow rate with a clear contrast between the highest values reached 2.5m³/s and the lowest values reached 0.1m³/s.

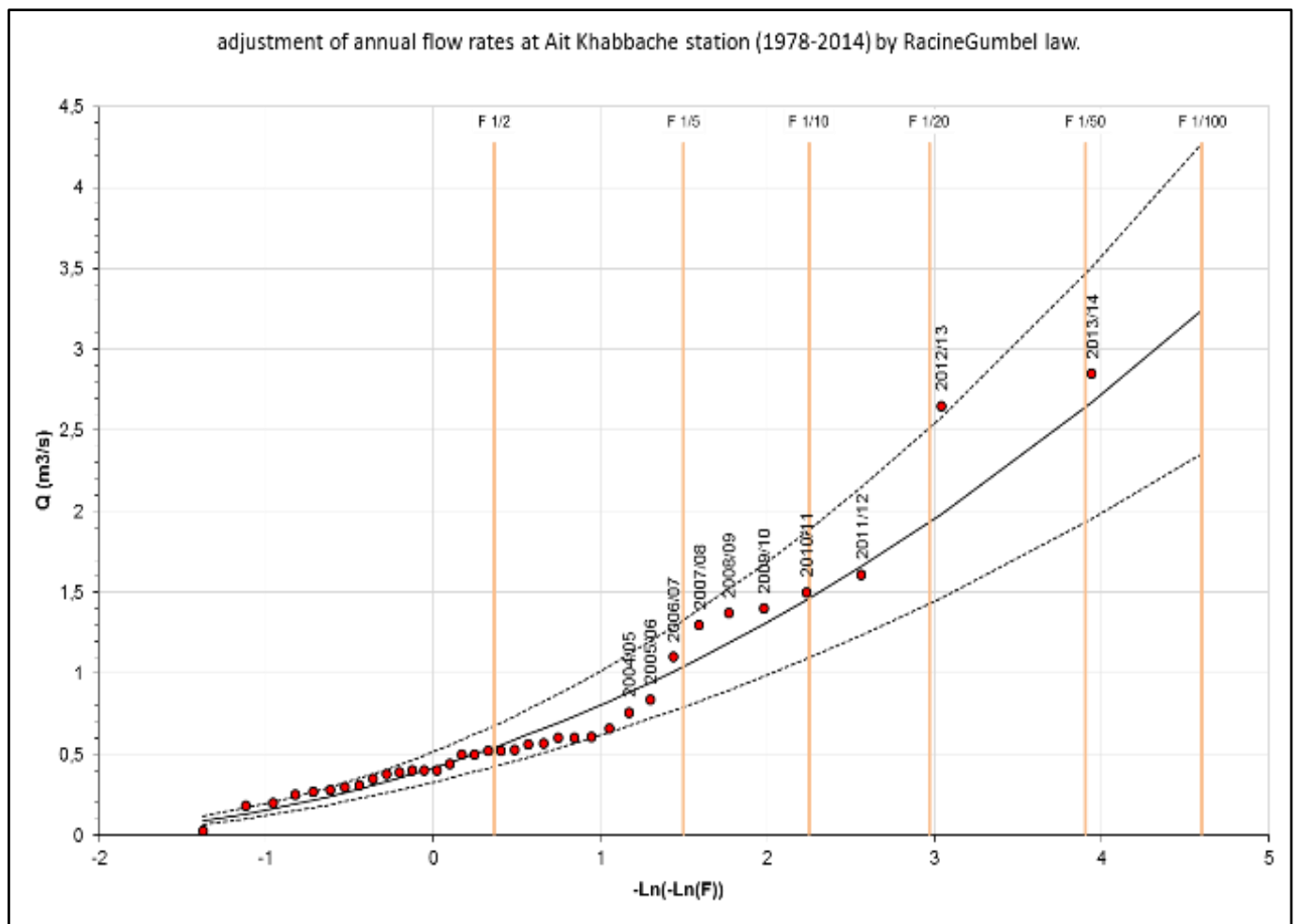


Fig 4: Adjustment of the Average Annual Flow Rates of the Rivers Guigou

In summary, the extreme flows recorded on the scale of the rivers Guigou do not present great water potential, which explains the hydrological dryness of this watercourse.

➤ Groundwater Resources

From a hydrogeological point of view, the Guigou plain coincides with the contact zone of two main hydrogeological basins, with different geochemistry: the Middle Atlas Folded aquifer and the Middle Atlas Tabular aquifer (fig. 5).

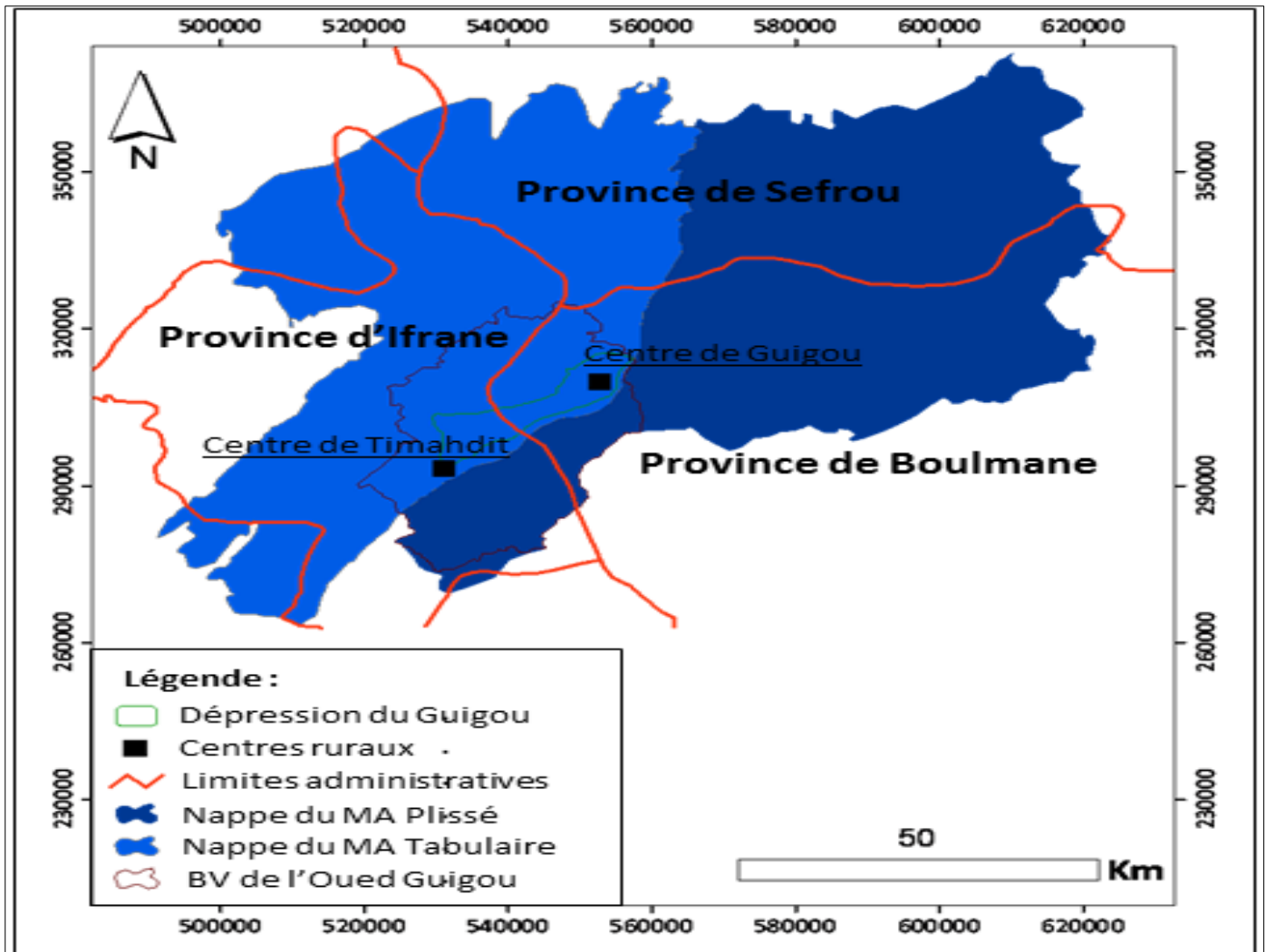


Fig 5: Hydrogeological Location of the Guigou Plain

In fact, the water mobilization of the water table in this area is supported by the two Middle Atlas water tables.

The drought of the 1980s, due to its severity and duration, largely contributed to the proliferation of wells, which caused an alarming decrease in the water table.

➤ The Tit Zil Source

Located on the left bank of the Rivers Guigou (fig. 5), in the middle part of the Guigou plain, it is made up of two emergences (upstream and downstream).



Fig 6: The Tit Zil Source Upstream from the Guigou Plain

The Tit Zil source has long played a significant socio-economic role. Part of its water is used to supply drinking water to the douars located downstream. It also provides water resources that ensure the sustainability of the Guigou River in this area.

On the other hand, for J. Nicod (1987), this source would be fed by the basalt aquifer, by the Lias limestone aquifer (captive under the Boulmane marls) thanks to a

probable fault (under basaltic cover) and by the aquifer of ancient alluvium under basaltic of Plio-Villafranchian age.

Quantifying the evolution of the waters of the Tit Zil source can be done by monitoring the evolution of the surface area of the two ponds fed by the spring. By using Landsat satellite images and aerial photos from the years 2007, 2011, 2014 and 2017, we can estimate the variability of the spring waters from the study of these ponds (fig. 6).

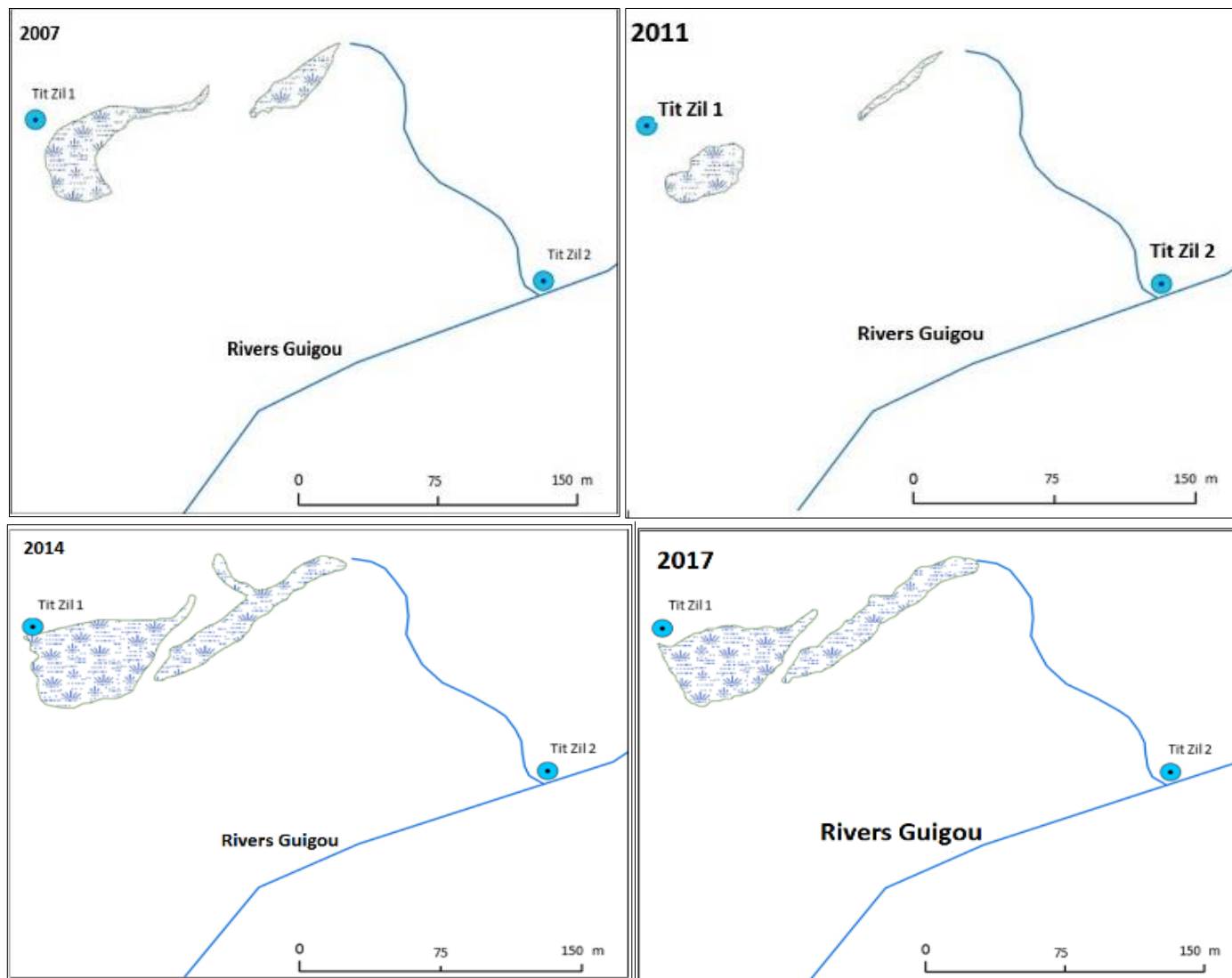


Fig 7: Evolution of the Ponds Fed by the Tit Zil source between 2007 and 2017

According to figure 6, it can be seen that the ponds fed by the Tit Zil source experience a fairly significant spatio-temporal variability. Over 10 years, the surface area of these water reserves has changed significantly, particularly the second pond, since it increased from 211m² in 2007 to

approximately 2519m² in 2017. For the second pond, the change is more or less significant, whose surface area increased from 878m² in 2007 to approximately 1705m² in 2017 (tab. 2).

Table 2: Evolution of the Ponds Fed by the Tit Zil Source between 2007 and 2017

Area (m ²)				
	2007	2011	2014	2017
Pond1	878	1616	3119	1705
Pond2	211	651	1757	2519

V. FACTORS INFLUENCING THE WATER POTENTIAL OF THE TIT ZIL SOURCE

A set of physical and anthropogenic factors are involved in explaining the regression of the waters of the Tit Zil source. Indeed, the climatic changes that have affected the study area and the development of irrigated agriculture accompanied by overexploitation of groundwater are at the origin of the drying up of the Middle Atlas springs and more precisely the Tit Zil source.

A. The Climate

Climate plays a key role in explaining every environmental phenomenon, particularly when it comes to hydrological hazards. Indeed, climate change can have negative effects in the event of drought, both for humans and for the physical environment. Regarding springs, their flow rates are closely linked to climate variability (fig. 7).

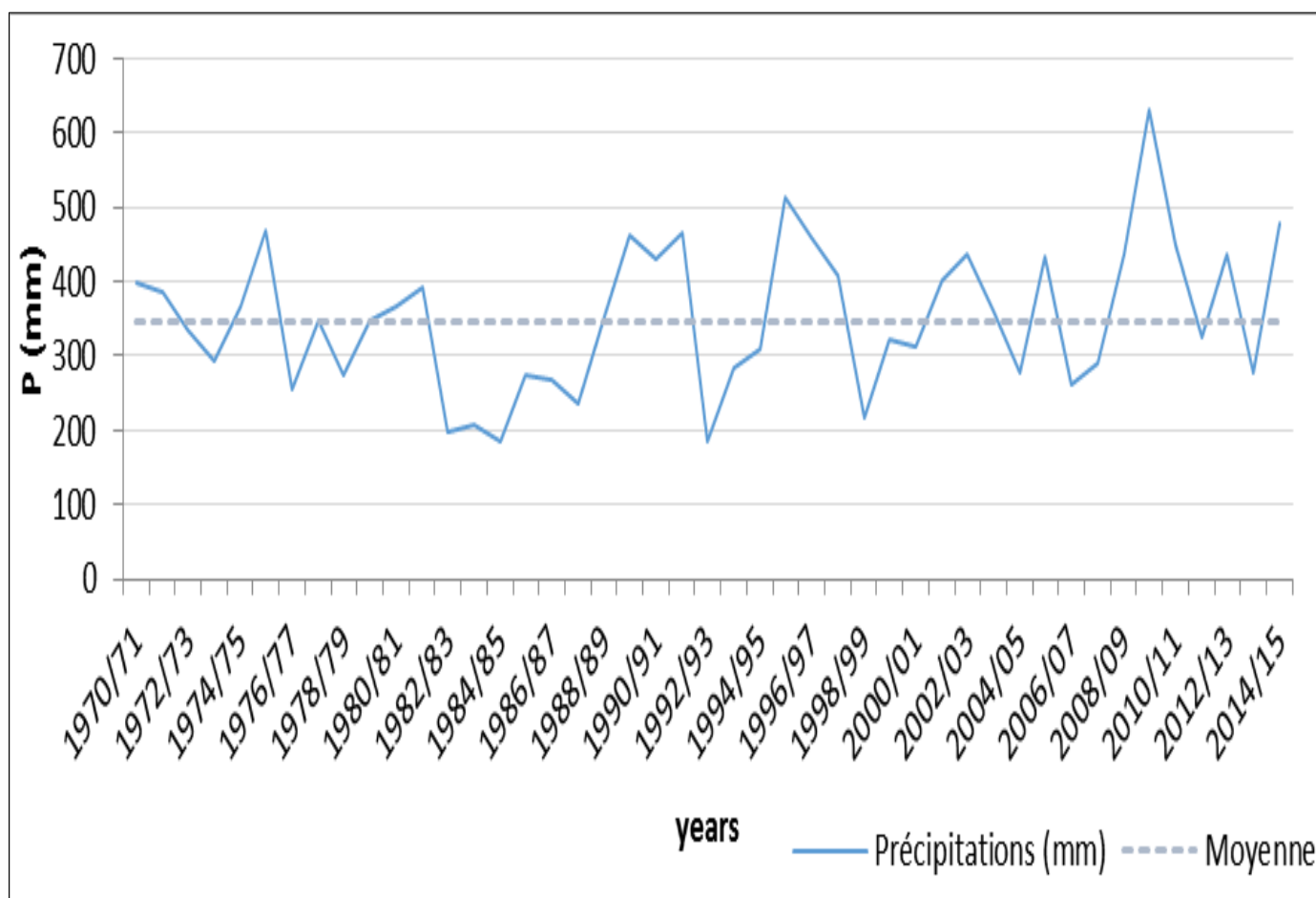


Fig 8: Variability of Annual Precipitation at the Ait Khabbache Station (1970 – 2015)

From figure 7, it can be concluded that precipitation in the Guigou plain is characterized by great temporal variability. The average recorded precipitation is low and does not exceed 346.5mm/year despite the relatively high

number of wet years compared to dry years. Maximum annual precipitation is around 630mm (2008-2009) and minimum is around 184mm (1992-1993).

Table 3: Characteristics of Annual Precipitation at the Ait Khabbache Station (1970 – 2015).

Station	P moy (mm)	P max (mm)	P min (mm)	N. years dry	N. years wet	Standard deviation
Ait Khabbache	346,5	630	184	21	23	97,7

B. CUSUM of Precipitation at the Ait Khabbache Station.

The treatment of the study chronicle by the method (CUSUM), allows to determine the homogeneity of the chronicle as well as the number of dry and wet years (fig. 8).

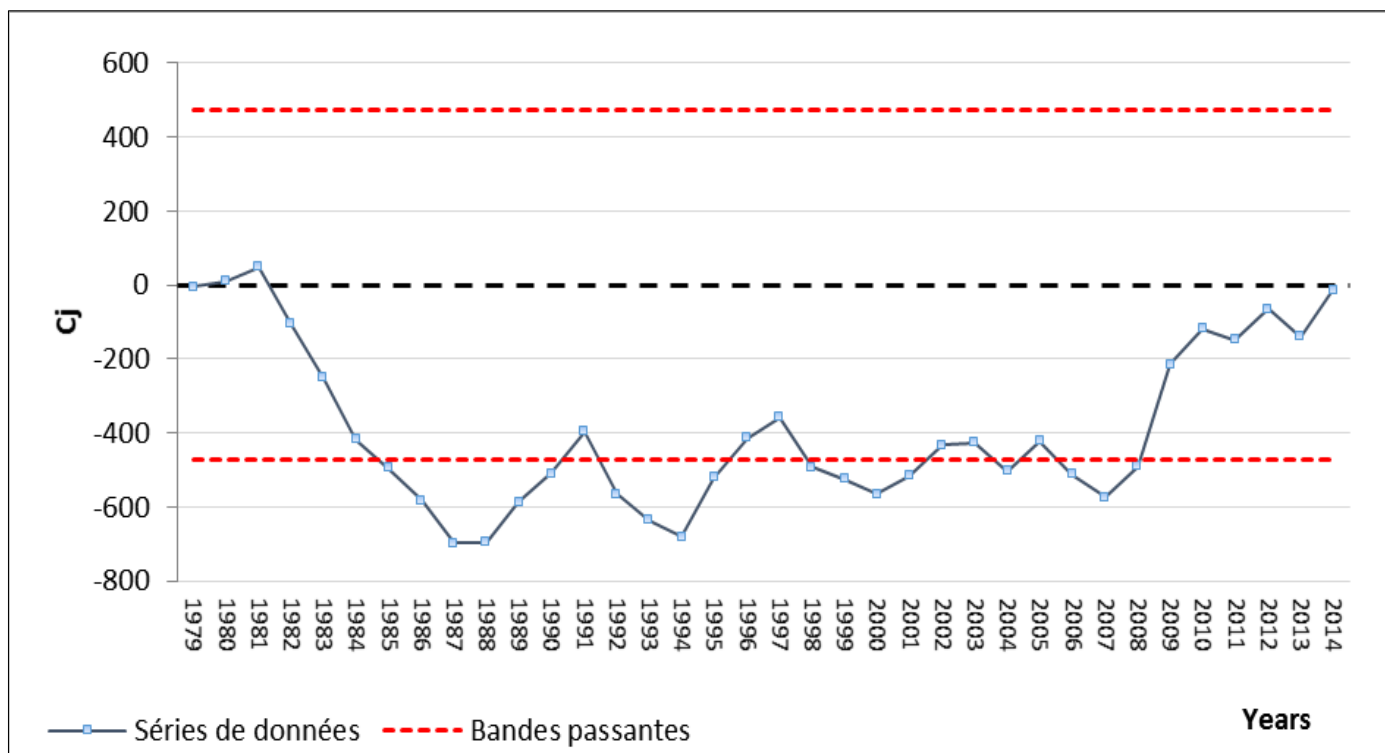


Fig 9: CUSUM of Precipitation at the Ait Khabbache Station (1979 – 2014).

The analysis of the chronicle (1979 – 2014) by the CUSUM method highlights approximately three series characterized by the variation of its rainfall quantities. After a more or less humid trend that lasted 3 years (1979 – 1981) where the average rainfall was 369mm, the Guigou plain

experienced a dry trend (1982 – 2009) where the average rainfall was 343mm. This dry series of about twenty years stopped in 2010/2011 where the study area will experience fairly significant rainfall, with an average of 393mm.

Table 4: Breakdown of the 1979 / 2014 Rainfall Chronicle

Period	Mean (mm)	Number of years	Diagnosis
1979/1981	369	3	Humid
1982 /2009	343	28	Dry
2010 / 2014	393	5	Close to average

Generally, during the study of the chronicle, it can be seen that there is a close relationship between the regression of the flow rates of the Tit Zil source and the evolution of the climate. Indeed, the succession of dry years, especially the 1980s, influenced the water potential of the said spring, since it does not exceed its average module in the last years 201/s.

VI. THE SOCIO-SPATIAL IMPACT UNDER THE REGRESSION OF THE TIT ZIL SOURCE

A. Tribal Conflicts

The climate changes experienced by the Guigou plain and the overexploitation of groundwater resources since the 1990s, accompanied by an increase in agricultural land, have negatively influenced the quantity of water in the Tit Zil source. This water risk generated in recent years has disrupted human-space and human-human relationships, which has favored the emergence of sometimes violent conflicts between tribes and douars in the study area.

Furthermore, Coser (1965) considers these conflicts as normal phenomena in any social relationship, they lead in a

certain number of cases to more or less violent confrontations.

On the Guigou Plain scale, the development of agricultural land and the pressure on water resources, accompanied by successive dry years, often produce conflicts between users, particularly during adverse weather conditions. During field surveys, we questioned farmers about these conflicts.

Regarding conflicts between users, 37% of farmers reported having had a conflict with other farmers. Furthermore, the number of conflicts between tribes or douars is remarkable. 85% of respondents cited conflicts or confrontations over water. These conflicts are sometimes violent, as was the case in 2015, and often stem from failure to respect customary rules.

In this sense, an old document dating back to the colonial period was posted by the local authorities, which gave the right to the douars existing near the source of Tit Zil (Ait Hamza, Ait Hssayne, Ait Telt, Ait Besri...) to exploit the

waters of the source all year round except for the summer season.

Generally, conflicts over the water from the Tit Zil source are very old, but did not present many problems, given the availability of water resources. Currently, conflicts are becoming increasingly violent, especially between the upstream tribes (Ait Hamza, Ait Telt, etc.) and those downstream (Ait Almis, Ait Helli, etc.), particularly with the environmental changes recorded in the study area.

B. Change of Culture Type

Given the climatic drought and the decline of the waters of the Tit Zil source, farmers in the downstream douars (Ait Helli, Ait Khabbache, Ait Said Ou Haddou, Ait Almis, etc.) have changed their crop type. Indeed, more than 60% of those surveyed have chosen to change the way they farm their land, focusing on cereal cultivation instead of market gardening.

VII. CONCLUSION

The study of the evolution of water resources in the Guigou plain since the 1970s shows a disruption of the hydrological regime of the Rivers Guigou, as well as a regression of the annual modules of the Tit Zil source. This disruption of the hydrosystems in the study area has been accentuated by anthropogenic action.

In terms of solutions, water resource governance is the appropriate solution for the deficient hydrological situation of the Guigou plain. Indeed, in order to find solutions to the water problem in the study area, it is sufficient to adopt a participatory and integrated approach that takes into consideration the characteristics of the local environment, as well as the adaptation of economic programs with the fragility of natural resources.

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