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Presented by

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The impact of Climate variability on the flow of wadi Boukiou

(Tafna, Algeria)

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DECLARATION

I, Nisrin BERREZOUG, do declare that this thesis represents my personal work, realized to the best of my knowledge. It has been submitted only to the Pan-African University, Institution of Water and Energy Sciences (Including Climate Change). I also declare that all informations, methods and materials, results from others works presented here, have been cited and referenced in accordance with the academic rules.

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CERTIFICATION

This is to certify that the work presented has been submitted with my approval as the supervisor.

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DEDICATION

To my dear father "Mustapha"

To my dear mother "Fatima Zohra"

To my husband "Mohammed"

And all my friends

I dedicate this work with all

The love and respect I have for them.

Nisrin BERREZOUG

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Nisrin BERREZOUG

Abstract

Wadi Boukiou watershed is a sub-basin of the Tafna located in Northwestern Algeria, in a region of high climatic variability where drought has an important effect on the hydrological behavior. The work focuses on the impact of this climatic variability on runoff in the study area to determine which indices will be used to monitor the intensity of the drought? Moreover, to estimate the performance of the semi-distributed model in the Boukiou wadi basin.

In addition, this study is based on:

- The analysis of the temporal variations of the rainfall and hydrological regime.
- The assessment of drought: the methodology is based on the use of climate indices (SPI, DI, PN, RAI, MCZI, CZI, Z-score, EDI) with different time steps (annual, monthly, seasonal, daily),
- Assess the impact of climate variability on water resources, basing on the rain-flow modeling of the watershed using the HBV Light model.

The analysis of rainfall and hydrological data shows the presence of chronological trends, which generate a decrease in rainfall and runoff between 1974 and 1981. The application of different climate indices using Meteorological Drought Monitoring software "MDM" indicates that our basin has experienced wet periods ranging from 1974/1975-1981/1982 and 2008/2009-2017-2018, while dry periods are spread out between 1981/1982-2008/2009 with a trend to dryness.

The use of the semi-distributed conceptual model "HBV Light" gave us satisfactory results during the calibration and validation stages, producing a Nash-Sutcliffe coefficient of 75% - 76% respectively. In addition, the values of the coefficient of determination R^2 during the two steps are 0.80 - 0.91 respectively.
Keywords: Wadi Boukiou, Climate variability, Drought indices, Trend, rainfall-runoff modeling, MDM software, HBV Light model,.

Résumé

Le bassin versant d'oued Boukiou est un sous bassin de la Tafna situé au Nord ouest algérien, dans une région de forte variabilité climatique où la sécheresse ayant un role important sur le comportement hydrologique. Le travail porte sur l'impact de cette variabilité climatique sur l'écoulement de la zone d'étude pour déterminer quels indices permettront de suivre l'intensité de la sécheresse ? Et pour estimer la performance du modèle semi-distribué dans le bassin d'oued Boukiou.

En outre, cette étudese base sur :

- L'analyse des variations temporelles du régime pluviométrique et hydrologique.
- L'évaluation de la sécheresse : la méthodologie se base sur l'utilisation des indices climatiques (SPI, DI, PN, RAI, MCZI, CZI, Z-score, EDI) avec différents pas du temps (annuel, mensuel, saisonnier, journalier),
- Evaluer l'impact de la variabilité climatique sur la ressource en eau, en se basant sur la modélisation pluie-débit du bassin versant à l'aide du modèle HBV Light.

L'analyse des données pluviométriques et hydrologiques montre la présence des tendances chronologiques qui engendrent une diminution de la pluviométrie et de l'écoulement entre 1974 et 1981. Par ailleurs l'application des différents indices climatiques fournis par le logiciel meteorological drought monitoring « MDM » indique que notre bassin a connu des périodes humides allant (1974/1975-1981/1982 et 2008/2009-2017-2018, tandis que les périodes sèches s'étalent entre 1981/1982-2008/2009 avec une tendance à la sécheresse.

L'utilisation du model conceptuel semi-distribué « HBV Light » nous a donnée des résultats satisfaisants durant calage et validation, produisant un coefficient de Nash-Sutcliffe de 75% - 76% respectivement. En outre, les valeurs du coefficient de détermination R^2 au cours des deux étapes sont respectivement de 0,80 - 0,91.

Mots clés : Oued Boukiou, Variabilité climatique, indices de sécheresse, Rupture, Modélisation pluie-débit, Logiciel MDM, Modèle HBV-Light.

LIST OF ABBREVIATIONS

A: Area.
AgMERRA: Agrimetsoft Agricultural and Meteorological Software.
ANRH: National Water Resources Agency.
C_{ir}: Coefficient of irregularity.
CZI: Chinese - Z Index.
Dd: Drainage density.
D_s: Specific height difference.
DI: Deciles index.
EDI: Effective Drought Index.
HBV Light: Hydrologiska Byråns Vattenbalansavdelning Light Model.
I: Aridity Index
Ig: The global slope Index.
Ip: Slope Index of ROCHE.
IPCC: Intergovernmental Panel on Climate Change.
K_c: Gravelius Compactness index
Q: Discharge or flow rate
Q_{obs}: Observed Discharge (mm)
Q_{sim}: Simulated Discharge (mm).
L: Length of equivalent rectangle.
l: Width of equivalent rectangle.
MCZI: The modified Chinese- Z Index.
MDM: Meteorological Drought Monitoring Software**.**
MIKE-SHE: MIKE- European Hydrologic System.
MSE: Mean Square Error.
NSE: Nash-Sutcliffe Efficiency.
O.R.S.T.O.M: Office for Scientific and Technical Research Overseas,
P: Precipitations (mm)
PET: Potential Evapotranspiration.
PN: Percent of normal index.
RAI: Rainfall Anomaly Index.
Rc: Confluence ratio.
R_l: The length ratio.
SPI: Standardized Precipitation Index.
T: Temperatures (° C).
C_T: Torrentiel Coefficient.
Tc: Concentration time
TOP Model: Topography-based Hydrological Model.
SMHI: Swedish Meteorological and Hydrological Institute.
WMO: World Meteorological Organization.
Z-Score: Z-Score Statistics Index
χ^2_{cal}: Calculated Chi Square.
χ^2_{Tal}: Tabulated Chi Square.

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1.1 -Background Information

Water is an essential part of life. It varies from one region to another depending on the climate that keeps changing. For a long time, the water has undergone many changes which sometimes cause dramatic consequences such as (desertification, drought, and floods).

Today, where the demand of water has become increasingly solicited, climate variability has become an emerging reality with significant socio-economic impacts.

Over the past decades, many scientific research has focused on the changes that have been the main cause of climate change (high temperature, sea-level rise, snowmelt, sea-level rise, declining agricultural production and water scarcity in several regions (Gherissi, 2018)

Drought is one of these changes, which is a complex climate phenomenon. Its beginning, its end and its severity are often difficult to predict. (Mellouk & Ghali, 2019). Drought affected many parts of the world, caused primarily by the decline in precipitation. Their impact on the environment is one of the major concerns of global scientific committees. (Lubès & al., 1994; Lubes-Niel & al., 1998; Amidou & al., 2010). This work identifies and assesses successive droughts as they occur. The latest statistics estimate that 35 countries will face water shortages by the year 2020 (Mahtab et al., 2013), this severity will increase more in the next 50 years (Bovolo & al., 2010). So water has become an increasingly inaccessible commodity in many parts of the world, and water supplies continue to decline.

Over the past century, the Mediterranean area has undergone climatic variations that are characterized by decreasing trends in rainfall, river flows, and increasing temperature trends (Djellouli, 2017). Algeria is subject to frequent periods of severe and persistent drought due to the aridity and semi-aridity of its territory. The most intense droughts are those recorded during the years 1980 to 1990 when the rainfall deficit was estimated at 50% for the central and western regions of Algeria and at 30% in the east (Khoualdia, 2014). Several studies have focused on this phenomenon (Agoumi & al, 1990; Haida & al., 1999; Meddi, 2001; Meddi & Hubert, 2003; Khaldi, 2005; Bekkoussa & al., 2008; Meddi H & al., 2009; Ghenim & al., 2010; Nouaceur & al., 2013; Baahmed, 2015, Belarbi & al., 2016; Djellouli, 2017; Gherissi, 2018; Bouguarra & al, 2020).

Drought indices are a useful tool for monitoring and evaluating different types of drought (meteorological, agricultural and hydrological drought), as they facilitate communication of climate anomalies to different water users. Many indices based on different variables have been developed to identify and quantify drought episodes. These include climate indices such as the

Standardized Precipitation Index **(SPI),** the Reconnaissance Drought Index **(RDI)**, the percent of Normal**(PN)**, Decile Index **(DI),** the Z-Score Index (**Z-Score),** the Rainfall Anomaly Index **(RAI),**Effective drought index (**EDI**), the China Z index (**CZI)** (Salehnia & al, 2017).

Studying the negative impact of drought on water resources has become increasingly urgent in Algeria. It is therefore necessary to monitor rigorously and periodically the quantity of this resource, to analyze its trend and to examine the factors influencing this trend.

Thus, water resource management, and the prediction of natural disasters require well-defined rain-flow models. Modeling hydrological behavior is an effective substitute for time-consuming flow measurements.

In this context, the wadi Boukiou watershed characterized by a semi-arid climate, which has seen several large droughts of varying magnitude during the last decades was the subject of this study to identify the influence of the climate variability on the flow.

For this, the research focuses on three parts:

1. **The study of the climate variability**: in this part we will analyze the series of hydroclimatic variables (rain and flow) at different times of the annual, monthly and daily time by applying the statistical tests (homogeneity test and trend test), for trend detection within rainfall and hydrometric series and to highlight climate variability.
2. **Drought Assessment Study**: the quantification and determination of the magnitude, duration and intensity of drought sequences, in order to identify the relationship between meteorological and hydrological drought.
3. **Hydrological modeling**: we use the HBV Light model to simulate basin flows. And with this model, we will be able to determine the impact of drought on water resources by assessing the different components of the hydrological balance.

In addition, we structured our work in the following chapters:

- A general introduction includes information on climate change in the world and Algeria, as well as hydrological modeling.

- **Chapter 1:** Literature Review that present the generalities on climate change, and the theory of hydrological modeling as well as the most common software.

- **Chapter 2:** addresses a general presentation of the Wadi Boukiou watershed (geographic location, morphometric study, and hydro-climatic study. As well as the detection of ruptures of the hydro-climatic series.
- **Chapter 3:** Study of the impact of climate variability using the 'MDM' meteorological drought monitor software.
- **Chapter 4:** HBV Light hydrological model modeling at the daily time to simulate the hydrological response and assess the impact of drought on the water resource of our watershed.
- Finally, a general conclusion will be given at the end of our study to summarize the main results obtained, and to list some perspectives associated with these results.

1.2 -Problem Statement

The watershed of wadi Boukiou located Northwest of the city of Tlemcen, with an area of 117.3 Km^2, characterized by a semi-arid climate regime and temporary flow. It will be the subject of this work, during the period extending from 1974/1975 to 2017/2018 it attended various manifestations of drought. To understand and assess the impact of this climate variability, especially the problem of drought on water resources and to identify the trend of our catchment area, we propose to study the rainfall and hydrological data observed over a period of 44 years in the Wadi Boukiou region.

To detect possible changes in rainfall and hydrological regime. We will use a number of drought indices to quantify its severity, and statistical tests. Then, to identify the main features of climate variability and its impact on water resources we use a hydrological modeling, which became indispensable tools for various areas especially for rain-flow relation.

1.3 - Objectives

The overall objective of the present study is to emphasis the impact of climate variability using the semi-distributed HBV Light model, for prediction of response of Boukiou basin to a rainfall event

1.3.1 - Specific objectives

The specific objectives were:

a. Predicting and analyzing the drought impact using various drought indices including SPI, DI, EDI, PNI, RAI, ZSI, CZI.
b. Breakage detection of hydro-climatic series.
c. To control the water balance of the basin and forecasting of hydrological phenomena:

simulate the hydrological processes in the watershed to reach at the end the simulation of water balance.

1.4 - Research questions

The objectives highlited above led to the following questions, which the research sought to response:

a. Which indice will be able to track drought intensity?
b. How does the performance of the semi-distributed model in Boukiou basin?

2.1 Bibliographic research on climate variability

2.1.1 Introduction

Drought is complex natural phenomenon and has no universal definition. Although the majority of people may consider extreme precipitation shortage as drought. Generally, it can be defined as a deficit in normal precipitation over a specific time for a specific region.

2.1.2 Drought definition

According to Wilhite and Glantz (1985), drought can have a conceptual or operational meaning.

Conceptual drought provides guidance and attempts to understand and establish assessments of drought. Operational drought can be used to calculate the probabilities of droughts of varying intensity, duration and spatial characteristics.

2.1.3 Types of drought

There are four main types of drought: meteorological, hydrological, agricultural and socio-economic.

2.1.3.1 Meteorological drought

It based on the degree of dryness relative to normal and the duration of the dry period (UNISDR.,*2011in* Belharazem and Benbrahim,*2019).*

Meteorological drought is often area specific, as a normal weather condition changes dramatically from region to region.

The examples to be considered for this type of drought in the world are numerous according to Wilhite and Glantz (1985):

- Less than 2.5 mm of rainfall in 24 hours (United States).
- Fifteen days, none of which receives as much as 0.25 mm (Britain).
- When annual rainfall is less than 180 mm (Libya).
- Actual seasonal rainfall is Deficient by more than twice the mean deviation (India).
- A period of six days without rain (Bali).

2.1.3.2 Hydrological Drought

Hydrological drought is associated with the effects of periods of drought on surface and underground hydrology.

The frequency and severity of hydrological drought is often defined on the basis of its influence on river basins.

Linsley & al (1975), considered hydrological drought as “a period in which flows are insufficient to supply a hydrological system.

2.1.3.3 Agricultural Drought

Agricultural drought is defined as a significant precipitation deficit that reduces agricultural production relative to normal or expected values for a large area. (Mokssit, 1996 *in* Belharazem and Benbrahim,2019).

It combines various characteristics of meteorological (or hydrological) drought with impacts on agriculture, including rainfall shortages, differences in actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels. (Vicente-Serrano et al., 2010 *in* Djellouli, 2017)

2.1.3.4 Socio-economic drought

Socio-economic drought is associated with the failure of water resource systems to meet water needs. It happens when water scarcity begins to affect people, individually and collectively. Furthermore, most socio-economic definitions of drought are associated with the supply and demand of an economic sector. (AMS, 2004 *in* Djellouli, 2017).

2.1.4 Characteristics of drought

The three characteristics that differentiate one drought from another are intensity, duration, and spatial extent.

Intensity refers to the degree of lack of precipitation and/or the severity of associated impacts. It is also closely linked to the duration of the event. Droughts normally take two to three months to become established but may then persist for months or years, although the intensity and spatial character of the event will change from month to month or season to season. (Wilhite, 2000)

2.1.5 Relationship between the various types of drought

Drought has been grouped by type as follows: meteorological, hydrological, agricultural, and socioeconomic (Wilhite and Glantz 1985). The interrelationships between these drought types may differ (Figure 2-1).

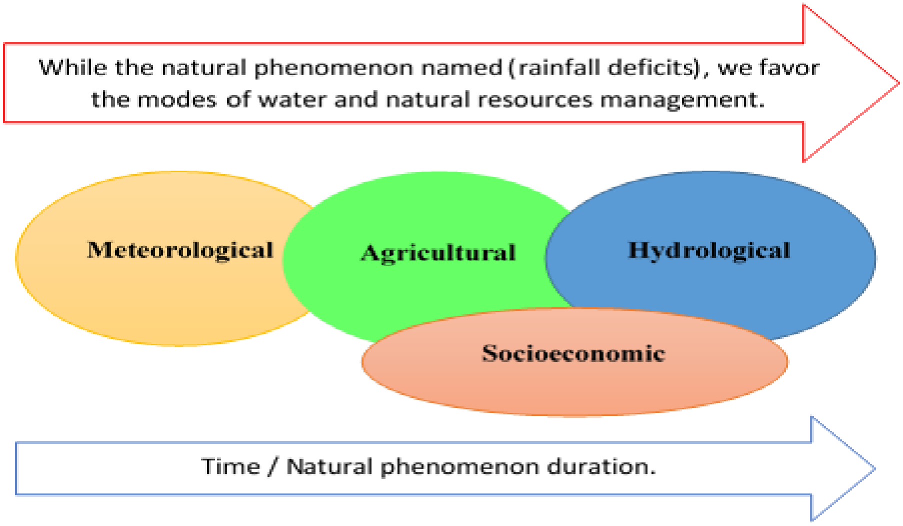


Figure 2-1: Relation between the various types of drought.

(Source: National Drought Centre, University of Nebraska-Lincoln, USA)

(Wilhite , D.A, 1985)

2.1.6 Consequences and impacts of drought

An episode of drought inevitably has consequences for human activities: the impacts can be environmental (poor water quality), social (human health) and economic (reduction of agricultural production). Figure 2- 2 provides a general schematic of this sequence.

2.1.6.1 Social Impact

The social impact is present in times of extreme and persistent drought. According to Khaldi (2005), drought causes under-nutrition, which is the cause of low disease resistance, and significant mortality, especially among children and the elderly. With the increase in population and scarcity of water resources, waterborne diseases are becoming a major risk.

2.1.6.2 Economic Impact

The economic impact occurs in agriculture (irrigation and production), as well as in tourism, which depend on the supply of surface and underground water, In addition to significant reductions in crop yields and animal production. Drought is associated with increased wind erosion, insect infestations, and plant diseases.

2.1.6.3 Environmental Impact

It results from damage to plant and animal species, forests and fires, air and water quality, degradation of landscape quality, loss of biodiversity and soil erosion. Some of the effects are short-lived and normal conditions are quickly restored. Other effects persist for some time or may even become permanent. For example, water supply problem, intensive exploitation of agricultural groundwater, loss of soil fertilization, degradation of landscape quality, including increased soil erosion, may result in a permanent loss of biological productivity of the site. (Djellouli, 2017)

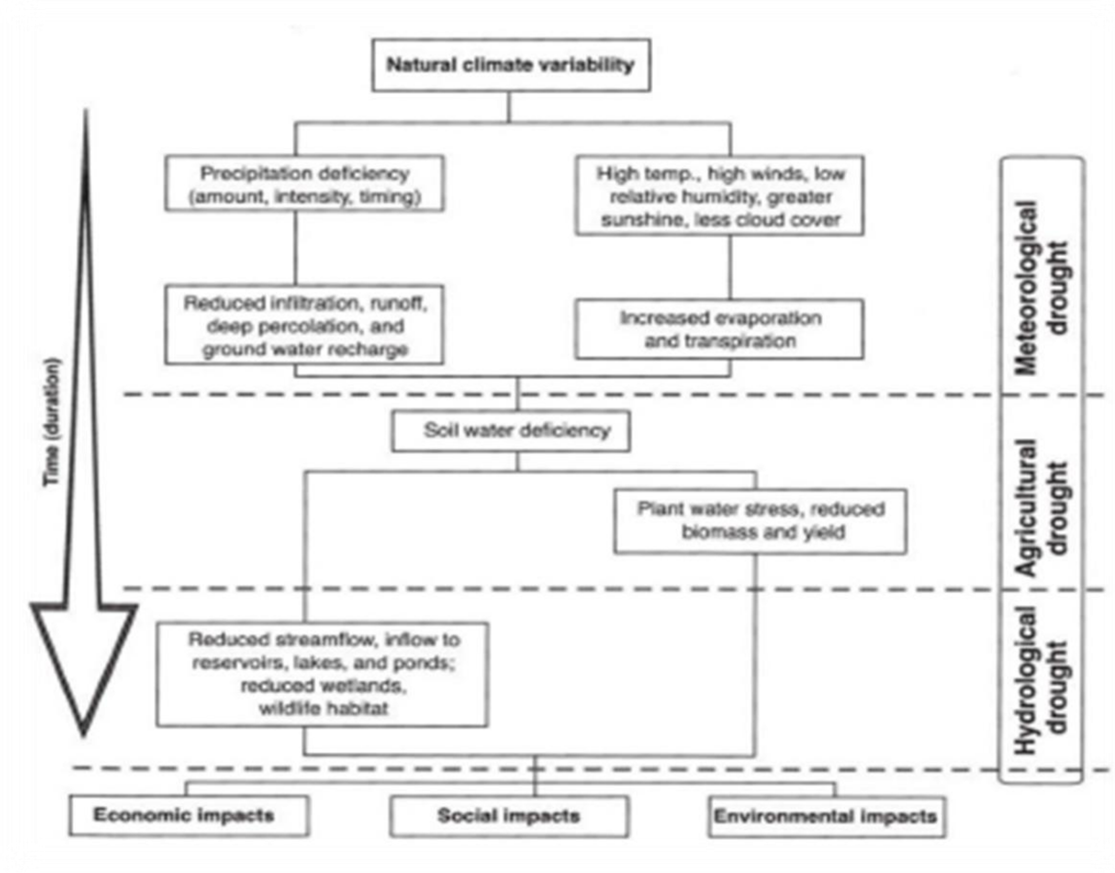


Figure 2-2: Causes and consequences of droughts.
Source: National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.) (Wilhite , D.A, 2000)

2.1.7 Previous Studies on drought in Algeria

In the history of the Maghreb countries, drought has always been present. 1.4 billion people were affected by drought events from 1967 to 1991(Obassi, 1994), according to the World Meteorological Organization (WMO).

Several works have been carried out on rainfall, based on a superficial analysis (calculation of average) on a few stations. In 1946, Seltzer carried out work on climate in Algeria, with detailed analyses of precipitation.

Then, the work of Demmak & al (1994) have illustrated the intensification of the magnitude of the rainfall deficit from East to West during the period 1974-1992.And generating drought trends during the last twenty years and showing similar droughts during the years 1913 and 1940 (Gherissi, 2018). A comparative method of annual averages (1974-1992) used in relation to Chaumont (1913-1963) and the long-term average (1922/1992).

By applying analysis as an important component, Matari & Douguédroit, (1999) in (Gherissi, 2018) resulted in a regional division of Western Algeria for a spatio-temporal analysis of rainfall. They have observed that the drought of the 1940s is mainly due to a decrease in spring rain and those of the 1980s is due to a decrease in the rain of winter.

Meddi & Hubert, 2003 have showed that rainfall is reduced in the 1970s in the North-West of Algeria, based on a statistical test approach (Pettit, Lee Héghinian and the segmentation of Hubert), on 10 rainfall stations with a long series of measurements. In order to establish a typology of droughts, the authors applied a simple method expressing the rainfall deficit as a percentage of the annual average.

In 2005, Khaldi studied the severity of drought, by using different methods such as those of quintiles. The results confirmed the persistence of the deficit years during the two decades 1980-1990-2000 for the Northwest of Algeria. The author concluded that drought is an evil that cannot be combated. It should be managed and strategies developed to overcome its effects.

Also, Ghenim & al. (2010) studied precipitation and specific flows during the 66-years period (1939-1940 to 2004-2005) to highlight the severity of the drought in the Tafna region. The results show that the estimated rainfall deficit of 27% is the one that generated an estimated decrease in flow of 69%.

In addition, using the SPI index, Ghenim & Megnounif (2013) have shown that drought in the Tafna basin over the past sixty years has increased since the mid of 1970s, and its distribution for 10 years is heterogeneous with peak registration during the period 1980-1990.

Another approach used by Meddi & al., (2013) in the same watershed, it combines breakage tests, Markov chains, the SDI (Dry Flow Index) and SPI index. The Dry Flow Index (SDI) is applied for two hydrometric stations, to detect hydrological drought at different time steps 3, 6, 9, 12 and 24 months over the period 1941-2010. Moreover, the SPI used for four rainfall stations, to identify the meteorological drought. The results show that almost all stations suffered from drought during the study period but more accurately after 1975 with the recording of extreme droughts.

2.1.8 Drought assessment and monitoring

In arid and semi-arid regions, monitoring meteorological drought is of critical importance for both agricultural and natural resource management. In addition, droughts may be exacerbated under projected global climate change, further highlighting the importance of drought monitoring (IPCC, 2014).

The prediction of drought can play an important role in the mitigation of its effects (Quang Tri & al., 2019). In recent years, many studies have developed a variety of indices to assess meteorological drought and hydrological drought based on different variables and parameters. These indices are important for the analysis and management of droughts in time and space. (Quang Tri & al.,2019).In Vietnam, the study focuses in drought indices while the result show that drought, on a national scale, mainly occurs in winter and spring. Particularly, drought in the South-Central region occurs in spring and summer, while drought in the North-Central region occurs in summer.

In 2017, Salehnia et al, used eight drought indices to monitor drought in the Kashafrood Basin of Iran based on two different rainfall data sources: Ag MERRA and observed data in the station. They obtained a high cross-correlation coefficients (R^2>0.90) among (Z-Score Index) ZSI, CZI (China Z-Score), and SPI (Standardized Precipitation Index), and among SPI, (DI Decile Index) and PNI (Percent of Normal Index), and between CZI and MCZI (Modified- CZI)in both data sources (Ag MERRA and station observation).

Many studies have focused on individual drought categories, whereas only a few studies have analyzed the relationships between meteorological drought and hydrological drought. This is due to the complexity in the underlying conditions, such as land cover, vegetation, topography, and other associated hydrologic and climatic variables (Quang Tri and al., 2019).

2.1.9 Drought Indices

The scientific community uses a number of indices to measure the intensity, duration and spatial extent of the drought. It is also useful to refer to these scientific indices to monitor the drought situation and make decisions. In addition, several indices have been proposed by researchers to quantify the drought severity which are related to hydro-meteorological variables.

Drought monitoring can be performed using appropriate drought indices. Different drought indices have been proposed in recent decades to anticipate, track and characterize the different extreme events that affect different parts of the world. Most drought indices have been developed in the United States, but are often used on other continents (Szczypta, 2012).

The selection of the drought index depends on the application and assessment of drought. These could be meteorological, hydrological or agricultural assessments. In addition, several time scales of drought indices make it difficult to decide which time stage is better for monitoring and evaluating drought characteristics. Among the meteorological indices we can find: the Standardized Precipitation Index SPI, China Z-Score Index (CZI) and modified CZI (MCZI),Statistical Z-Score (Z-Score),the Effective Drought Index (EDI),the Percent of Normal

Index (PNI), Rainfall Anomaly Index (RAI), Decile Index (DI) and Keetch Byram Drought Index (KBDI).

Most of the indices are developed for specific regions and have limitations on use under different climatic conditions due to the inherent complexity of drought phenomena, for example, the Chinese Z-Index (CZI) is used by the National Meteorological Centre in China (Wu & al. 2001 in Djellouli, 2017). In addition, each index has its own strengths and weaknesses.

More details and description of calculation of those meteorological indices will be clarified in the chapter of data and methodology.

2.1.10 Conclusion

The climatic variations that have affected the world have influenced the global climate. These changes will have global consequences, such us, an increase in the frequency of the occurrence of extreme climatic events (Drought, Floods), a significant regional rise in temperatures, a decrease in agricultural production, sea level rise, human migration from one region to another, degradation of freshwater quality…etc. Today, climate change is considered one of the greatest threats to the environment, the economy and also to the human well-being.

During drought, agriculture is usually the first sector to be affected because soil moisture will normally be the first component of the hydrological system to be affected. However, when the rains return, soil moisture levels may dramatically improve, and over a short period of time. Thus, agricultural drought, particularly on rain-fed cropland, can have drastic consequences. Depending on the timing of these rains, however, impacts may linger because potential crop yields may already have been reduced substantially. Hydrological drought may continue for many months or years, since recharge of reservoirs and groundwater is a long process.

To understand and assess the impact of this climate variability, (especially the drought problem on water resources), and to identify the trend of the behavior of our watershed, we will add a modeling study of the rain- flow relationship, which allows us to assess the different components of hydrological balance. Consequently, in the next part of this chapter, we will give an overview on the use of modeling and its interest.

2.2 Generality on hydrological modeling

2.2.1 Introduction

Due to rapid urbanization and industrialization, as well as deforestation, land cover transformation, irrigation, various changes have been occurred in hydrologic systems. Along with climate change, soil heterogeneity also has a direct impact on the discharges of many rivers around the world. Different hydrologic phenomena can be studied to highlight these variations.

The use of various hydrological models becomes an inevitable task to discover the impact of climatic variability on the hydrology of watersheds. These models can be applied in very complex basins with distinct sizes and characteristics. (Gayathri & al, 2015)

2.2.2 Water Balance

In a system with no external inflows from neighboring catchments and territories, the water is entering the system via precipitation (P), converted into evaporation (E) and/or runoff (R) (surface, subsurface or groundwater) and associated storage (S) or change in storage ΔS during the time period investigated, as expressed in the following general equation (EU,2015)

$$P = R + E \pm \Delta S \qquad \text{(Equation 1-1)}$$

P: Precipitations (mm/y)

E: Evapotranspiration (mm/y)

R: Streamflow (mm/y)

ΔS: Change in storage over time (mm/y)

Runoff model is the base of most of the hydrological models means that river flow computed according to the meteorological data for a given basin. Water balance equation used in this case to model the runoff by calculating the amount of precipitations focusing on the quantities directed as runoff R which also depending on other factors (ET, T, etc.). Water balance equation determining the runoff is:

$R = P – E – \Delta S$ (Equation 1-2)

The runoff process contains three components (Figure 2-3): (a) the overland flow, (b) the interflow, and (c) the base flow. (EU, 2015)

The overland flow: (also known as surface runoff (Rs)) occurs when the rate of precipitation (or Snowmelt) exceeds the interception requirements and the infiltration rate / capacity.

The interflow: (or subsurface runoff (R sub)) is the portion of infiltrated rainfall that moves laterally through the upper soil layers until it reaches the stream channel. It depends on the physical characteristics of the catchments and the spatiotemporal characteristics of the rainfall.

The base flow: (or groundwater runoff (R gw)) is the portion of infiltrated rainfall that reaches the groundwater table and then discharges into streams. It responds much more slowly to rainfall and does not fluctuate rapidly.

The overland flow with the interflow are the two components of the Direct Runoff. And the Direct Runoff, combined with the Base flow Runoff (resulting from groundwater runoff and/or delayed subsurface runoff) contributes to the Total Discharge (or streamflow) as illustrated in Figure 2-3.

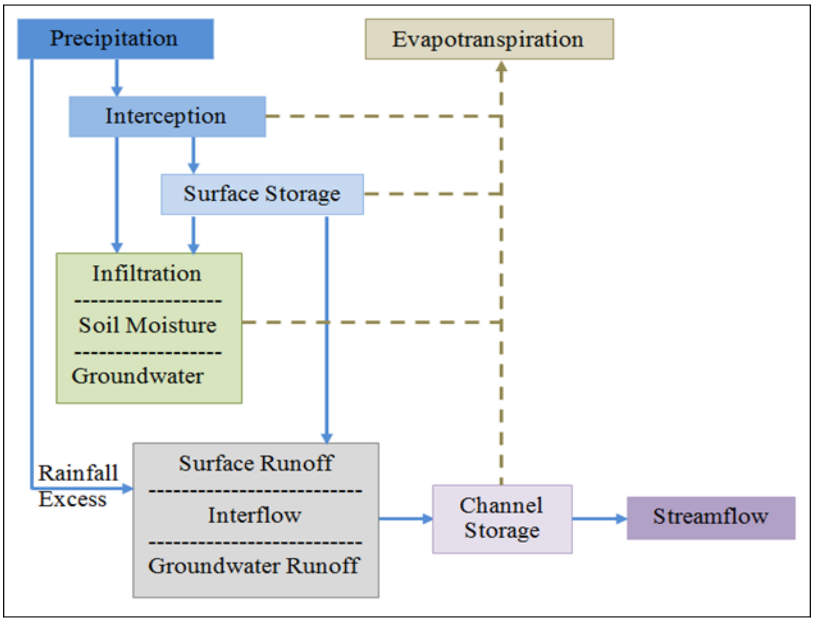


Figure 2-3: The runoff process components and their contribution to the streamflow. (EU, 2014 in EU,2015)

2.2.3 Hydrological modeling and Rainfall –Runoff model

A model is a simplified representation of real system. The best model is the one which give results close to reality with the use of fewer parameters and less complexity. (Sorooshian et al, 2008).

Rainfall-runoff models have been used very successfully to estimate runoff at small and large catchments under different climate regimes (McMillan & all, 2012). Generally, rainfall-runoff models use rainfall and other climate data such as temperature and or potential evapotranspiration to estimate runoff. Even though the main emphasis of rainfall-runoff models is to estimate runoff, they are normally designed to simulate real evapotranspiration to account for soil water balance. However, they have no direct interest in quantifying surface energy fluxes (McMillan & al, 2012).

The parameters used in the rainfall-runoff models are usually optimized such that the runoff simulated matches as closely as possible to the recorded runoff. A variety of model calibration techniques (including manual calibration and automatic calibration techniques) have been developed and implemented to highlight conformity between the model simulations of system behavior and observations (Hongxia & al, 2015). (McMillian, Krueger, & Freer, 2012)

2.2.3.1 Why the Rainfall -Runoff model is important?

Currently, hydrological models are considered as an important and necessary tool to optimally answer the various questions related to environment and water resources management (supply and demand) (Sorooshian & al, 2008).

According to Beven (1996), every hydrological model requires two essential components:

- one to determine how much of rainfall becomes part of the storm hydrograph,
- and the other takes account of the distribution of the runoff in time, to form the shape of the hydrograph referred as routing.

The applications of these hydrological models are varied and multiple, according to Mathevet (2005) in (Djellouli, 2017) the models can be used for:

- **Simulation**: to fill gaps existing in a time series flow or expansion of flow series.
- **Hydrologic prevision**: the purpose is the prediction of responses of a catchment or river basin to a rainfall event (preventive water resources management, which is based on anticipating future changes in river flows during periods of stretching and anticipating flood risks during periods of flooding).
- **Predetermination**: is to generate long historical rainfall to study extreme events by frequency analysis (delimitation of flood zones).

2.2.3.2 Modeling Steps

Several authors such as Anderson & Woessner, 1992, De Marsily, 1994, Refsgaard, 1996, Ambroise, 1999, Cudennec, 2000, specified the essential steps of development and implementation hydrological models (Figure 2-4):

a- **Definition of the model and its objectives**

b- **Identification of the model**: Analysis of the structure of the system to be modeled, (characteristics, variables and parameters).

c- **Construction of the model**: Develop the algorithm to be incorporated into a computer tool able to performing the instructions. This algorithm must be followed by verification of the software. (De Marsily, 1994; Ambroise, 1999),

d- **Calibration of the model**: by adjusting the values of the various parameters to be calibrated. So, depending on deductive criteria or inputs and outputs observations, the calibration data will be used.

e- **Verification or sensitivity Analysis**: by comparing the response simulated response to an experimental result, using different data from those used for calibration.

f- **Validation of the model**: using this step to test different aspects of the simulations obtained in terms of performance.

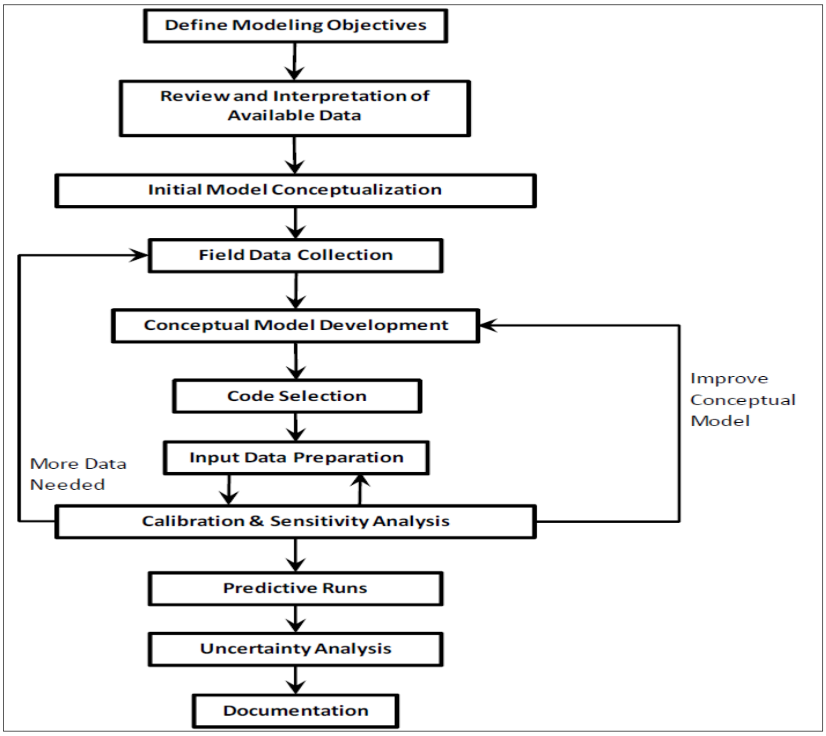


Figure 2-4: Model construction process (Wels, 2012)

2.2.3.3 Classification of the model

Rainfall-runoff models are classified based on model input and parameters and the extent of physical principles applied in the model. (Gayathri & al, 2015). It can be classified as lumped and distributed model based on the model parameters as a function of space and time.

Also, there are deterministic and stochastic models which are based on the other criteria as well as (the nature of the variables, parameters and/or relationships between them). (Ambroise, 1998).

Deterministic model will give same output for a single set of input values whereas in stochastic models, different values of output can be produced for a single set of inputs.

In lumped models, the entire river basin is taken as a single unit where spatial variability is disregarded, and hence the outputs are generated without considering the spatial processes. Where as a distributed model can make predictions that are distributed in space by dividing the entire catchment in to small units, usually square cells or triangulated irregular network, so that the parameters, inputs and outputs can vary spatially. (Sorooshian & al, 2008).

Another classification is dynamic and static models based on time factor. Dynamic model include time while static model exclude time. (Gayathri & al, 2015).

Sorooshian & al. (2008) had classified the models as event based and continuous models. The former one produce output only for specific time periods while the latter produces a continuous output. One of the most essential classifications is conceptual models, empirical model, and physically based models.

2.2.3.4 Types of hydrological model

In this part, we will provide a brief overview of three most important models categories used in hydrology.

2.2.3.4.1 Empirical Model

This model involves mathematical equations derived from concurrent input and output time series and not from the physical processes of the catchment.

2.2.3.4.2 Conceptual Model (grey box model)

The model describes all of the component hydrological processes. It consists of a number of interconnected reservoirs which represents the physical elements in a catchment (Gayathri & al, 2015). It is based on the knowledge of the physical phenomena that act on the inputs to obtain the outputs: in which they are recharged by rainfall, percolation and infiltration, and are emptied by evaporation, drainage and runoff.

2.2.3.4.3 Physically based model (mechanistic models or white box model)

It is an idealized mathematical representation of the real phenomena which based on spatial distribution (Space and time), evaluation of parameters describing physical characteristics. According to Gayathri & al in 2015, it is considered as a complex model that Require human expertise and computation capability.

2.2.3.5 Modeling Evaluation Criteria

The process of evaluating the performance of models is important not only at the stages of model development and calibration, but also during the communication of results to other researchers and stakeholders (Schaefli& Gupta, 2007 in Birundu, 2016). The performance of a model is assessed according to the objectives that are set and therefore the criteria that are chosen.

In addition, several criteria for evaluating the performance of models that have been developed as well as graphical criteria, analytical criteria. The criteria most commonly used in hydrology are:

a- The mean absolute error

It is defined by the average of the deviations between the observed and calculated (simulated) discharge at each time step. (Perrin, 2000)

$$\varepsilon = \frac{1}{n}\sum_{i=1}^{n} |Qobs,i - Qcalc,i\,| \qquad \text{(Equation 1-3)}$$

Where:

n: Number of observations,

Q obs,i: Observed discharge at time step “i”.

Q calc, i: Calculated (simulated) discharge at time step “i”.

b- The mean square error: “MSE”

It is calculated as the square root of the mean squares of the deviations between the observed and calculated discharge. (Gaume, 2002)

$$MSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(Q_{obs,i} - Q_{calc,i})^2} \qquad \text{(Equation1-4)}$$

Where:

n: Number of observations,

Q obs,i: Observed discharge at time step “i”.

Q calc, i: Calculated (simulated) discharge at time step “i”.

c- Nash - Sutcliffe Efficiency ‘’NSE”

NSE varying in]-∞, 1], has the advantage of being of easy interpretation. It estimates the adjustment improvement obtained by using the model to simulate the discharge in relation to a 'zero' model (reference model) which would give a constant discharge equal to the average discharge over the entire period considered.

$$NSE = \left[1 - \frac{\sum_{i=1}^{n}(Qobs,i - Qcalc,i)^2}{\sum_{i=1}^{n}(Qobs,i - \bar{O}obs\,)^2}\right] \qquad \text{(Equation 1-5)}$$

Where:

Q obs,i: Observed discharge at time step “i”,

Q calc, i: Calculated (simulated) discharge at time step “i”.

Ōobs : Mean observed discharge over simulation period “n”.

This means that an:

NSE value = 1.0: indicates perfect fit; the model perfectly simulates the target output,

NSE value = 0: simulation as good (or poor) as the constant-value prediction,

NSE value of < 0: indicates a very poor fit.

Therefore, it is preferred to have NSE values greater than Zero and closer to one, which is an apparent normalization because the implicit reference model has different implications for different case studies." As a result, the NSE does not measure how good a model is in absolute terms (Nash & Sutcliffe, 1970).

However, according to (Ewen , 2011), one of the strengths of the NSE, as a result of being based on the square, is that it is sensitive to differences for peaks. One of its weaknesses is that it is also quite sensitive to differences in timing. Handling and interpreting differences in timing is one of the most difficult problems faced when computing hydrographs. The sensitivity of NSE to timing arises because even quite small misalignments in the timings of peaks can give rise to large differences in amplitude between the hydrographs. This sensitivity can result in poor value for NSE even when the size and shapes of the peaks in the two hydrographs are very similar. However, it is common practice for modelers to show hydrograph time series plots in which model simulation" goes up and down" in a similar.

2.2.3.6 - Model Construction

2.2.3.6.1 - Calibration

Once the model structure is chosen, the algorithms are verified and parameterization is defined in terms of the basin, some parameters are often difficult to measure or assess. This incomplete identification of the model requires estimating the missing parameters with a calibration (adjustment). Therefore, the calibration procedure is one of the important steps in the hydrological modeling approach, which consists in searching for optimal values of the parameters.

There are three calibration methods: manual calibration, automatic calibration and mixed calibration: (Refsgaard & Storm, 1996)

2.2.3.6.1.1 - Manual calibration

Manual calibration is based on the assessment of parameter using a number of simulation runs. This involves manually adjusting values to the parameters and estimating the error between the simulated and observed values. It can consume a lot of time to calibrate (many tests must be carried out until the values of the parameters are obtained which give the appropriate results in relation to the objective set).

2.2.3.6.1.2 - Automatic calibration

The parameters in this method are adjusted automatically, it involves use of a numerical algorithm which searches for the limit value of a given numerical criteria. (Refsgaard & Storm, 1996). This method is fast and less subjective.

2.2.3.6.1.3 - Mixed Calibration

It consists the possibility of combining the two techniques (Refsgaard & Storm, 1996) reported that this combination is not widespread. We can start with one calibration method and finish with the other. If we start with a manual calibration, it is necessary to determine the variation deviation of the parameters, and then an automatic calibration is used in this interval to determine the optimal parameters. In the opposite case, we should to do a sensitivity study on the parameters, to target the potential parameters, then a manual calibration can be used to determine the values of these parameters. (Djellouli, 2017)
The successful use of a hydrological model depends on its quality calibration.

2.2.3.6.2 - Sensibility Analysis

The sensitivity analysis identified the effect of changing the calibration parameters on streamflow. (Neitsch & al., 2002). Identification of the key parameters and the parameter precision that required for calibration it is mandatory (Arnauld & al., 2012 and Ma & al., 2000). Sensitivity analysis can most likely complete the calibration step varying, successively or simultaneously, the parameters around optimal values (measured or calibrated), clarifies the domain of indifference of each parameter within the quality of the simulation which is not significantly impaired (Sorooshian & Gupta, 1985). This allows detecting the parameters to which the model is insensitive, and simplifies the calibration step.
Sensitivity of rain-flow models to input data: rainfall and potential evapotranspiration.

2.2.3.6.2.1 - Sensitivity of rain-flow models to PET input

In 2004, Oudin used four rain-flow models to analyze their sensitivity to PET (Potential Evapotranspiration) input over a large sample (308 watershed) such as: GR4J model and simplified versions of the HBV, IHACRES and TOPMODEL models. It tested 27 PET formulae of various designs, with the aim of studying the impact of PET calculation models and the spatial variability of the latter on the performance of the rain-flow model. The result obtained overall is:

Rain-flow models are not very sensitive to PET input. Highly different design formulas lead to equivalent performance in terms of flow simulation,

In the context of global rain-flow modeling, PET models commonly used to estimate this variable do not appear to be adequate tools at the watershed scale; their relative complexity is not justified.

2.2.3.6.2.2 - Impact of bad knowledge of rainfall

Djellouli (2017) mention that some authors like (Dawdy & Bergmann (1969), Wilson & al. (1979) and Biggs & Atkinson (2011)) have analyzed the uncertainties of flow simulations in response to bad rainfall estimation. They found that flow simulations deteriorate when the quality of rainfall estimation decreases. Andreassian & al. (2003) reported that the performence of the rain-flow model increases with the density of the measuring network.

Imperfections in precipitations input data are compensated by adjusting rain-flow model parameters to the calibration phase.

2.2.3.6.3- Validation

Model validation is the most critical step, its procedure represents the reality of the results. It defines as a "test of model performance with calibrated parameters for an independent period " (Seibert, 2005), starting by verifying if the calibrated model simulates correctly the series of data (spatially and temporally), which is not used during the step of calibration. It can be done using the comparison of the simulated hydrograph with the observed hydrograph for the validation period can assess if the fit is acceptable therefore the model prediction is valid (confirm). According to Abadie, (2006), this validation (or control) should include the following iterative steps:

- Calibration within a certain period and within a reference basin, if possible, for several variables of interest.
- Validation within other periods for the same basin, and internal variables of the basin without modifying the set of estimated or calibrated parameters.

The eventual goal of the modelers is to seek to improve the values of the adjustment criteria, reflecting the performance of their simulations.

2.2.3.7 - Hydrological model Structures

The first computer based hydrological models appeared in the late 1960s (BERGSTRÖM, 2006), and since then numerous models structures have been developed over time for various purposes. Surprisingly good results were obtained by rather simple models, and this simplicity was a necessity due to the limited data that were normally available. In addition, an overview of some of the best known hydrological models can be found in the work by Singh (1995). This research has adopted from existing conceptual model structures and the examples of more recent models are the British TOPMODEL (Beven & Kirkby, 1979), the Danish MIKE-SHE (Refsgaard & Storm, 1995) and HBV Light version 6 (Bergström, 1992).
From literatures, those three potential model structures were identified:

2.2.3.7.1 -TOPMODEL (topography-based hydrological model)

TOPMODEL is a semi distributed conceptual rainfall-runoff model that takes the advantage of topographic information related to runoff generation. But according to Beven and Kirby (1979), Beven (1989), it is considered as a physically based model as its parameters can be theoretically measured. In other words, it can be defined as a variable contributing area conceptual model. TOPMODEL can be used in single or multiple sub catchments using gridded elevation data for the catchment area. It helps in the prediction of hydrological behavior of basins. The major factors considered in this are the catchment topography and soil transmissivity.

The main aim is to compute storage deficit or water table depth at any location. The storage deficit value is a function of topographic index (a/tanβ) (Beven, 1989), where a is drained area per unit contour length and tanβ is the slope of the ground surface at the location. Since the index is based on basin topography, the model gives calculations only for representative values of indices. It is obtained by manual analysis of contour maps. The model use exponential Green-Ampt method of Beven (1989) for calculating runoff and it is advised to reduce the number of parameters. The output will be in the form of area maps or simulated hydrographs.

2.2.3.7.2 -MIKE SHE MODEL (european hydrologic system)

It is a physically based model and hence it requires extensive physical parameters (Gayathri & al, 2015). The purpose of this model is to model the continental part of the water cycle and can theoretically be applied to areas ranging from the plot to the entire watershed (Abbott & al.,1986 in Maison, 2000). The full detail and manual of MIKE SHE code is given in the user's guide (DHI-WE, 2005). In addition, Refsgaard & Storm (1995) have provided the detailed description of the structure and set up of the model. The code involves pre-processing and post processing modules and has various options for displaying results.

2.2.3.7.3 -HBV LIGHT MODEL

HBV Light (Hydrologiska Byrans Vattenavdelning) Model at SMHI, Sweden) is a recent version of the HBV model. It is an example of semi distributed conceptual model (Bergstrom, 1976 in Gayathri & al, 2015). This model was developed in 1972 by the Swedish Meteorological and Hydrological Institute (SMHI) from being a forecasting model to become a more general tool in many types of applications, whenever there is a need to transform meteorological observations into runoff for ungauged watersheds. Then, it is known for its robustness, despite its relative simplicity. It has been applied to more than 45 rivers in Sweden and more than 30 countries worldwide (Bergström, 1992), with such different climatic conditions, for example; Sweden, India, Zimbabwe, Colombia, Tunisia, and Algeria as well.

Like most hydrological models, it consists of three main components: subroutines for snow accumulation and melt, subroutines for soil moisture accounting and response and river routing subroutines. This model simulates daily discharge using daily temperature and precipitation as inputs, as well as monthly estimates of potential evapotranspiration.

The main structure of HBV Light model is shown in the figure below:

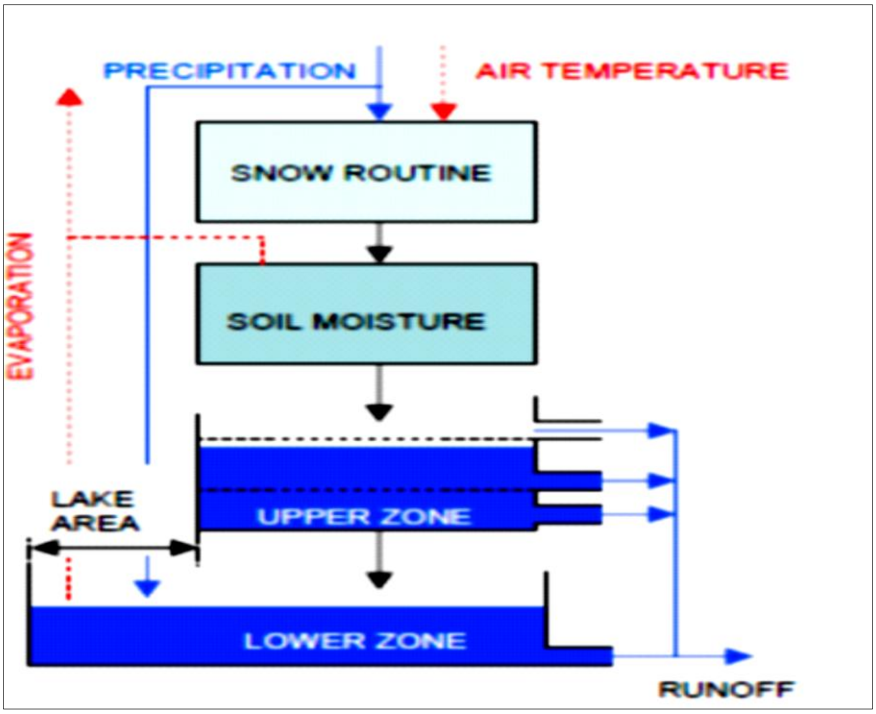


Figure 2-5: Main structure of the HBV Light model (Killingtveit & Sælthun 1995).

The main idea behind the development of the HBV Light was to provide an easy useful tool. The basic equations conform to the SMHI" HBV 6 version "(Bergström, 1992) with only two few modifications. In the original version, only integers values allowed for the MAXBAS routing setting. It is possible to use a correction of the long-term average of the potential evaporation of the values proposed by Lindström & al. (1997). The HBV Light version offers two options that do not exist in the old version (Bouguerne, 2017)

- The first is the ability to include observed groundwater levels in the analysis,
- The second is the ability to use a different response routine with a delay.

2.2.3.7.3.1 -Description of HBV Light parameters

The model simulates daily discharge using daily rainfall, temperature and potential evaporation as input. Precipitation is simulated to be either snow or rain depending on whether the temperature is above or below a threshold temperature, TT [°C]. All precipitation simulated to be snow, i.e. falling when the temperature is bellow TT, is multiplied by a snowfall correction factor, SFCF [-]. Snowmelt is calculated with the degree-day method (Equation 1-6).

$$\text{Meltwater} = \text{CFMAX}\,(\text{T(t)} - \text{TT}) \text{ in (mm/d)} \qquad \text{(Equation 1.6)}$$

Meltwater and rainfall is retained within the snowpack until it exceeds a certain fraction, CWH [-], of the water equivalent of the snow. Liquid water within the snowpack refreezes according to Equation 7.

$$\text{Refreezing} = \text{CFR CFMAX}\,(\text{TT} - \text{T(t)}) \qquad \text{(Equation 1-7)}$$

Where:

CFR: Refreezing coefficient,

CFMAX: Degree-day factor in (mm °C-1 d-1),

TT: Critical Temperature of snowmelt (°C),

T (t): Starting Temperature (C°),

Rainfall and snowmelt (P) are divided into water filling the soil box and groundwater recharge depending on the relation between water content of the soil box (SM [mm]) and its largest value (FC [mm]) (Equation 8).

$$\frac{recharge}{P(t)} = \left(\frac{SM(t)}{FC}\right)^{BETA} \qquad \text{(Equation 1-8)}$$

Where :

FC: Maximum soil moisture storage (mm),

SM: Soil moisture (mm),

Groundwater recharge (mm),

BETA: Parameter that determines the contribution of rainwater or snowmelt (-)

Actual evaporation from the soil box equals the potential evaporation if SM/FC is above LP [-] while a linear reduction is used when SM/FC is below LP (Equation 1-9).

$$Eact = Epot.\min\left(\frac{SM(t)}{FC.LP},1\right) \quad \text{(Equation 1-9)}$$

LP: Soil moisture value above which Eact reaches Epot (mm),

Epot: Evapotranspiration (mm)

Groundwater recharge is added to the upper groundwater box (SUZ [mm]). PERC [mm d-1] defines the maximum percolation rate from the upper to the lower groundwater box (SLZ [mm]). Runoff from the groundwater boxes is computed as the sum of two or three linear outflow equations depending on whether SUZ is above a threshold value, UZL [mm], or not (Equation 10).

Q GW(t) = K 2SLZ +K 1SUZ+ K 0 max (SUZ− UZL, 0) (Equation 1-10)

This runoff is finally transformed by a triangular weighting function defined by the parameter MAXBAS (Equation 11) to give the simulated runoff [mm d-1].

$$\left.\begin{array}{l} Q_{Sim}(t) = \sum_{i=1}^{MAXBAS} C_i Q_{GW}(t-i+1) \\ ouC(i) = \int_{i=1}^{i} \frac{2}{MAXBAS} - \left| u - \frac{MAXBS}{2} \right| \frac{4}{MAXBAS^2}\, du \end{array}\right) \quad \text{(Equation 2-11)}$$

If different elevation zones are used the changes precipitation and temperature with elevation are calculated using the two parameters PCALT [%/100 m] and TCALT [ºC / 100 m] (Equation 12 and 13).

$$P(h) = Po\left(1 + \frac{PCALT(h-ho)}{10000}\right) \quad \text{(Equation 1-12)}$$

$$T(h) = To - \frac{TCALT(h-ho)}{100} \quad \text{(Equation 2-13)}$$

The long-term mean of the potential evaporation, Epot, M for a certain day of the year can be corrected to its value at day t , Epot (t), by using the deviations of the temperature, T(t), from its long-term mean, TM , and a correction factor, CET [°C-1] (Equation 2-14).

$$E_{pot}(t) = (1 + C_{ET}(T(t) - T_M)).E_{pot,M} \quad \text{(Equation 2-14)}$$

Where:

Epot (t): Potential evaporation corrected on day d-1,

CET: Correction factor,

T (t) : Temperature on day t (°C)

TM: Average long-term temperature for this day of the year (°C)

Epot, M: Long-term average evaporation for this day of the year (mm.d-1)

The general structure and equations of HBV Light can be summarized in the figure below, which describe all the data from the 15 optimized parameters of this model and that contribute to the three components of total flow (Direct runoff (Q0), Quick runoff (Q1) and (Q2) base flow).

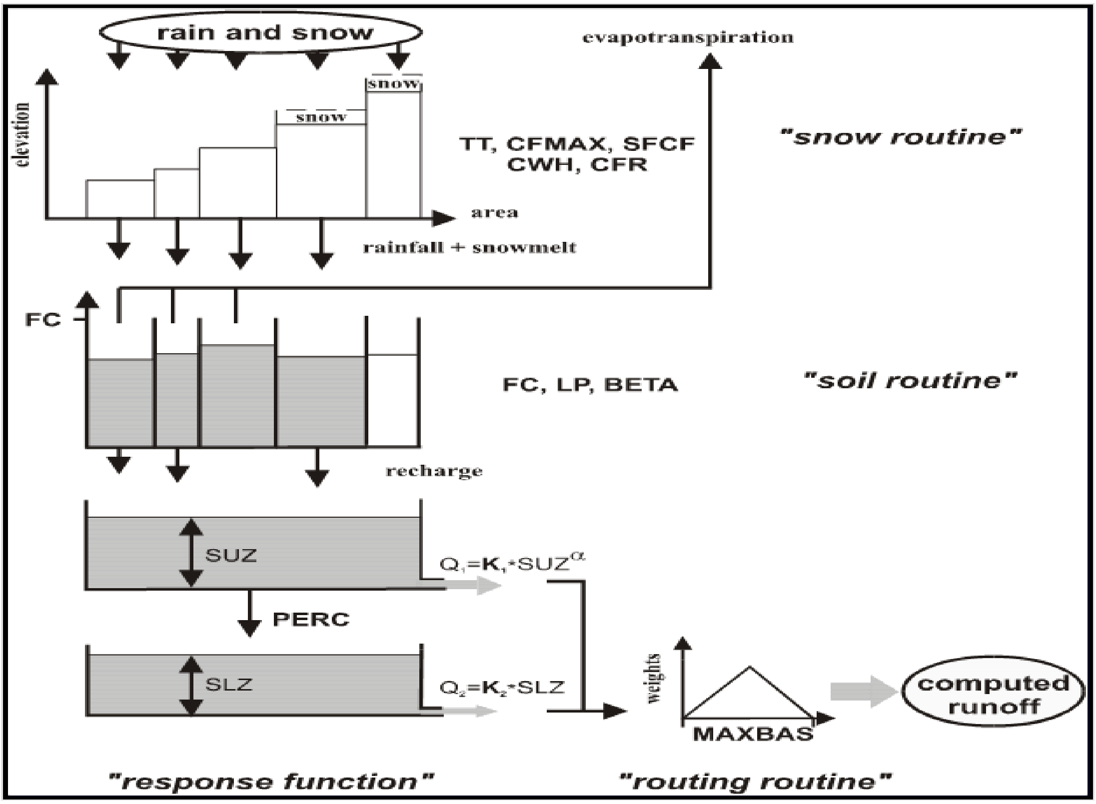


Figure 2-6: General Structure and equation of HBV Light model (Gherissi, 2018)

Note:

SUZ has no upper limit.

Q2 can never exceed (PERC / SLZ) and can never exceed (PERC/K2).

The 3 coefficients (K0, K1 and K2) of the 3 components of simulated flow (Q 0, Q1 and Q2): are parts of manual optimization during the calibration of the model

2.2.3.7.3.2 -Choice of application model in the rainfall-runoff modeling relation-ship

According to the diversity of the models and their limitations of use, the difficulty of application, the unavailability of data, under its technical problems, the decision must be made

in a rigorously manner for the choice of the application model in the rain-flow modeling relationship. HBV Light model has been successfully employed in several studies evaluating the effects of climate variability on river catchments around the world as well as in Norway, Sweden, Finland (Bergström, 2006). In addition, it was applied to differents catchments in Tunisia by (Dakhlaoui, 2014; Korchani, 2016); as well as in Kenya by (Birundu, 2016); in Ethiopia by (Abebe and Kebede, 2017); in Nepal by (Bhattarai & al, 2018); and in various watershed in Algeria like: (Bouguerne, 2017; Boucebha, 2018; Gherissi, 2018…etc)
In 2017, Sagar Shiwakoti used this model in his study to simulate climate change This model has developed impacts on the runoff processes of the Karnali River Basin of Nepal. He confirmed that the choice of the HBV Light model for simulating streamflow and snowmelt has been proven to be effective, the Nash Sutcliffe-efficiency criterion has shown the effectiveness of the model in simulating rainfall-runoff processes. Model performance is highly sensitive on the initial choice of parameter values. For this raison, the HBV Light model will be applied in our catchment area "Boukiou".

2.2.4 Conclusion

Hydrological models become a helpful tool for decision-making, management of available water resources and for studying the impact of climate variability on the water resources, due to significant progress in computing field and Geographic Information Systems.

The three model (MIKE SHE, TOPMODEL and HBV Light) structures were evaluated in this part based on the following considerations, the complexity of the model structure, data requirements, flexibility for adaptation, and suitability for modeling rainfall-run-off and previous modeling success in hydro climatic environments.
After describing this three models, we choose to apply HBV Light model to study the climate variability on the flow of Boukiou watershed (Tafna, Algeria)

The model must perfectly reproduce the observed data. It is impossible to have a perfect fit between model simulations and observations. It is good to remind that the model is just a simplification of reality; it represents the simplified dynamics of physical processes (Bessiere, 2008 in Gherissi, 2018) and regardless of the uncertainty associated with the observations and structure of the model.

3.1- Introduction

Atmospheric precipitations have an important role in the supply of rivers and groundwater. However, not all the rain is going to feed the lakes, the aquifers or the rivers. One part flows, another infiltrates, or it evaporates. Also, the response of a watershed depends on several parameters like topography, land use, geology, etc. In this chapter, we present a brief overview of the geography, geology and hydrogeology, the main physical characteristics of the Boukiou watershed, and then hydrological study of the region.

3.2- General description of Tafna watershed

The Boukiou basin belongs to the Tafna watershed which is located in the North-West of the Algerian territory, and extends over almost the entire wilaya of Tlemcen over an area of 7245 km^2 and spills over the Kingdom of Morocco. According to the codification of the National Water Resources Agency “ANRH “of Tlemcen . It contains code 16 of Algeria's 17 basins, which belongs to the hydrographic region of the Oranie-Chott Chergui complex. (Figure 3-1).

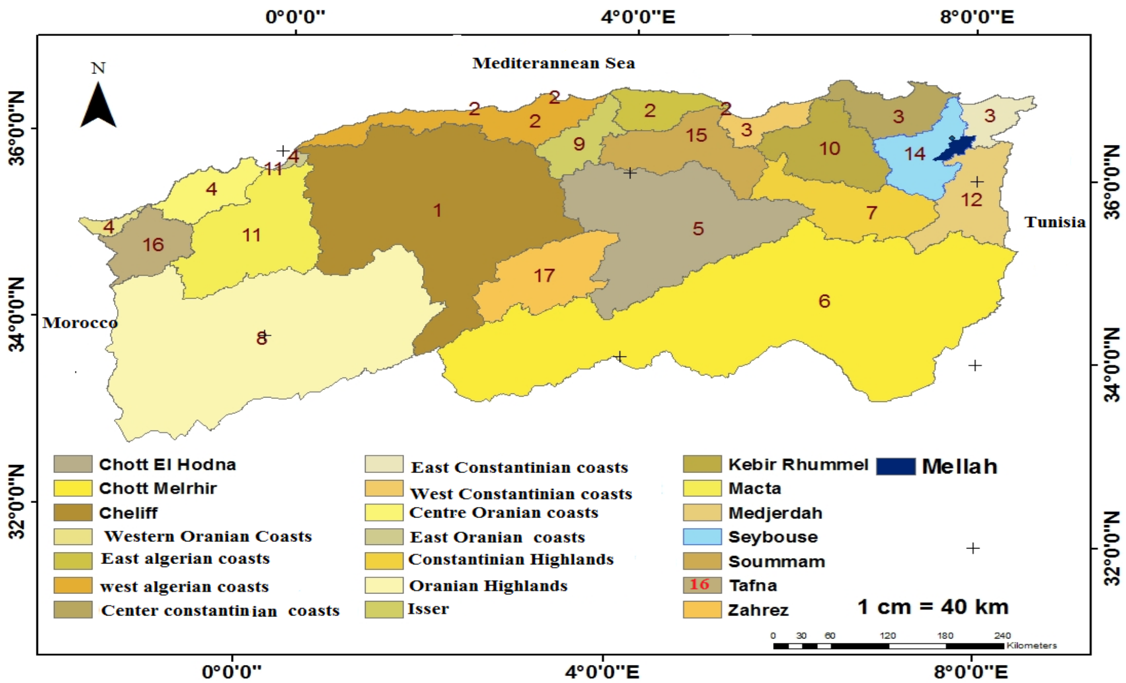


Figure 3-1: Geographical location of the Tafna watershed. (Source: A.N.R.H.)

(Modified by Berrezoug, 2020)

The Tafna watershed can be subdivided into three major parts: the Upper Tafna, the Mean Tafna and the Lower Tafna.

- Upper Tafna (Western part): includes Sebdou basin, Khemis basin and Mouilah basin.
- Tafna mean (Eastern part): including the main tributaries: Isser basin and Sikkak basin.
- The lower Tafna (Northern part): The wadi Boukiou, Boumessaoud and Zitoun are the main tributaries of this part (Figure 3-2)

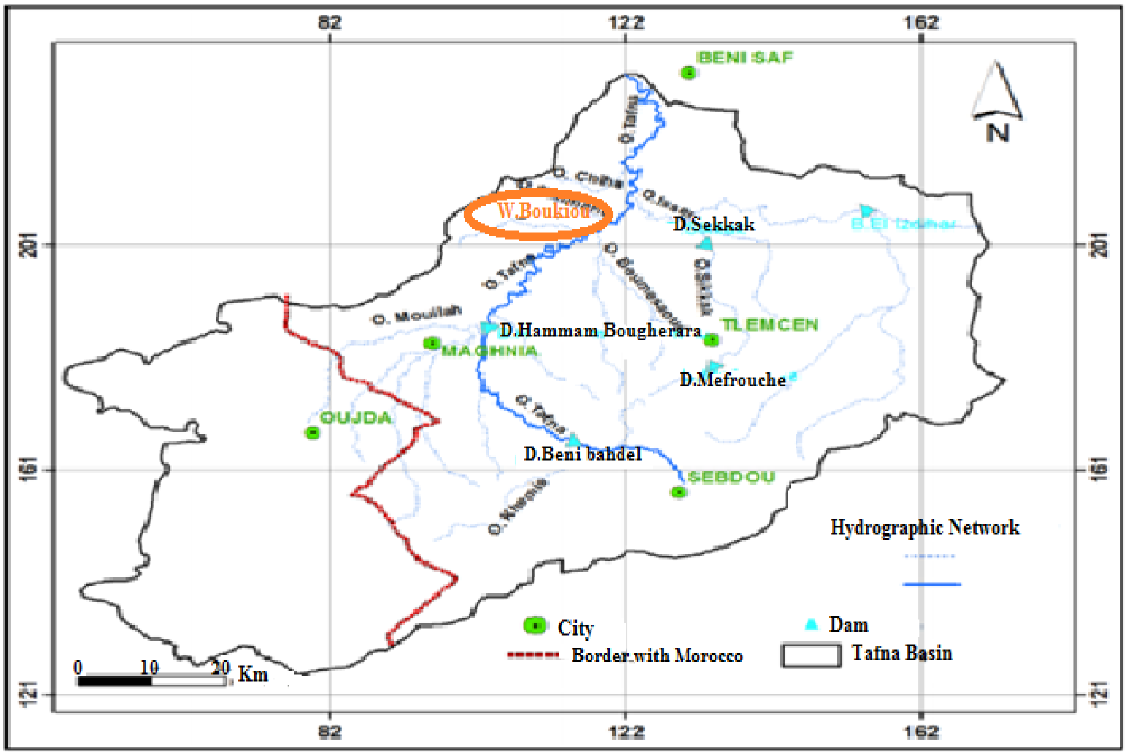


Figure 3-2: Hydrographic network of Tafna (Benmoussat, 2011)

(modified by Berrezoug,2020)

3.2.1- Geographical location of wadi Boukiou

The wadi Boukiou is a tributary of Tafna, it is located between 1° 29’41" and 1°43’ 32" of west longitude, and between 34° 59’ 52" and 35° 6’ 42" of North latitude. It has elongated shape and occupies an area of 117.3 km² within a perimeter of 58 km.

Boukiou basin is limited : (Figure 3-3)

- To the west by the mountains of Traras,
- In the North by the mountains of Djebel Dahr Eddis,
- To the South-West by the reliefs of the Djebel Filaoucène,
- In the Eastern part by the plain of Hennaya.

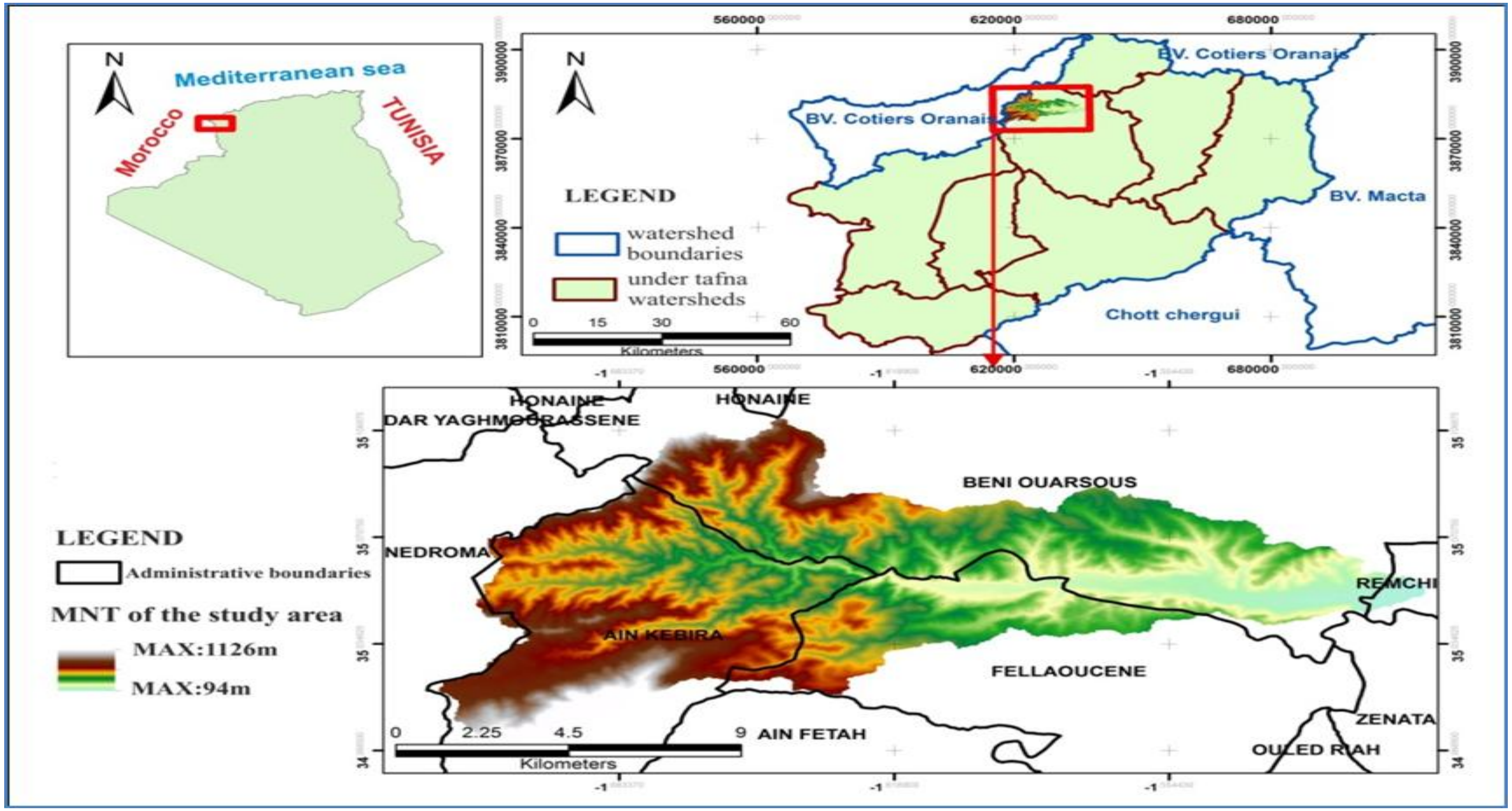


Figure 3-3: Geographical situation of study area (Zennaki & al, 2020)

3.3-Morphometric characteristic study

The purpose of using various types of morphometric parameters is to quantify the factors characteristic of the physical of a catchment.

The main morphometric parameters that affect the variation of the hydrological regime, which we will discuss in this section, are: the shape, the order of the streams, the relief and in particular, the density of drainage, the frequency of streams, the lengthening and the profile of streams.

3.3.1-Geometric Characteristics

3.3.1.1-Area

The area is the portion of the plane bounded by the ridge line, or contour of the basin, which can be determined by planing on suitable scale maps or using current digitization techniques.

The area of Boukiou watershed is 117.3 Km^2. (Berrezoug, 2016)

3.3.1.2-Perimeter

The perimeter is the length of the contour line of the basin, its measurement is made using a curvimeter or by software.

Boukiou watershed has a perimeter of 58 km. (Berrezoug, 2016)

3.3.2-Shape Characteristics

These are the purely geometrical characters of the basins that can be achieved by the competition of topographical surveys alone.

3.3.2.1-Gravelius Compactness index (K_c) (1914)

Gravelius Compactness index (K_c) provides information on the shape of the catchment area which has a great influence on the overall flow of the river and especially on the speed of the hydrogram at the outlet of the catchment area resulting from a given rainfall.

It is established by comparing the perimeter of the basin with that of a circle that would have the same surface. It is expressed by the following formula:

$$K_c = 0.28 \frac{P}{\sqrt{A}} \quad \text{(Equation 3-1)}$$

Where:

K_c : Gravelius Compactness Coefficient.

P: Perimeter of the watershed (Km) =58 km

A: Area of the watershed (Km^2) =117.3 km^2

This index determines the shape of the catchment. It is close to 1 for a basin of almost circular shape and when it is greater than 1, the basin is elongated.

For our basin K_{c} = 1.50, which expresses that the basin is therefore relatively elongated and compact, reflecting linear and regressive erosion.

Based on the value obtained from the compact coefficient of Kc ≥1.12, the basin can be represented by an equivalent rectangle.

3.3.2.2-Equivalent Rectangle

This concept was developed by Roche in 1963. It compares the influence of form on flow in different watersheds. The dimensions of the equivalent rectangle are determined by the following formulae.

$$P = 2\,(L+1) = \frac{Kc * \sqrt{A}}{0.28} \qquad \text{(Equation 3-2)}$$

With, **A =L *l**

L: Length of rectangle.

l: Width of rectangle.

- **Length "L":**

$$L = \frac{K_C\sqrt{A}}{1.12}\left[1+\sqrt{1-\left(\frac{1.12}{K_C}\right)^2}\right] \qquad \text{(Equation 3-3)}$$

L= 24.14 km

- **Width "l ":**

$$l = \frac{Kc\sqrt{A}}{1.12}\left[1-\sqrt{1-\left(\frac{1.12}{K_C}\right)^2}\right] \qquad \text{(Equation 3-4)}$$

l= 4.86 km

Table 3-1: Shape characteristic of Boukiou watershed

Basin	Area (km^2)	Perimeter (km)	Kc	Equivalent Rectangle	
				Length (km)	Width (km)
Boukiou Catchment	117.3	58 km	1.50	24.15	4.86

3.3.3-Relief characteristics

The relief has a significant impact on the different hydro-climatic parameters of a watershed. This is an essential factor in determining a large part of the runoff capacity and the infiltration of the land.

3.3.3.1-Hypsometry

The hypsometric curve is the surface curve in km^2 or as a percentage of the watershed where the altitudes are above a given 'h' rating.The relief of a basin is often characterized by the curve of its hypsometric distribution.

We have established the elevation-in-altitude distribution of the Boukiou watershed (Table 3-2), and the hypsometric curve (by postponing in y- axis the altitudes (m). and in the x-axis the percentages of cumulatives areas) (Figure 3-4), and the altimeter frequency histogram (Figure 3-5).

Table 3-2: Hypsometric repartition of the Boukiou watershed

Altitudes (m)	Areas (km^2)	partielles areas Ai (%)	Cumulated areas (Km^2)	Cumulated areas (%)
1338 – 1100	0.30	0.26	0.30	0.26
1100 – 1000	0.73	0.62	1.03	0.88
1000 – 900	0.58	0.49	1.60	1.37
900 – 800	1.05	0.90	2.65	2.27
800 – 700	2.38	2.02	5.03	4.29
700 – 600	6.23	5.31	11.25	9.60
600 – 500	15.65	13.34	26.90	22.94
500 – 400	20.33	17.33	47.23	40.27
400 – 300	24.45	20.84	71.68	61.11
300 – 200	33.48	28.54	105.13	89.65
200 – 100	12.15	10.36	117.30	100.00
Total	**117.30**	**100**		

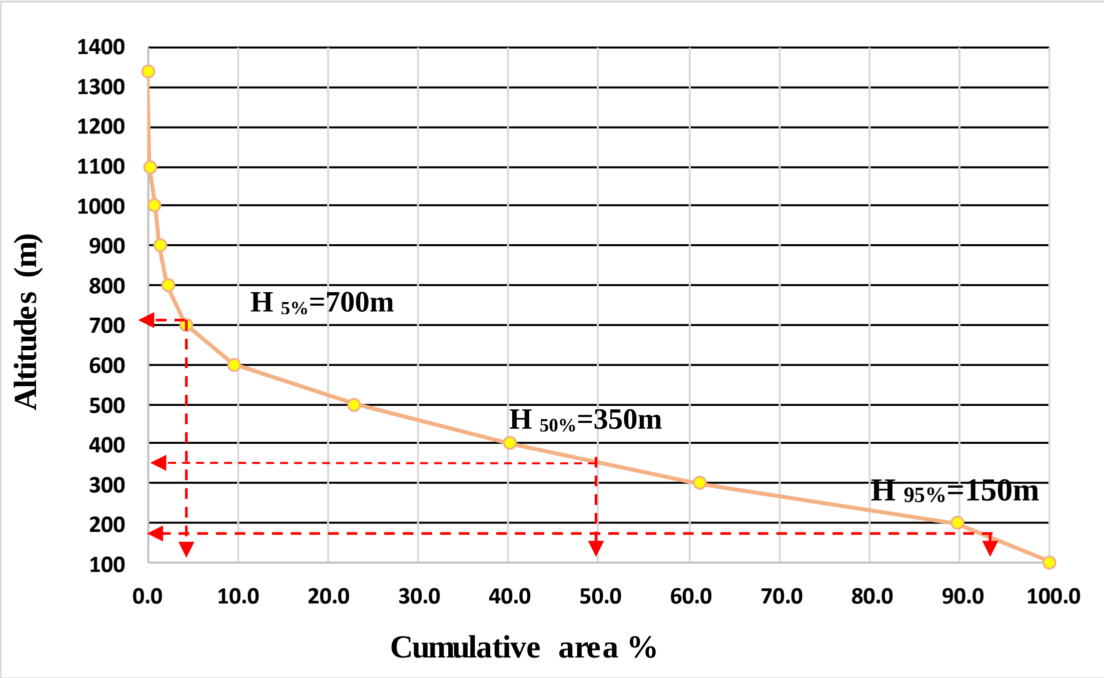


Figure 3-4: Hypsometric curve of Boukiou watershed.

The hypsometric curve seems quite regular (Figure 3-4). From 600m of altitude, there is a concavity towards the top reflecting recent erosion. It is observed that towards high altitudes the slope of the curve is quite strong which indicate the presence of a plateau, and at the level of the low altitudes (outlet), the low slope of the hypsometric curve indicates the presence of a deep valley.

The altimeter distribution of the areas of Boukiou basin is quite heterogeneous (Figure 3-5), we found that the most common altitude is between the intervals [200 – 300 m], it corresponds to the maximum of the diagram of altimetric frequencies which equal 28.54%.

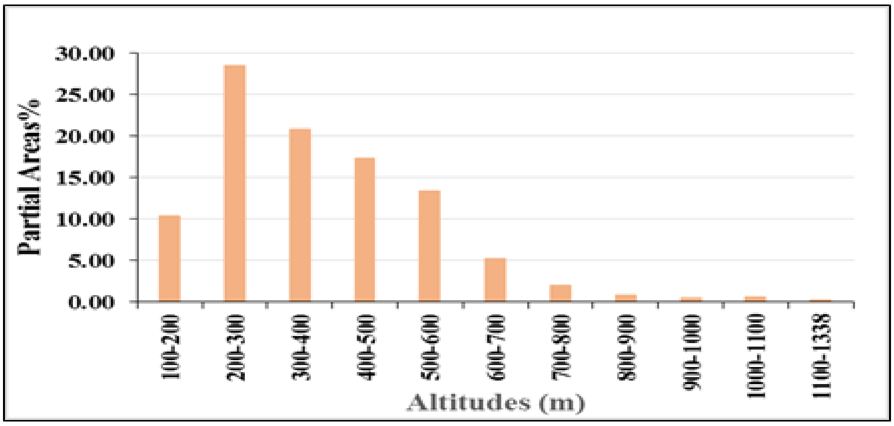


Figure 3-5: Histogram of altimetric frequencies of the Boukiou watershed

The characteristic altitudes determined from the hypsometric curve are given as follow and summarizing in the table 3-4:

- **Maximum altitude**

It corresponds to the top of the watershed.

H_{max}= 1338 m

- **Minimum altitude**

It corresponds to the lowest outlet point at the confluence point of the watershed.

H_{min}= 100 m

- **The median or frequency altitude ½.**

The median altitude corresponds to the altitude in the point of x-axis, we take the value corresponding to the 50% of the total surface of the basin, on the hypsometric curve. It is:

H_{median}= 350 m

- **The average altitude**

The altitude that corresponds to the average of the hypsometric curve. It is defined as followed using the Table 3-3

$$H_{average} = \sum(Ai * Hi) / A \qquad \text{(Equation 3-5)}$$

$H_{average}$= 382.74 m

Where:

H_{mean}: Average altitude of the basin (m),

Ai: Area between two levels curves (km^2),

Hi: Average altitude between two level curves (m),

A: Total watershed area (km^2).

Table 3-3: Calculation of the mean (average) altitude of Boukiou basin

Altitudes ranges (m)	Area ''Ai'' (km^2)	Hi (Average Altitude) (m)	Hi* Ai
1338-1100	0.3	1219	365.7
1100-1000	0.725	1050	761.25
1000-900	0.575	950	546.25
900-800	1.05	850	892.5
800-700	2.375	750	1781.25
700-600	6.225	650	4046.25
600-500	15.65	550	8607.5
500-400	20.325	450	9146.25
400-300	24.45	350	8557.5
300-200	33.475	250	8368.75
200-100	12.15	150	1822.5
Total	117.3		44895.7

Table 3-4: Characteristics Altitudes of Boukiou watershed

Basin	Maximum Altitude (m)	Minimum Altitude (m)	Mean Altitude (m)	Altitude 50 % (m)	Altitude 5% (m)	Altitude 95% (m)	Observation
Boukiou basin	1338	100	382.73	350	700	150	Old basin

3.3.4-Slope Indices

These indices are intended to describe the slopes of the basin and allow for comparisons and classifications.

3.3.4.1-Slope Index of ROCHE "Ip" (1963)

It characterizes the overall slope of the watershed. It is expressed by the following equation:

$$Ip= \frac{1}{\sqrt{L}} \sum_{n}^{1} \sqrt{ai \times di} \qquad \text{(Equation 3-6)}$$

Where:
L: Length of the equivalent rectangle (m)
a_i: Fraction in % of area "A" between two level curves, adjacent distance to "di".

Ip= 1.8 Km/m

3.3.4.2- The global slope Index "Ig"

This index is determined according to the hypsometric curve, which is already drawn; we take the points such that the upper or lower surface is equal to 5% of the total surface.

$$Ig = \frac{D}{L} = \frac{H\,5\% - H95\%}{L} \qquad \text{(Equation 3-7)}$$

Where:

L: Length of the equivalent rectangle (m)
D: Height difference is therefore equal to D = H5% - H95%: altitude expressed in m.
Ig: Global slope index of ROCHE.
Ig =0.0228=2.28%

3.3.4.3- Specific height difference "Ds"

$$Ds = Ig \times \sqrt{A} \qquad \text{(Equation 3-8)}$$

The specific height difference therefore appears as a correction of the simple height difference by the application of a coefficient that depends on the shape of the basin.

Ds = 247m

3.3.5- Classification of the Boukiou watershed

3.3.5.1- According to the relief

We are referred to the classification drawn up by O.R.S.T.O.M (Office for Scientific and Technical Research Overseas, 1943), to classify the basin according to its relief. (Table 3-5)

Table 3-5: Relief Classification according to Ig and Ds by l'O.R.S.T.O.M

Relief	Relief type	Values of Ig	Values of D_s
R1	Very low relief	$I_g < 0.002$	$D_s < 10$
R2	Low relief	$0.002 < I_g < 0.005$	$10 < D_s < 25$
R3	Fairly low relief	$0.005 < I_g < 0.01$	$10 < Ds < 50$
R4	Moderate relief	$0.01 < I_g < 0.02$	$50 < Ds < 100$
R5	Fairly strong relief	$0.02 < Ig < 0.05$	$100 < Ds < 250$
R6	Strong relief	$0.05 < I_g < 0.5$	$250 < Ds < 500$
R7	Very strong relief	$0.5 < I_g$	$Ds > 500$

- The "Ig'' value found $0.02 < Ig = 0.0228$ being less than 0.05 indicates that the Boukiou watershed has a fairly strong relief, according to the classification of the O.R.S.T.O.M. (Table 3-5)

- The high value of Ds (Table 3-5), reflects the importance of the mountain volume and the strong incision of the relief. The results are summarized in the table below:

Table 3-6: Slope indices values and types of relief of the Boukiou watershed.

Basin	Ip [km/m]	Ig	Relief according to « Ig »	Ds (m)	Relief according to « Ds »
Boukiou	1.8	0.0228	Fairly Strong	247	Fairly Strong

3.3.5.2- According to the area of the watershed

We can also classify the watershed according to its area as in the following table.

Table 3-7: Classification of the watersheds according to their area.

Very Small watershed	Small Watershed	Big watershed	Very big watershed
$0 < A \leq 10$ km²	**$10 < A \leq 200$ km²**	**$200 < A \leq 2000$ km²**	**$A > 2000$ km²**

3.3.6- Characteristics of the hydrographic network

It is defined by the set of natural streams in which water from runoff or from groundwater flows either as a source or by continuous restoration along the river. (Roche 1963).

3.3.6.1- Network Hierarchy

To present the hydrographic network of the region, we based on the classification of the thalwegs (rivers) and tributaries, for each order we determine the number and the total length of thalwegs. In our topological classification of the hydrographic network, we will follow the Horton rules as modified by Schumm. Actually, it is the most useful method, its principle is as follows:

- Any stream without a tributary is said to be of order 1,
- At the confluence of two rivers of the same order n, the resulting stream is of order (n+1),
- A stream receiving a tributary of lower order keeps its order.

Table 3-8: Characteristics of the hydrographic network of the Boukiou waterched (Kacemi & Senina, 2015)

Order	Number of Stream	Confluence ratio	Cumulatives length (km)	Average Length (km)	Length Ratio
1	1063	4.74	157	0.14	3.21
2	224	5.46	101	0.45	2.44
3	41	4.55	45.1	1.1	1.99
4	9	4.5	19.75	2.19	2.51
5	2	2	11	5.5	2.72
6	1	-	15	15	-

According to the classification of Schumm, the analyses of the table 3-8 show that our basin is of order 6.

The most important parameters that characterized the hydrological regime of a stream are: drainage density (Dd), confluence ratio (Rc) and the length ratio (Rl).

3.3.6.1.1- Confluence ratio (Rc)

3.3.6.1.1.1- Analytical method

It is defined by the ratio of the number of order ‘n’ thalwegs by that of order (n+1):

$$Rc = N_n / N_{n+1} \qquad \text{(Equation 3-9)}$$

Where:

N_n: the number of streams or rivers with (n) order.

N_{n+1}: the number of streams or rivers with (n+1) order.

Table 3-9: Calculation of the confluence ratio of Boukiou basin using analytical method.

Order	1/2	2/3	¾	4/5	5/6	Average
Confluence ratio	4.74	5.46	4.55	4.5	2	**4.25**

3.3.6.1.1.2- Graphical method

The Points carried over to the semi-logarithmic diagram are aligned along a straight line (Figure 3-6).The average confluence ratio is equal to the slope of the adjusted right to all points**.**

Figure 3-6: Graphical representation of the confluence ratio

The average confluence ratio is represented by: $Rc = \log^{-1} a$

With the slope of the right is given as: $\mathbf{a}= \frac{\log 1063 - \log 224}{2-1} = 0.68$

Therefore: $Rc = 4.79 < 5$

The figure 3-7 shows that the network is well organized, the numbers of streams of successive increasing order form a reverse geometric series. The average confluence ratio is inferior of 5 which means that the network is Oak-type.

3.3.6.1.2- Length Ratio (R_L)

3.3.6.1.2.1- Analytical Method

It is defined as the ratio between the average lengths of (n+1) order thalwegs according of (n) order thalwegs.

$R_L = L_{n+1} / L_n$ (Equation 3-10)

Where:

L_n : Average length of (n) order thalwegs.
L_{n+1}: Average length of (n+1) order thalwegs.

Table 3-10: Calculation of the length ratio of Boukiou basin using analytical method.

Order	1	2	3	4	5	Average
Length ratio	3.21	2.44	1.99	2.51	2.72	**2.574**

3.3.6.1.2.2- Graphical Method

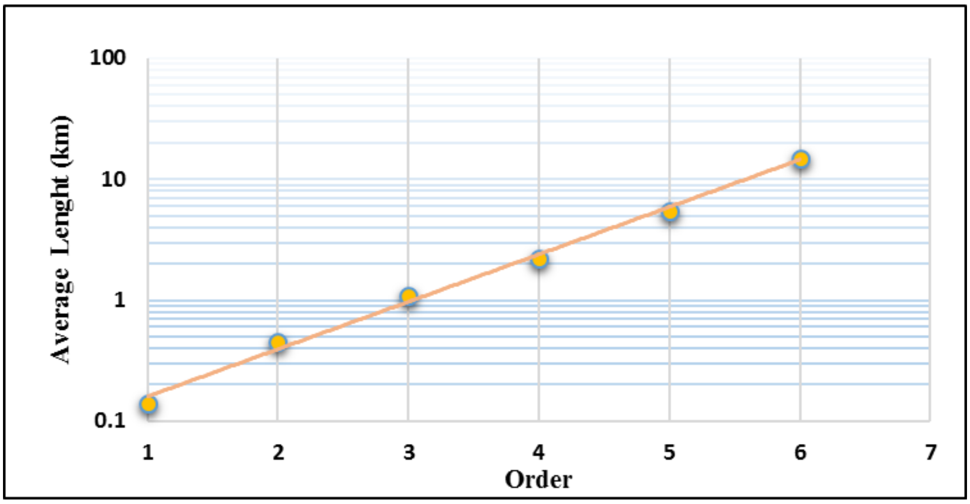


Figure 3-7: Graphical representation of the lengths ratio.

According to the figure 3-7, the average length ratio is represented by: $R_L = \log^{-1} a$

a= the slope of the right = $\frac{log15 - log0.14}{6-1}$ = 0.40

Therefore: R_L= 2.57

The figure 3-7 shows that the network is well organized, the average lengths of the thalwegs of successive increasing order form a direct geometric series.

3.3.6.2- Drainage density

In 1945, Horton introduced the drainage density as total length of the hydrographic network per watershed unit. It is defined by the following equation:

$D_d = \sum_1^n L / A$ (Equation 3-11)

Where:

A: Watershed area in (km^2)
L: Cumulative length of streams (Km)
D_d: Drainage density (Km^{-1})
Therefore: D_d = 2.97 km^{-1}

3.3.6.3- Frequency of streams

It represents the number of streams (N) per unit area (A), It is calculated by the following formula:

$$F = Ni / A \qquad \text{(Equation 3-12)}$$

Where:

N: Number of streams,

A: Watershed area (km^2),

We obtained F= 11.42, which corresponds to the average number of streams (rivers) per km^2.

3.3.6.4- Torrentially Coefficient

This coefficient takes into account both the density of elementary thalwegs by drainage density:

$$C_T = D_d * F_1 \qquad \text{(Equation 3-13)}$$

Where:

D_d : Drainage density (Km/Km^2),
F_1: Frequency of elementary streams, $F_1 = N_1 / A$ with (N_1 is the number of stream order 1= 1063)
Therefore: C_T=26.95

The high value of the torrential coefficient corresponds to the hydrographic system coming from a mountainous and rainy area. (Bouanani, 2004)

3.3.6.5- Concentration Time

This is the time that takes a particle of water from the furthest part of the basin to reach the outlet, for its calculation, we use Giandotti's formula:

$$T_c = \frac{4\sqrt{A} + 1.5\,L}{0.8 * \sqrt{(H\,average - Hmin)}} \qquad \text{(Equation 3-14)}$$

Where:
Tc: Concentration time (Hours).
A: Watershed area km^2.
L: Principal length of stream (km).
$H_{average}$: Average altitude (m).
H_{min}: Minimum altitude (m).
Therefore: T_c= 06 hours

The concentration time of water depends not only on the surface but also on other parameters such as lithology, rainfall and terrain. (Bouanani, 2004)

3.3.6.6- Long profile of the wadi Boukiou

The profile along the principal streams of the catchment area (Figure 3-8) does not provide complementary elements to those provided by the study of drainage density, except at the western end where, we note a relatively steep slope, but it is not explanatory in relation to the resulting slopes. The slope changes are due to those of lithology.

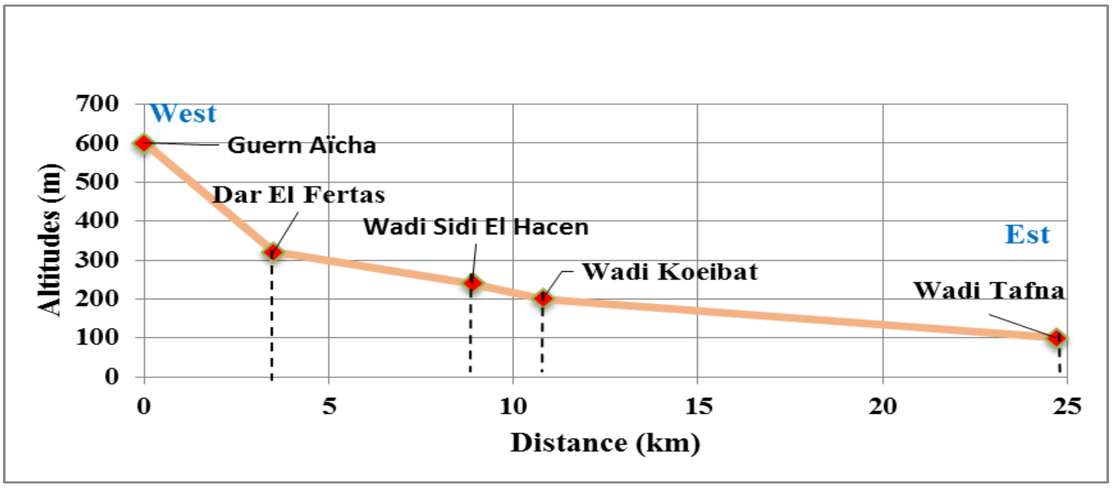


Figure 3-8: Long profile of the wadi Boukiou.

3.3.6.7- Cross profile of the wadi Boukiou

The cross profile (Figure 3-9) to the south, shows steep slopes due to the overlap of the Filloussène mountain on the shale massifs. It should be noted that the southern and northern beaches are the main drift due to their steep slopes.

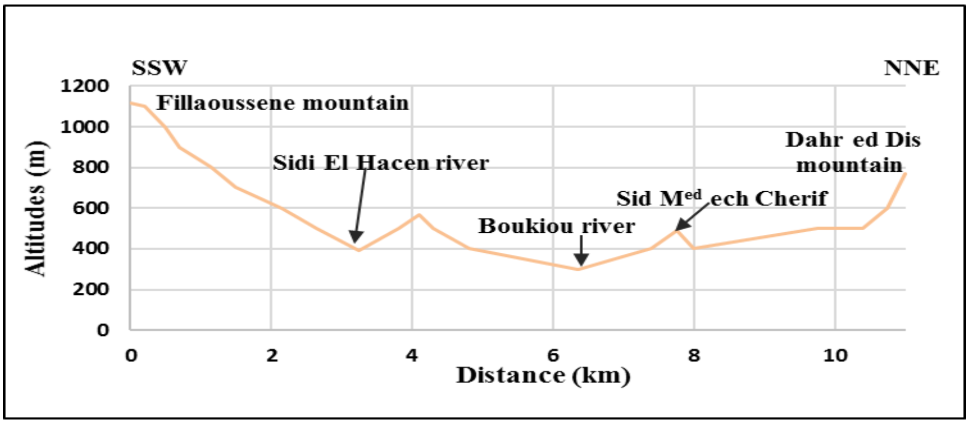


Figure 3-9: Cross profile of the wadi Boukiou.

3.4-Land cover

Vegetation is a determining factor in the speed of surface runoff, of evaporation rate and retention capacity of the basin. Therefore, the presence of vegetation has a role of «Regulator» in the flow regime. Land cover has a direct influence on river flow as well as orographic and climatic factors. Indeed, when vegetation is developed, the runoff is delayed and the peak of flood is mitigated, the flow being longer, and the share of water taken up by the evapotranspiration increases and the volume of the flood decreases. The forest for example, intercepts a part of the downpour by its frond. On the other hand, bare soil with low retention capacity promotes very rapid runoff. This influence of the forest on the water regime in the Mediterranean area has a considerable role. (Bouanani, 2004)

The vegetation in the Tafna Basin has been extensively degraded and cleared in the mountains by fire and by small extensive agriculture, resulting in water loss through evaporation and accelerated erosion.

Regarding the types of land use, the most representative of Boukiou watershed are scrub and brush, cereals and rangeland, forest (Bouanani, 2004). In addition, our watershed is occupied upstream in its central part by scrub, and some vineyards and cereal cultivation with little arboriculture. Downstream, the Traras Mountains are covered with forests with a proportion of annual rangelands and crops.

Land use in our basin is shown in figure 3-10, based on the analysis of the percentages of the values of the types of occupations; we note that our basin is experiencing acceptable agricultural activity.

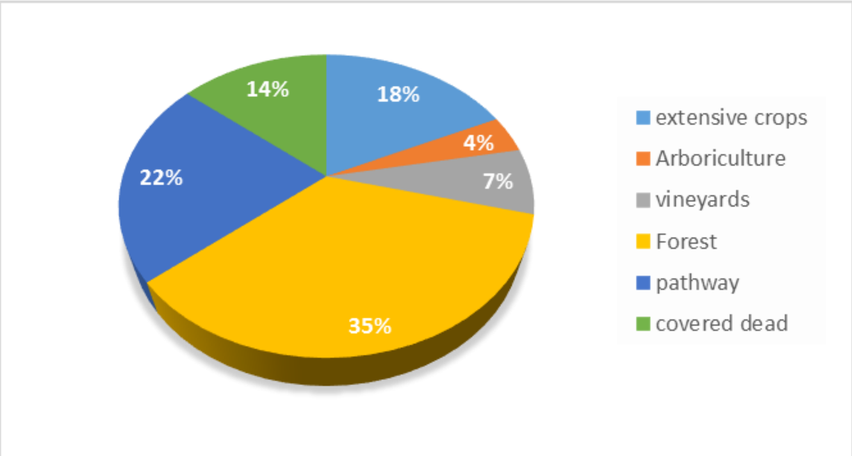


Figure 3-10: Distribution of land cover of Boukiou watershed
Source: Tlemcen Agricultural Services Departement (2012/2013)

3.5- Geological and Hydrogeological overview of the study area

3.5.1- Geological study

The wadi Boukiou watershed has an inflexible substrate of ancient Fellaoussene mountain rocks to the west, growing to 1138m, (Figure 3-11) that is characterized by very compact shales quartzic formations of the Devonian. The center includes clay, and marls greater or much less dolomitic and gypsum from the Triassic and middle Jurassic durations. Further, in the East there are formations of the lower and center Miocene with an alternation of pudding stones fashioned by dolomitic limestone elements with limestone-sandstone cement and collection of Marl Clay, in that are interspersed decimal banks of friable ferruginous sandstone (Bouanani 2004).

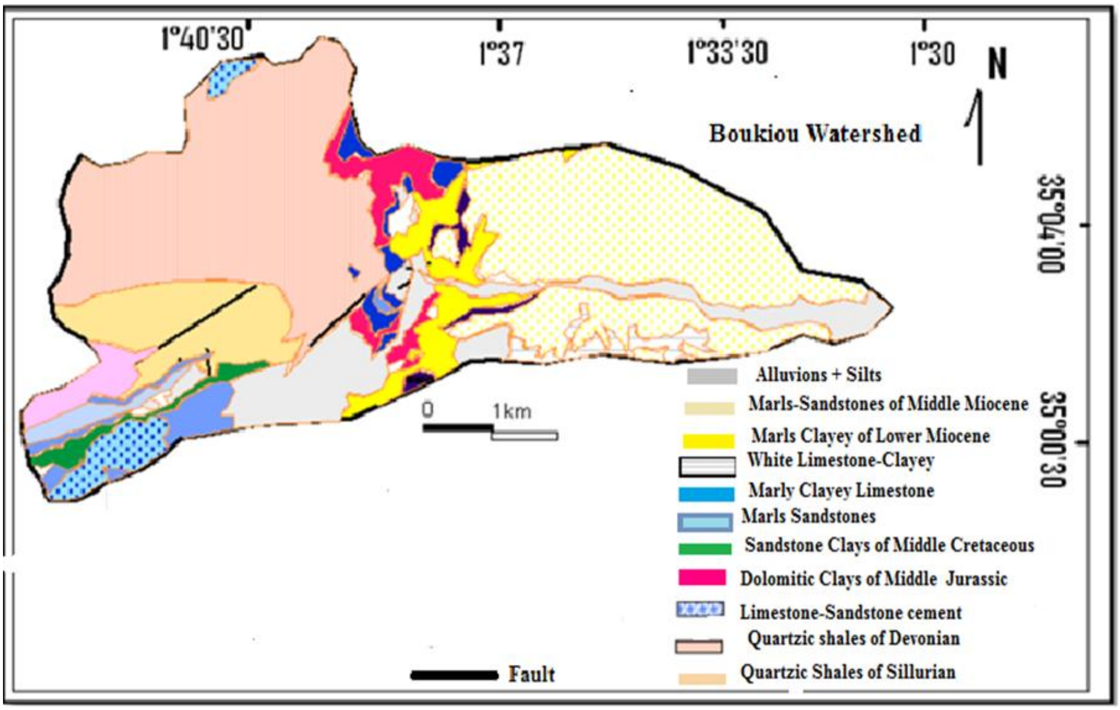


Figure 3-11: Geological map of Boukiou watershed (Bouguerra, 2018 *)*

3.5.2- Lithostratigraphic study

The vertical evolution of the terrains encountered extends from the Primary to the Quaternary and presents three distinct huge lithostratigraphic series which are from bottom to top:

3.5.2.1- Primary substratum (Infrasilurian to Devonian)

Represented by:

- The quartzic shales formation from Infrasilurian (Guardia, 1975).

- The granite massif of Nedroma outcropping to the North.
- The granite intrusion forming a metamorphic aureole.

3.5.2.2- Secondary cover (Permo -Trias to Basal Cretaceous)

It is very thick, affected by a flexible and brittle tectonics very complex, the base of the secondary series is represented by using a detritic sedimentation (volcano-sedimentary complex) and a carbonate formation of the medium Lias. (Benhamou,1983)

3.5.2.3- Miocene depression

In the East, where we see the establishment of powerful Mio-Plio-Quaternary series, as it is shown in the (Figure 3-12)

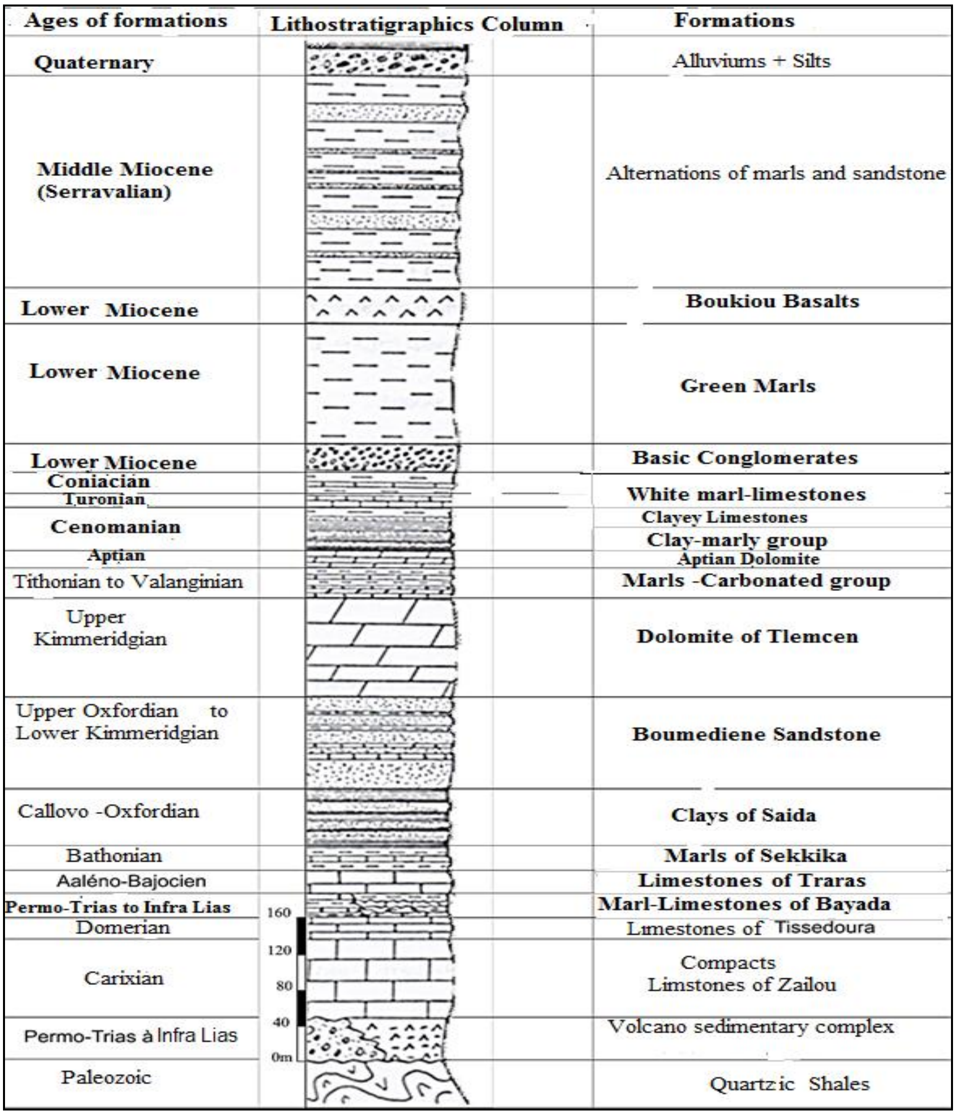


Figure 3-12: Synthetic log of the study area.
(Kebir & Miri, 1992) modified by Berrezoug, 2020)

3.5.2- Hydrogeological study

The substratum formed by the primary and secondary formations is covered with Miocene and quaternary sediments. The deep structures due to vertical movements are masked by Miocene formations affected by flexible deformations.

We distinguish among the groundwater resources of our study area:

- Hypothetical confined aquifer,
- Unconfined aquifer.

The permeable alluvial formation covers the entire bottom of the valley wadi Boukiou (Figure 3-13).

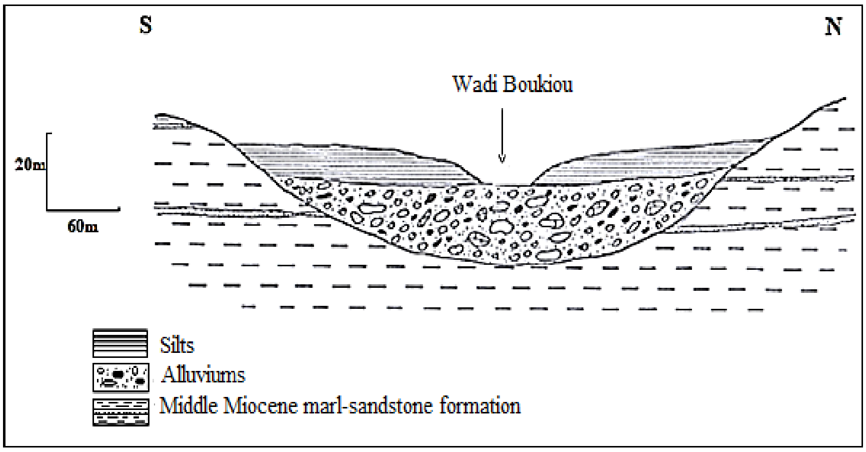


Figure 3-13: Cross section of the alluvial plain of Boukiou watershed (Miri & Kibir. 1992)

3.6- Hydroclimatic Context

The Climate is defined by the whole meteorological phenomena (winds, evapotranspiration, precipitations and temperatures) that vary from one place to another on the earth's surface. Their study is more necessary to be able to understand and analyze the hydrological behavior of streams, and to establish the water balance of watersheds.

The study of the hydrometric series conducted over a fairly long period of time thus makes it possible to assess the response of rivers to climate variations. Nowadays, we will examine the evolution of precipitations and runoffs over the last few decades in Boukiou wadi watershed.

3.6.1- Presentation of the measuring station

The data used consist of rainfall and hydrometric measurements at the "Djebel Chouachi" station (table 3-11 and figure 3-14) over a common measurement period of 44 years (1974/1975-2017/2018). These data were collected from the National Agency of Hydraulic Resources (A.N.R.H).

Table 3-11: Characteristics of the measurement stations.

Stations	Code	Coordinats			Observation Period	measured parameters
		longitude	Latitude	Altitude(m)		
Djebel Chouachi	160518	01°31'W	35°14' N	130	1974/1975-2017/2018	P, Q
Zenata	605310	01°46'W	35°01'N	247	1974/75-2017/18	T

Source: A.N.R.H

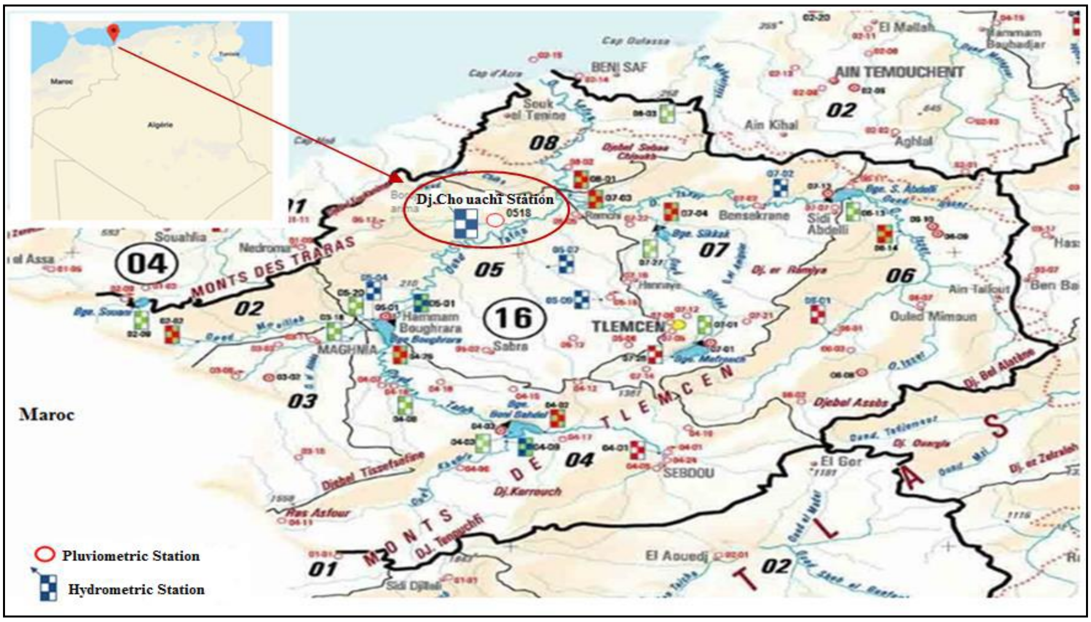


Figure 3-14: Situation of Djebel Chouachi hydroclimatic Station.

3.6.2- Rainfall Study

Réméniéras G., (1986) defined precipitations as a height of the water slide collected by the rain gauge, whatever the origin of this water, rain, snow, hail, or other forms of condensation. In this study, we will focus on precipitations, which is the primary factor in the hydrological behaviour of the region. It varies in the time and space.

3.6.2.1- Inter-annual variation of rainfall

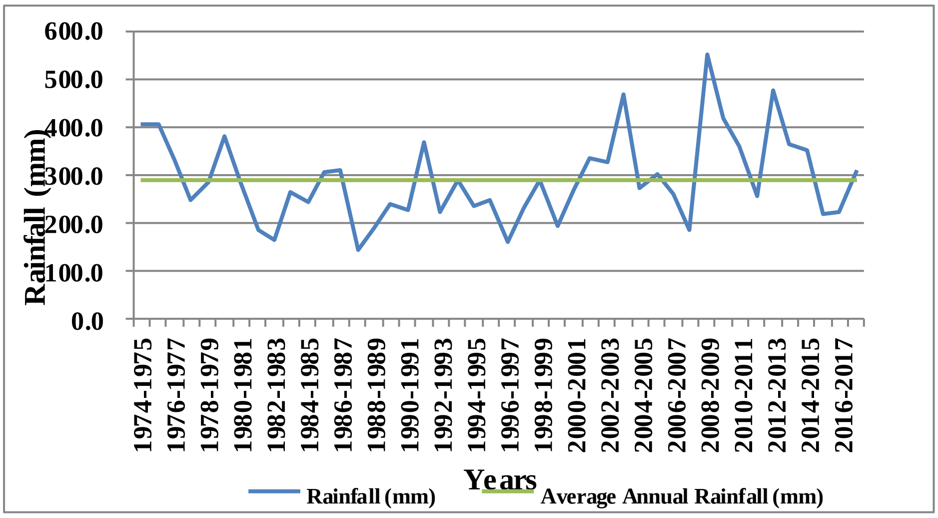


Figure 3-15: Interannual variation of precipitation at Djebel Chouachi station (1974/1975-2017/2018).

The variation of the annual precipitation of Boukiou wadi is represented in the above graphic during the period 1974/1975 until 2017/2018. The maximum precipitation recorded during the year (2008-2009) reaches 551.2 mm; this characterizes a relatively wet period. While the minimum of 143.2 mm was recorded in (1987-1988) that characterizes a relatively dry period. The interannual average observed at the station is 290.5 mm.

The coefficient of irregularity expressed by the ratio of maximum (P_{max}) and minimum (P_{min}) precipitations. It highlights the irregularity of the annual regime from one year to another, which means that the regime of Mediterranean type is very irregular as in our study area.

The Coefficient of irregularity = $\mathbf{C_{ir}} = \frac{P\ max}{P\ min}$ (Equation (3-15)

Where:

C_{ir}: Coefficient of irregularity
P_{Max}: Maximum Precipitations = 551.2 (mm)
P_{Min}: Minimum Precipitations = 143.4 (mm)
C_{ir} = 3.8

3.6.2.2- Variation in monthly rainfall

The distribution of the monthly rainfall data recorded at the Djebel Chouachi station during the period (1974/1975-2017/2018) is represented in the following table**:**

Table 3-12: Monthly average precipitation values (1974/1975-2017/2018).

Months	S	O	N	D	J	F	M	A	M	J	Jl	A
P (mm)	10.2	21.2	45.5	32.0	38.5	47.2	37.2	27.5	23.1	3.7	0.9	3.6

The analysis in the figure 3-16 shows the distribution of monthly average precipitations over the period studied. The minimum of precipitations is observed in "July" with 0.9mm, which indicates the driest month, and the maximum in February with 47.2 mm that designate the wettest month.

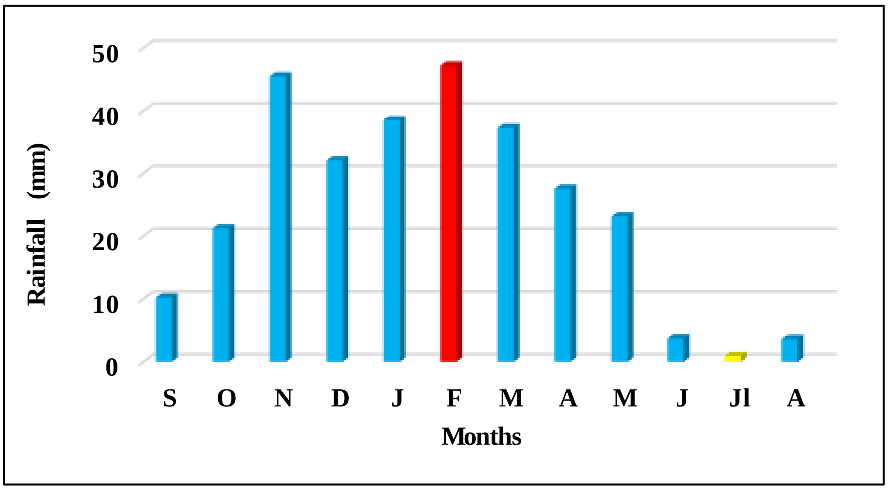


Figure 3-16: Variation in monthly average precipitations (1974/1975-2017/2018).

3.6.2.3- Variation of seasonal rainfall

The study of seasonal variability is more important (Table 3-13) to see if the decrease or increase in rainfall is specific to a particular season or to several seasons.

Table 3-13: Distribution of seasonal rainfall of study area.

Seasons	Autumn			Winter			Spring			Summer		
Months	S	O	N	D	J	F	M	A	M	J	Jl	A
P (mm)	10.2	21.2	45.5	32	38.5	47.2	37.2	27.5	23.1	3.7	0.9	3.6
Average (mm)	76.9			117.7			87.8			8.2		

According to the analysis of the distribution of seasonal rainfall of our study area shows in the below graphic, winter is the wettest season (December, January and February), when most of the runoff occurs. However, the driest season corresponds to summer (June, July and August).

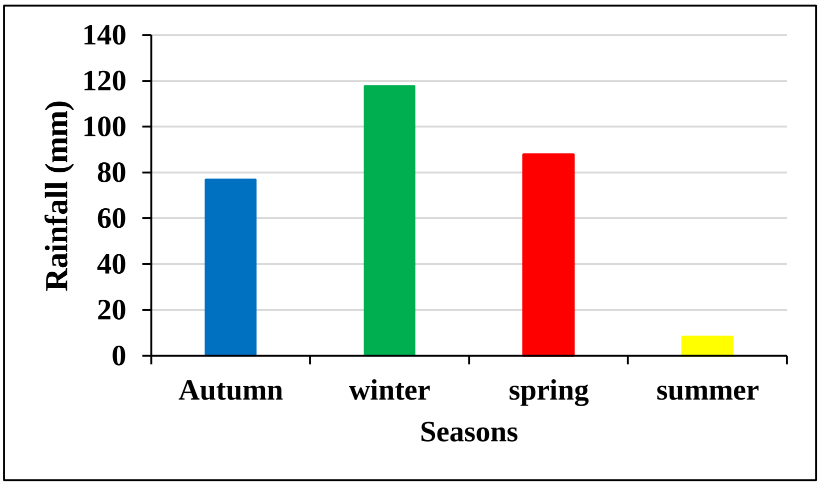


Figure 3-17: seasonal variation of rainfall (1974/1975-2017/2018).

3.6.2.4- Daily variation of rainfall

The Figure 3-18 shows the distribution of mean daily rainfall of Dj Chouachi station in the period (1974/1975-2017/2018). We notice that the increases followed by continuous and progressive decreases from one day to the next with rainfall peaks representing very important values in the series. The maximum value 125 mm is recorded on 08 February 2009, it corresponds to the wettest year of the series (2008/2009).

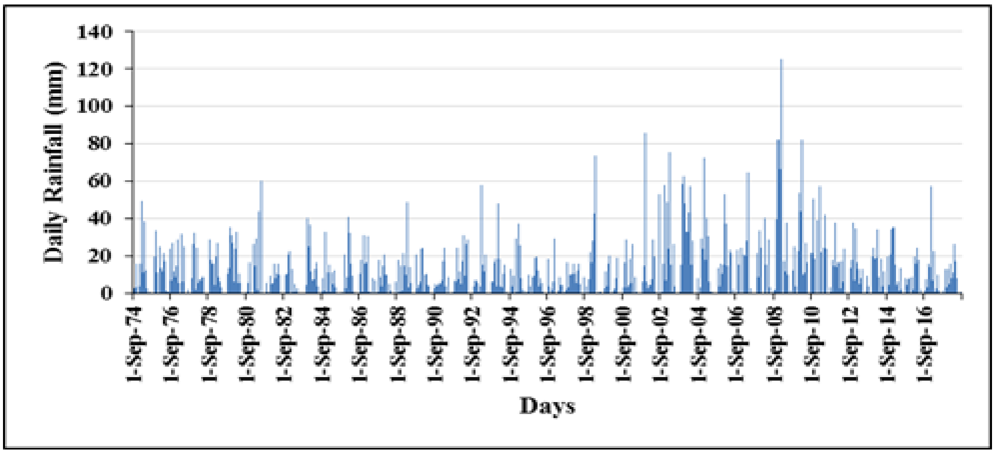


Figure 3-18: Distribution of mean daily rainfall in the period (1974/1975-2017/2018)

3.6.3- Temperature Study

Temperature is an important factor for determining climate. It allows with the precipitations the calculation of runoff deficit and climate indices.

For the realization of this study, we have available the measurements carried out on the Zenata station during the period 1974/1975-2017/2018 (Table 3-11). This, in the absence of measurement at Djebel Chouachi station.

3.6.3.1- Annual Average Temperatures

The annual mean temperatures shown in table below and figure 3-19 are irregular and tend to increase from one year to the next, with an interannual mean temperature of 18°C.

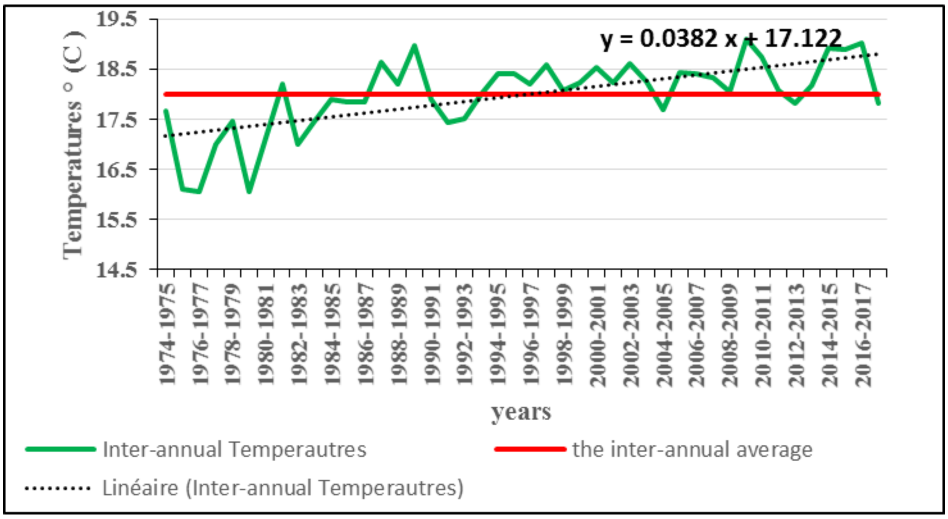


Figure 3-19: Variation in average annual temperatures at Zenata station (1974/1975-2017/2018).

Table 3-14: Result of average annual temperatures (1974/1975-2017/2018).

Average annual (t°c)	Years	Average annual (t°c)	Years
17.7	1974-1975	18.2	1996-1997
16.1	1975-1976	18.6	1997-1998
16.1	1976-1977	18.1	1998-1999
17.0	1977-1978	18.2	1999-2000
17.5	1978-1979	18.5	2000-2001
16.0	1979-1980	18.2	2001-2002
17.1	1980-1981	18.6	2002-2003
18.2	1981-1982	18.2	2003-2004
17.0	1982-1983	17.7	2004-2005
17.4	1983-1984	18.4	2005-2006
17.9	1984-1985	18.4	2006-2007
17.8	1985-1986	18.3	2007-2008
17.8	1986-1987	18.0	2008-2009
18.6	1987-1988	19.1	2009-2010
18.2	1988-1989	18.7	2010-2011
19.0	1989-1990	18.1	2011-2012
17.9	1990-1991	17.8	2012-2013
17.4	1991-1992	18.2	2013-2014
17.5	1992-1993	18.9	2014-2015
18.0	1993-1994	18.9	2015-2016
18.4	1994-1995	19.0	2016-2017
18.4	1995-1996	17.8	2017-2018

3.6.3.2- Average Monthly Temperatures

The variations in average monthly temperatures at the Zenata station (Figure 3-20) and the table below, show that the coldest month is January with ≈ 11°C, and the warmest month is August with 26.3°C.

Table 3-15: The average monthly temperatures at Zenata station (1974/75-2017/18).

Months	S	O	N	D	J	F	M	A	M	J	Jl	A
T (average)	23.6	19.8	15.1	12.2	10.8	11.8	13.6	15.6	18.5	22.5	25.9	26.3
T (MAX)	27.3	22.3	17.9	16.1	14.1	14.5	16.1	18.0	21.1	25.2	28.6	28.9
T(MIN)	20.5	16.2	11.3	9.9	8.1	8.7	10.4	12.0	15.7	18.8	23.0	17.5

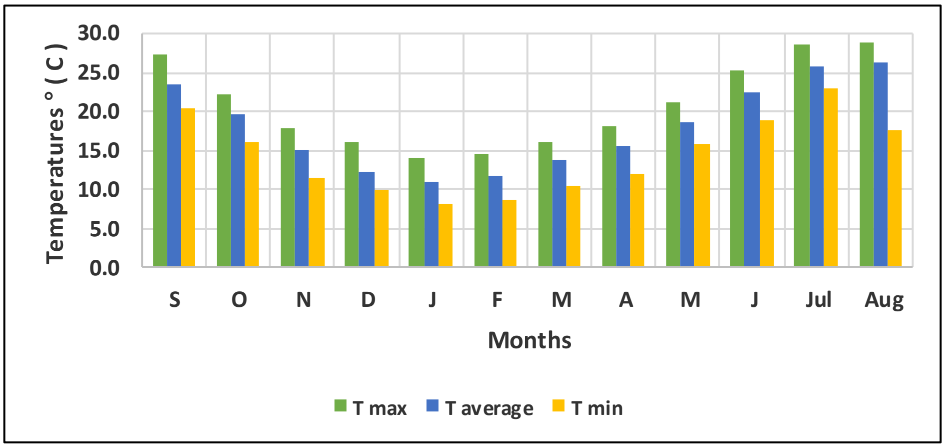


Figure 3-20: Variation in monthly average temperatures at Zenata station (1974/1975-2017/2018).

3.6.4- Climate Study

The climate study and climate indices will be based on monthly average temperature and precipitation data during the period (1974/1975-2017/2018).

Table 3-16: Monthly Average Precipitations and Temperatures (1974/1975-2017/2018)

Months	S	O	N	D	J	F	M	A	M	J	Jl	A
P (mm)	10.2	21.2	45.5	32	38.5	47.2	37.2	27.5	23.1	3.7	0.9	3.6
T(°C)	23.6	19.8	15.1	12.2	10.8	11.8	13.6	15.6	18.5	22.5	25.9	26.3

3.6.4.1- Graphic Method (Gaussen and Bagnouls method, 1952)

This method is a graphical representation where two curves are drawn, one of the precipitation and the second of the average monthly temperatures with two different arithmetic scales of which (P ≥ 2T).

According to Gaussen and Bagnouls, a wet month is one in which the average total rainfall is more than twice the average temperature (P >2T), in the opposite case the month is considered dry.

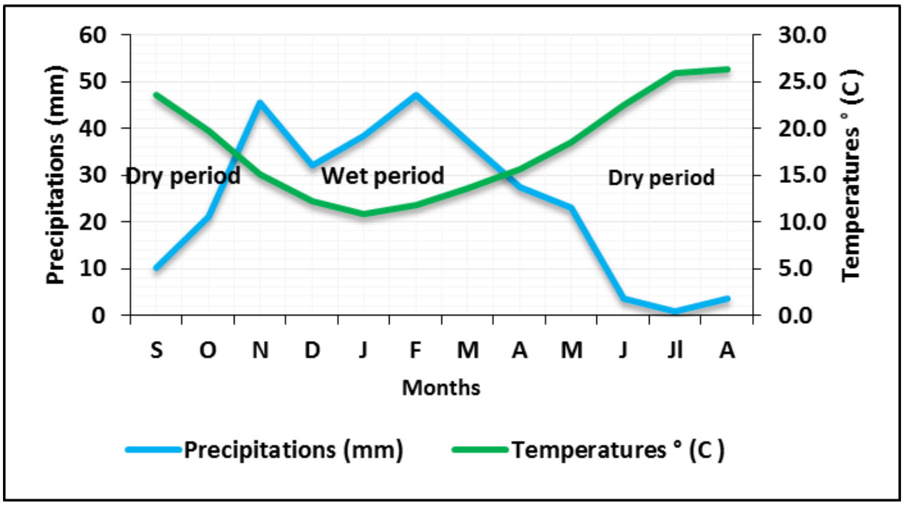


Figure 3-21: Rain-thermal curve of Gaussen and Bagnouls at Djebel Chouachi station (1974/1975-2017/2018)

The rain-thermal curve at Djebel Chouachi station (Figure 3-21) allows to visualizing the alternation of two seasons:

- A wet season, from November to mid of April.
- A dry season, covering the rest of the months of the year.

3.6.4.2- Climatic indices

In this part, we use the annual aridity index which is a function of temperatures and precipitations, it allows us to find the type of climate that characterizes our watershed, and is calculated by the following formula:

$$I = \frac{P}{10+T} \qquad \text{(Equation 3-16)}$$

Where:
P: Annual average rainfall.
T: Annual average temperatures.
I= Aridity index = $\frac{290.5}{10+18}$ = 10.375

We obtained an annual aridity index for the Djebel Chouachi station, I=10.375. This value reported on the Demartone chart indicates a semi-arid climatic regime with a temporary runoff. (Figure 3-22)

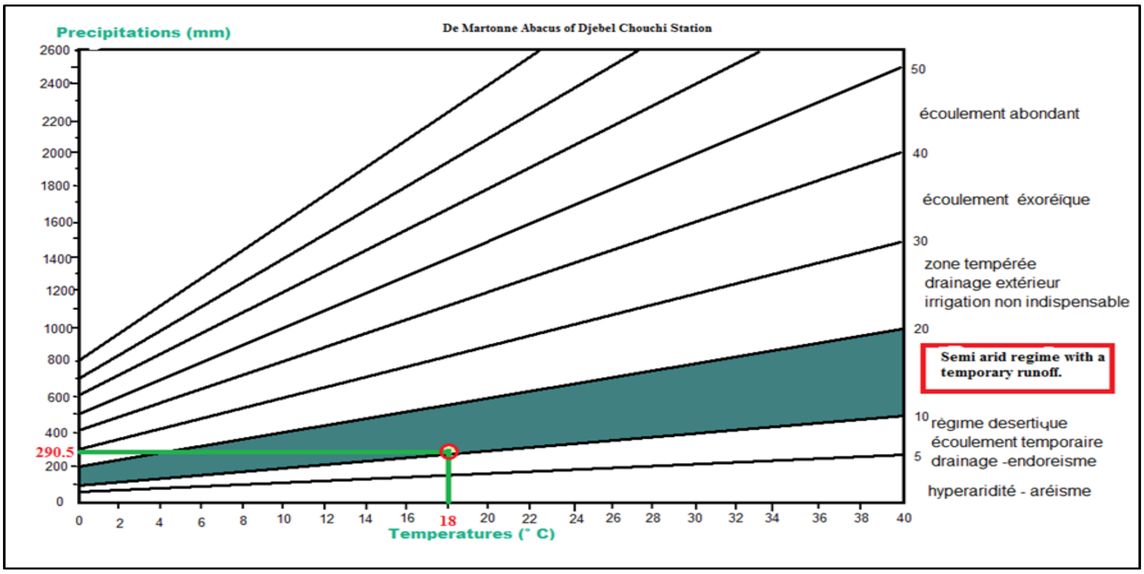


Figure 3-22 : De Martonne abacus of Djebel Chouachi Station.

3.6.5- Study of flow rate

The flow rate is a value of a flow expressed in mm. It is obtained by dividing the volume of water flowing at a measuring station by the surface of the catchment area at that station. It is very commonly expressed in (mm), which allows comparison with the rainfall that caused it.

3.6.5.1- Variation of interannual flow rate

The interannual variations of the flow recorded at the Djebel Chouachi station during the period 1972/73-2013/14 shows a progressive decrease with an interannual modulus of 32.3 mm. We observe the maximum annual values in 1972/1973 with 217.9 mm, and in 1973/1974 with 102.4 mm in 1976/1977 with 166.1 mm, while the minimum module recorded in 1981/1982 and 2007/2008 with a module of 0.35 mm.

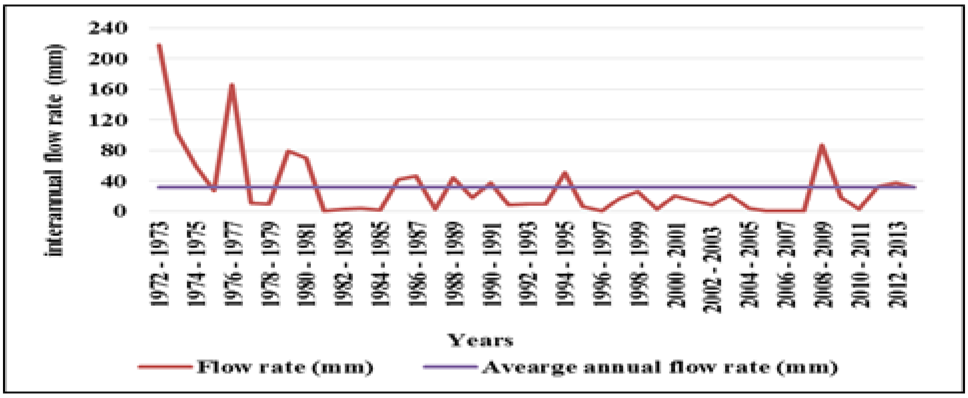


Figure 3-23: Variation of interannual flow rate at Djebel Chouachi station (1972/1973-2013/2014)

3.6.5.2-Monthly variation of flow rate

The evolution of the monthly flow rate (Figure 3-24) shows a minimum in August with 0.1 mm and evolves towards higher values, reaching its maximum in March with 9.7 mm.

The hydrological regime of our basin is characterized by two periods: a wet period from November to May, and a low water period from June to October. The period of October and November is devoted to the reconstitution of the reserves.

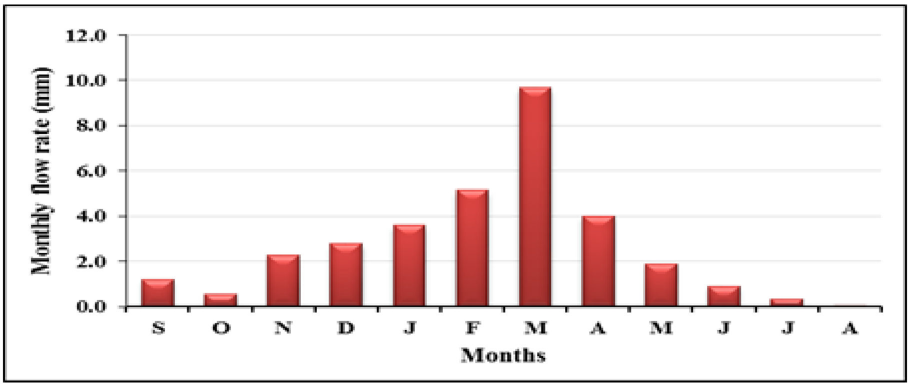


Figure 3-24: Monthly variation of flow rate at Djebel Chouachi station (1972/1973-2013/2014)

The comparison between monthly flow rate and rainfall (Figure 3-25) shows us the existence of a lag between the maximum flow rate and rainfall. This time lag during a hydrological cycle gives us information on the water storage capacity of the soil at the catchment level. If the time lag is small, it implies that we have a low storage capacity and that the role of groundwater is negligible. On the other hand in our case, the time lag is important, it is about two months (between November and December), we can assume that we have a hydrological functioning by contributing saturated surfaces and the role played by the water table can be important. During this period (from November to December), the rain is rather used to recharge the underlying reservoir.

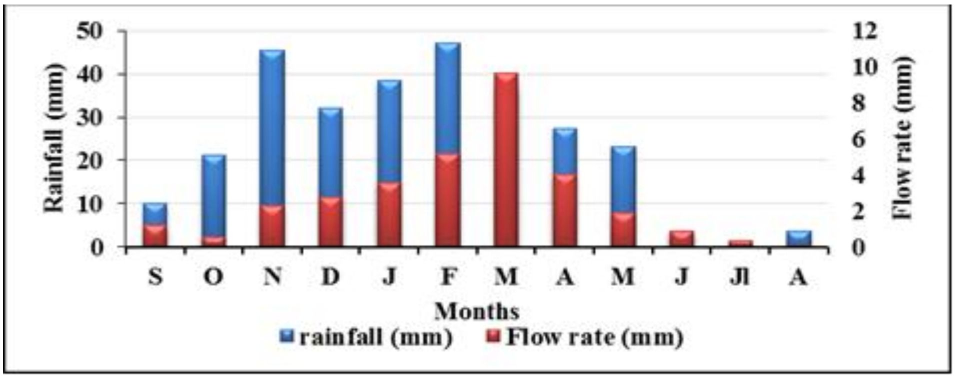


Figure 3-25: Monthly variation between flow rate and rainfall (1974/1975-2013/2014)

While, the yearly variation between flow rate and rainfall during the series (1974/1975-2013/2014) represented in the figure 3-26 show that the maximum rainfall occurred during the year 2008/2009 reaches 551.2 mm and the maximum flow rate observed during 1976/1977 reaches 166 mm. However the minimum rainfall and flow rate recorded during 1987/1988, 1980/1981 respectively.

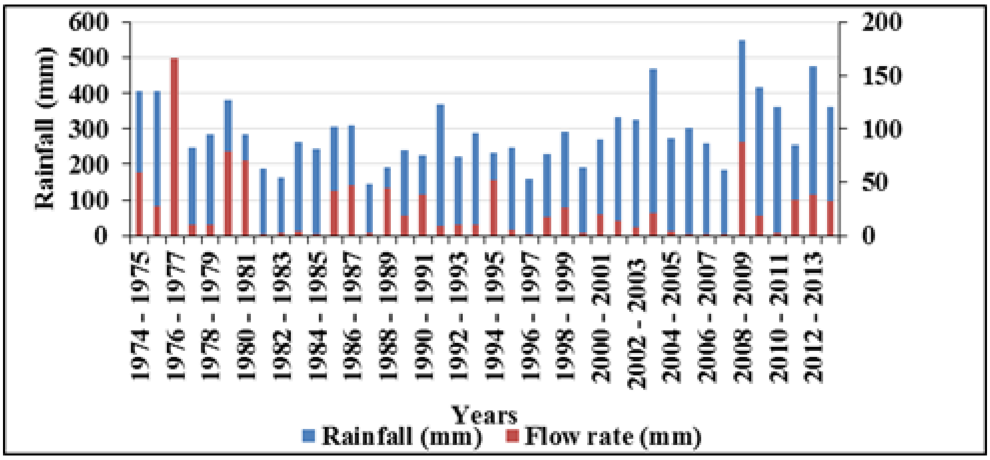


Figure 3-26: Yearly variation between flow rate and rainfall (1974/1975-2013/2014)

3.6.5.3- Seasonal variation of flow rate

Seasonal variation of flow rate (Figure 3-27) illustrate that Spring and Winter are the seasons when most of the flow occurs, due to the presence of heavy rains during these two seasons. The maximum is recorded in Spring with a value of 15.5 mm. Therefore, the importance of the rains and the state of soil in Spring allow a good flow at the level of the Boukiou wadi.

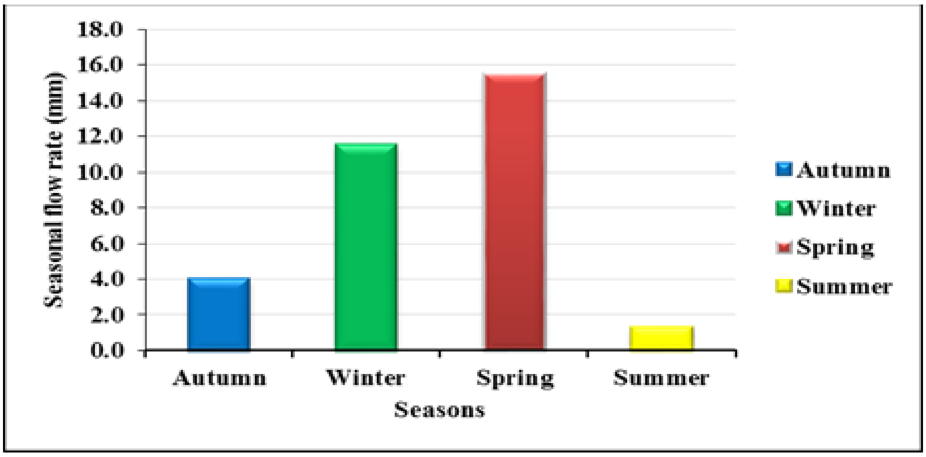


Figure 3-27: Seasonal flow rate distribution (1972/1973-2013/2014)

3.6.5.4- Daily discharges (mm)

The daily variation of the flow rate (Figure 3-28) shows that in the series there are a significant irregularity from one day to the next. Indeed, a low flow can occur one day, it can double the next day and decrease sharply the day after.

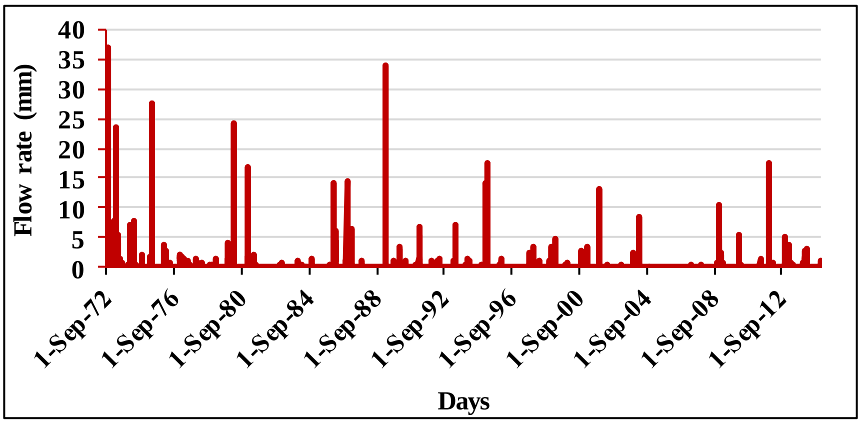


Figure 3-28: Daily flow rate distribution at Djebel Chouachi station (1972/1973-2013/2014)

3.6.6- Statistical study of precipitation and flow data

Statistical adjustment consists in testing hypotheses of homogeneity between a random variable and a calculated model. It was performed using the Hyfran Plus software developed by the Canadian institute (INRS-ETE). This software proposes the statistical adjustment and determines the model of one or more laws that best fit the data set.

3.6.6.1- Adequacy of precipitation data to a statistical law

Statistical analysis is used to identify the interannual irregularity of rainfall and to specify the conditions of the rainfall regime in our study area. In addition, it will also help us to estimate rainfall for given recurrences (any return period).

The frequency of each value will be calculated by the following formula:

$$F_i = i / N+1 \quad \text{(Equation 3-17)}$$

Where :

i : Rank

N : Number of years.

The obtained rainfall series allows us to calculate the statistical parameters (the position and dispersion parameters) and to judge the distribution of interannual rainfall. The results of the statistical study are shown in the following table.

Table 3-17: Position and dispersion parameters of precipitation according normal law.

Djebel Chouachi station	Parameters	Formulas	Values	Unit
Position parameters	**Average**	$\bar{P}=\frac{1}{N}\sum_{i=1}^{a} Pi$	290.5	mm
Dispersion parameters	**Variance**	$\delta^2 = \frac{1}{N}\sum_{i=1}^{a}(Pi^2 - \overline{P^2}$	7980.521	/
	Standard deviation	$\sigma = \sqrt{\delta^2}$	89.334	/
	Coefficient of Variation	$C_v = \frac{\sigma}{\bar{P}}$	0.308	/

Since the coefficient of variation of our series is less than 0.5 (Cv < 0.5), so, the precipitation series can be adjusted to a normal and the Log normal distribution. The Chi-square 'χ^2' test will verify this suitability.

3.6.6.1.1- Normal distribution Adjustment

3.6.6.1.1.1- Graphical Test

According to the Figure 3-29, we note that the distribution of precipitation at the normal distribution provides an acceptable point alignment. We obtain a distribution represented by a straight line (Henry's line) of equation:

$$P= \sigma . u + \bar{P} \quad \text{(Equation 3-18)}$$

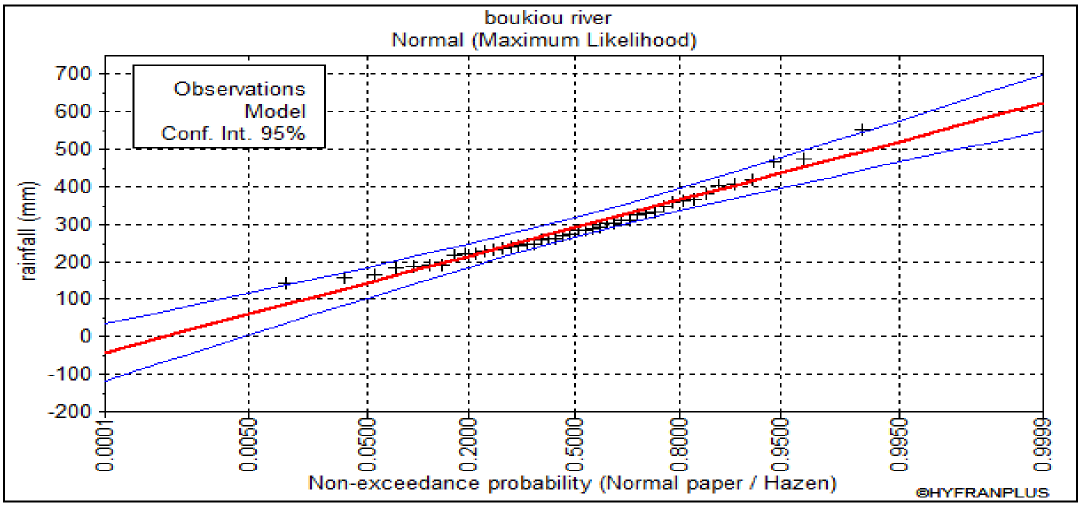


Figure 3-29: Graphical adjustment of annual precipitation to the normal distribution law.

σ: Standard deviation
$\bar{P}$: Average rainfall
u : Reduced variable of Gauss.

For: Fi = 0.5 ⟶ u = 0 ⟶ P = 290.5 mm.
Fi = 0.9 ⟶ u = 1.28 ⟶ P = 404.85 mm.

3.6.6.1.1.2- Chi-Square test

The use of the Hyfran Plus software gives the results of Chi-square (χ^2) values in the following table.

Table 3-18: Chi-square result by normal law

Parameters	Values
Calculated Chi-square	3.86
Tabulated Chi-square	12.59
Degree of freedom	6
Number of classes	9

As the calculated Chi- squared is lower than the tabulated Chi-squared ($\chi^2_{calculated} < \chi^2_{tabulated}$), the test is positive, so the adjustment allows to admit a normal rainfall distribution.

3.6.6.1.2- Log normal distribution Adjustment

The results of the statistical study (calculation of position and dispersion parameters) are shown in the table below

Table 3-19: Parameters of position and dispersion of precipitation according log normal law.

Djebel Chouachi station	Parameters	Formulas	Values	Unit
position parameters	Average	$\overline{Log\ p}=\frac{1}{N}\sum_{i=1}^{a}\log Pi$	5.62	mm
Dispersion parameters	Variance	$\delta^2=\frac{1}{N}\sum_{i=1}^{a}(Log P i^2-\overline{\log P^2})$	0.095	/
	Standard deviation	$\sigma=\sqrt{\delta^2}$	0.308	/
	Coefficient of Variation	$C_v=\frac{\sigma}{\overline{logP}}$	0.054	/

3.6.6.1.2.1- Graphical Test

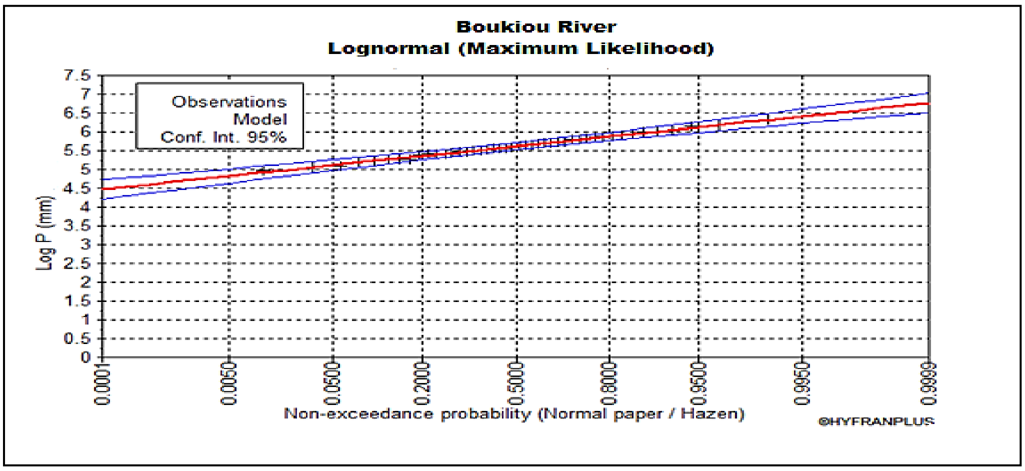


Figure 3-30: Graphical adjustment of annual precipitation to the log normal distribution law.

According to the Figure 3-30, we note that the distribution of precipitation at the lognormal distribution provides an acceptable point alignment. We obtain a distribution represented by a straight line (Henry's line) of equation:

Log P= $\boldsymbol{\sigma.u}$ **+ Log** $\overline{\boldsymbol{P}}$ (Equation 3-19)

With:
σ: Standard deviation,
Log $\overline{P}$: Average rainfall,
u : Reduced variable of Gauss.

3.6.6.1.2.2- Chi-square test

The table 3-20 shows the result of Chi-square (χ^2) values given by the Hyfran Plus software

Table 3-20: Chi-square result by log normal law.

Parameters	Values
Calculated Chi-square	5.09
Tabulated Chi-square	12.59
Degree of freedom	6
Number of classes	9

3.6.6.1.3- Adjustment result

Calculated Chi-square χ^2 is lower than the tabulated chi-square χ^2 for a degree of freedom (ddl = 6) and a probability threshold of 5% (α = 0.05). Therefore, according to the result represented in the table 3-21, we note that the adjustment of annual rainfall with the log normal and normal distribution is acceptable. However the normal law has a better result.

Table 3-21: Comparison between Calculated and Tabulated Chi-square (normal and log normal law)

	Tabulated Chi-square	Calculated Chi-square	Comparison	Result
Normal law	12.59	3.86	$\chi^2_{cal} < \chi^2_{tab}$	Accepted
Log normal law	12.59	5.09	$\chi^2_{cal} < \chi^2_{tab}$	Accepted

3.6.6.1.4- Calculation of precipitation for a given return period

We can calculate precipitation values for a return period 'T' with a known value using the normal distribution and the log normal distribution. Starting from the normal distribution equation: P = 290,5 + 89,334u, and the log normal distribution: Log P= 5,62 + 0,308u.

Then, we will calculate a number of typical precipitation events, replacing "u" with its value. The results are given in Table 3-22

Table 3-22: Calculation of precipitation for a given return period using the normal and log normal distribution.

			Normal	Log normal	
	Return Period T (year)	U	P (mm)	Log p	P (mm)
Wet period	5	0.84	365.5	5.87872	357.4
	10	1.28	404.8	6.01424	409.2
	20	1.64	437.0	6.12512	457.2
	50	2.05	473.6	6.2514	518.7
	100	2.33	498.6	6.33764	565.5
	1000	3.29	584.4	6.63332	760.0

Dry period	5	-0.84	215.5	5.36128	213.0
	10	-1.28	176.2	5.22576	186.0
	20	-1.64	144.0	5.11488	166.5
	50	-2.05	107.4	4.9886	146.7
	100	-2.33	82.4	4.90236	134.6
	1000	-3.29	-3.4	4.60668	100.2

The results in the table 3-22 show that there is a small convergence between the values found by the two methods, but the most satisfactory result is the one given by the log normal distribution**.**

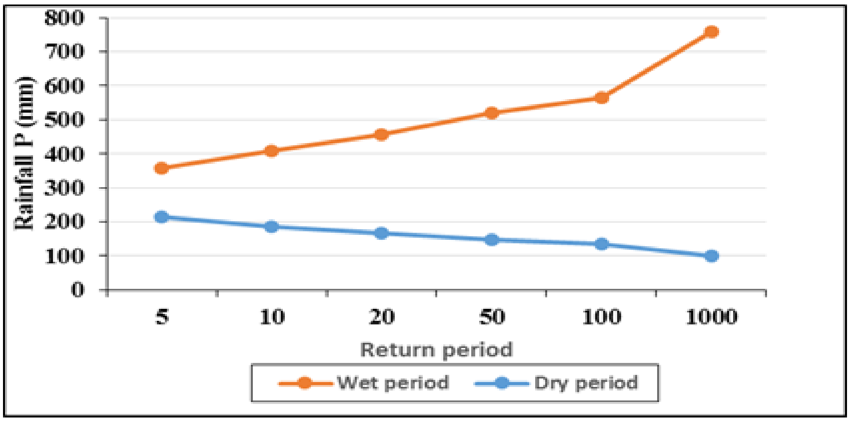


Figure 3-31: Return period of rainfall by normal law.

According to the figure above, we note that there is a divergence between two curve indicating the rainfall for recurring periods for the wet period ranging from 350 to 750 mm, while for the dry period is ranging from 200 to 100 mm.

3.6.6.2- Adequacy of discharge (mm) data to a statistical law

The statistical analysis of the hydrometric data aims to defining the regimes through certain characteristic and representative values.

Table 3-23: Position and dispersion parameters of discharge (mm) at Djebel Chouachi station.

Djebel Chouachi station	Parameters	Formulas	Values	Unit
position parameters	**Average**	$\overline{Q}=\frac{1}{N}\sum_{i=1}^{a}Q$	32.335	mm
Dispersion parameters	**Variance**	$\delta^2=\frac{1}{N}\sum_{i=1}^{a}(Q^2-\overline{Q}^2$	1993.216	/
	Standard deviation	$\sigma=\sqrt{\delta^2}$	44.645	/
	Coefficient of Variation	$C_v=\frac{\sigma}{\overline{Q}}$	1.3806	/

The strong dispersion of the flow rate, highlighted by the high value of the coefficient of variation Cv > 0.5, suggests that an adjustment to a log-normal distribution is possible, as opposed to the adjustment to the normal law which will not be acceptable, but we check this adjustment with the Hyfran Plus software in the figure 3-32

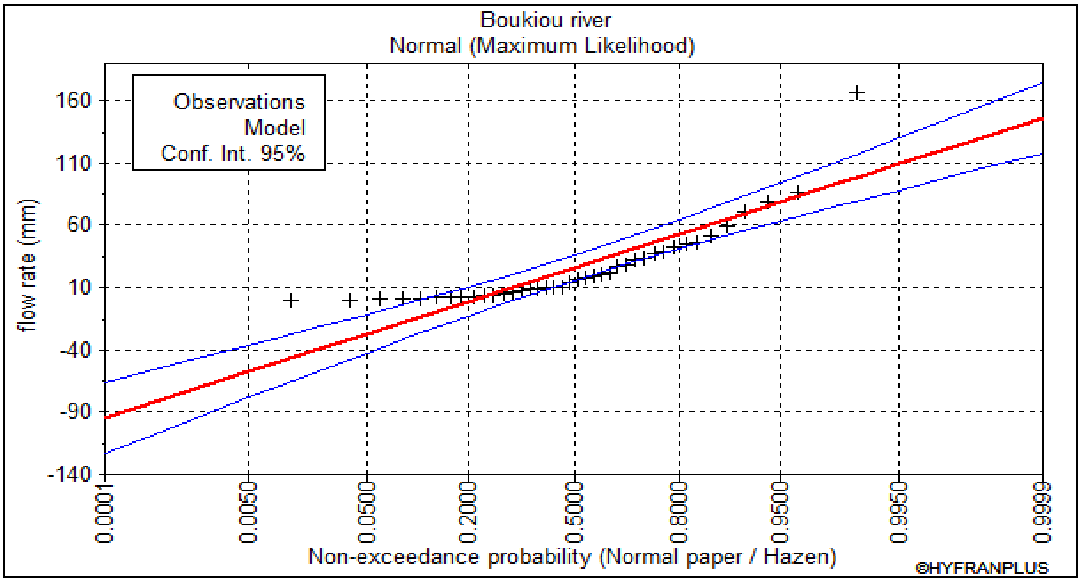


Figure 3-32: Graphical adjustment of annual flow rate at the normal distribution law

3.6.6.2.1- Adjustment of annual discharge (mm) to the log normal law

In this case, the statistical variable does not express the flow rate, but their logarithms.

Log Q = Log $\bar{Q}$ + σ Log.u (Equation 3-20)

Table 3-24: Position and dispersion parameters of log flow rate at Djebel Chouachi station.

Djebel Chouachi station	Parameters	Formulas	Values	Unit
position parameters	Average	$\overline{Log Q} = \frac{1}{N}\sum_{i=1}^{a} Log\ Q$	2.38	mm
Dispersion parameters	Variance	$\delta^2 = \frac{1}{N}\sum_{i=1}^{a}(Log\ Q^2 - \overline{Log\ Q^2})$	2.78	/
	Standard deviation	$\sigma = \sqrt{\delta^2}$	1.6	/
	Coefficient of Variation	$C_v = \frac{\sigma}{\overline{Log\ Q}}$	0.67	/

3.6.6.2.1.1-Graphical test

From figure 3-33, we can see that the distribution of the flow rate at the log normal distribution provides a better point alignment than the normal distribution.

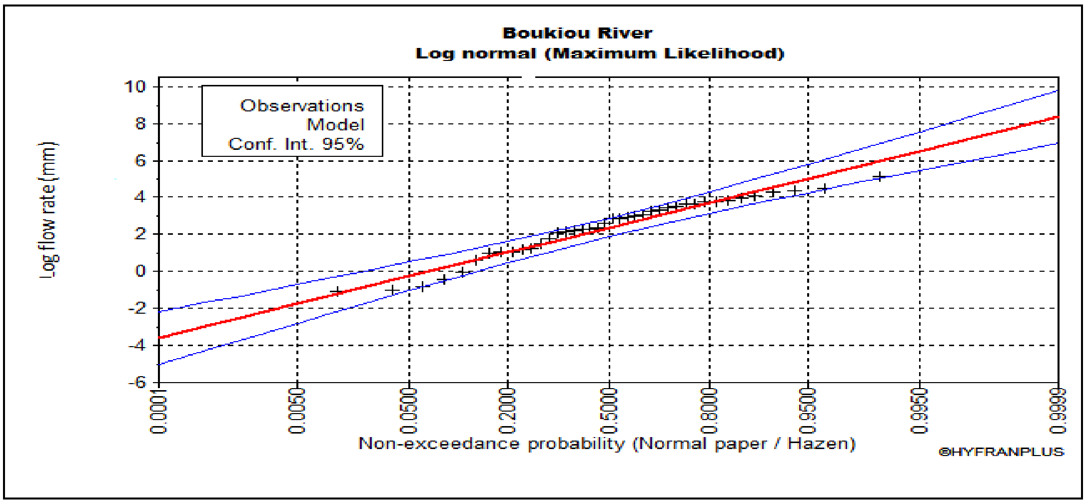


Figure 3-33: Graphical adjustment of annual flow rate at the log normal distribution law.

3.6.6.2.1.2-Chi-square test

The table 3-25, shows the result of Chi-square (χ^2) values of flow rate given by the Hyfran Plus software.

Table 3-25: Chi-square result by log normal law.

Parameters	Values
Calculated Chi-squared	7.60
Tabulated Chi-squared	11.07
Degree of freedom	5
Number of classes	8

The calculation of $\chi 2$ gives the value of 7.60 for 8 classes so, for a degree of freedom equal to 5 we will have a tabulated $\chi 2$ = 11.07. As the calculated χ^2 is slightly lower than the tabulated χ^2 ($\chi^2 c < \chi^2 t$), therefore, the adjustment allows for a log normal distribution of flow rate.

3.6.6.2.2- Calculation of flow rate for a given recurrence period

According to the equation of the log normal distribution: Log Q = 2.38 + 1.6u, we calculate the values of the flow rate corresponding to given recurrences.

From this equation, we can calculate a certain number of typical flow rates, replacing "u" by its value. The results are given in Table below:

Table 3-26: Calculation of flow rate for a given return period using the log normal distribution at Djebel Chouachi station.

Return Period T (year)		u	Log normal	
			Log Q	**Q (mm)**
Wet period	5	0.84	3.724	41.4
	10	1.28	4.428	83.8
	20	1.64	5.004	149.0
	50	2.05	5.66	287.2
	100	2.33	6.108	449.4
Dry period	5	-0.84	1.036	2.8
	10	-1.28	0.332	1.4
	20	-1.64	-0.244	0.8
	50	-2.05	-0.9	0.4
	100	-2.33	-1.348	0.26

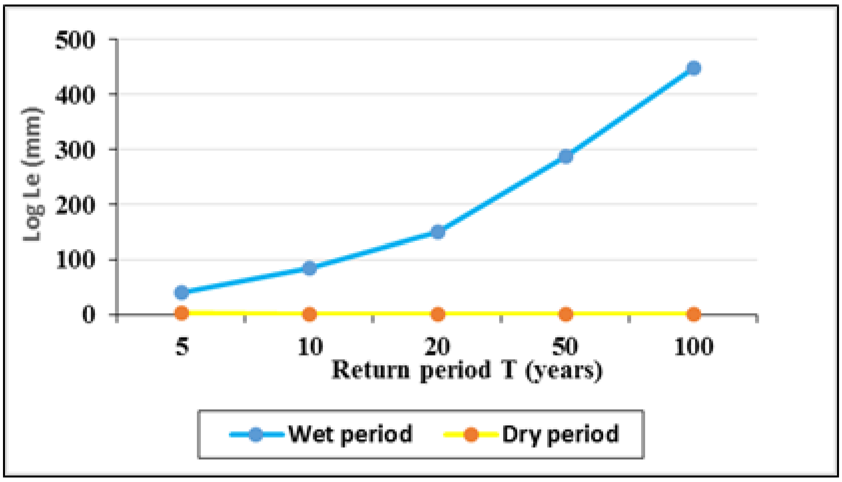


Figure 3-34: Return period of discharge (mm) by log normal law.

According to the figure above, we note that there is a surplus period indicating the flow rate for recurring periods for the wet period ranging from 50 to 450 mm, while for the dry period is equal zero indicating a deficit period.

3.7 Conclusion

In general, the morphometric study gave us the following information on the Boukiou basin:

- The surface area indicates that this basin is of a small type.
- The compactness index has a great influence on the overall flow of the river and especially on the speed of the hydrograph at the outlet of the basin resulting from a given rainfall. It confirms that our basin is compact.
- The hypsometric curve is a good reflection of the hilly aspect of the area.

- The main indices calculated allow us to classify the study area as having a fairly high relief.
- With regard to the overall layout of the hydrographic network, three essential facts that characterize the watershed must be retained.

Boukiou watershed shared between two large geological domains that are clearly different:

- The primary and secondary massif occupying the high altitudes.
- The Mio-plio-Quaternary occupying the plain at low altitude.

The analysis of the climatic parameters of the wadi Boukiou region shows that our basin has a semi-arid Mediterranean climate with a temperate Winter.

- Rainfall is variable, the average recorded during the period (1974/1975-2017/2018) is 290.5 mm/year, while the corresponding temperature is equal 18 °C.
- In general, maximum temperatures are recorded in the months of July and August, and minimum temperatures are observed in the months of December to February.
- As for flows, the hydrological study showed that this stream is characterized by an irregular flow regime due to the irregularity of the rainfall regime. The evolution of the seasonal water flows has shown that in Spring, most of the runoff occurs, which means the intensity of rainfall is high during this season.

4.1 -Climate Variability Study

4.1.1- Introduction

There are different indices for monitoring and assessing the amount of meteorological droughts. Through the rain-based meteorological drought, we can track the amount of drought just by precipitation's value of our study area at the Chouachi station from 1974/1975 until 2017/2018.

It should be remembered that there were no missing data in the series from 1974/1975 to 2017/2018.

4.1.2- Methodology

4.1.2.1 - Data using

The "MDM" (Meteorological Drought Monitoring) software application is a free software for calculating precipitation-based indices, which developed by (Agrimetsoft Agricultural and Meteorological Software). We have downloaded from the following site https://agrimetsoft.com/mdm. In this tool eight meteorological indices would be calculated, in form of yearly, monthly, seasonally, and moving average (for 3,6,9,12,18,24,and 48 months). All the calculations and the ranges of indices were presented in the paper with title of: "Estimation of meteorological drought indices based on AgMERRA precipitation data and station-observed precipitation data.

The MDM software consists of the following eight indices:

- Standardized Precipitation Index 'SPI'.
- Percent of normal index 'PN'
- Deciles index 'DI'.
- Effective Drought Index 'EDI'.
- Chinese Z Index 'CZI' and the modified Chinese Z Index 'MCZI'.
- Rainfall Anomaly Index 'RAI'.
- Z-Score Statistics Index 'Z-Score'.

In MDM software application, there are two main steps. Step1: Input data and Step2: calculating indices with differents time steps.

4.1.2.1.1- Step 1: Data Input

The input file type of the rainfall series is in Excel format. While, the input data must be organized in two columns, the first one contains the years, the second one contains the rainfall data, depending to the time steps (yearly, monthly or daily rainfall). Then, for monthly data, the precipitation data should be from January to December.

4.1.2.1.2 - Calculating indices

a. We open the data file of desirable station by clicking on the menu "File", then choose "open data file" as Figure 4-1.

b. Then, select the number of the Excel sheet (Figure 4-2).

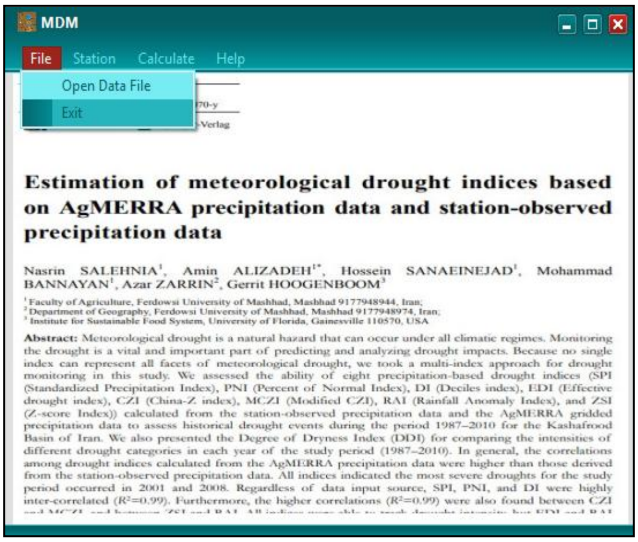


Figure 4-1: The file menu of MDM software.

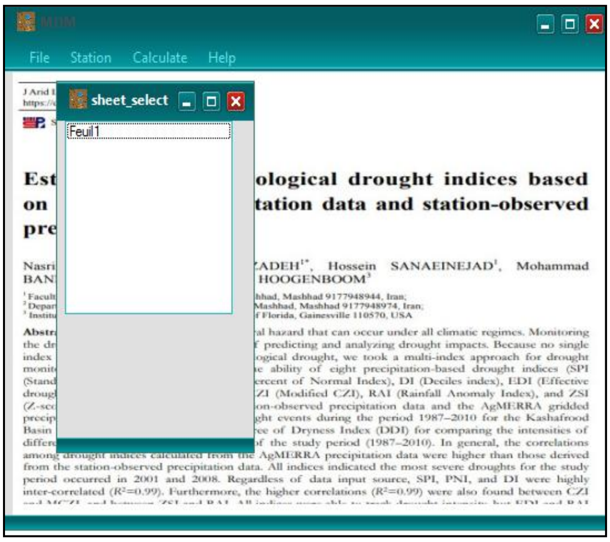


Figure 4-2: Select the sheet.

c. After the sheet has been selected, assign the variables according to the figure 4-3 and follow the simple process:

1- Select "Years" and its column header "Column 1" and click on "Load Column Data".

2- Select "Precipitation" and its column header "Column 2",

3- In addition, click on "load Column data".

4- Select the type of time series data.

5- Then click on "Back and Set".

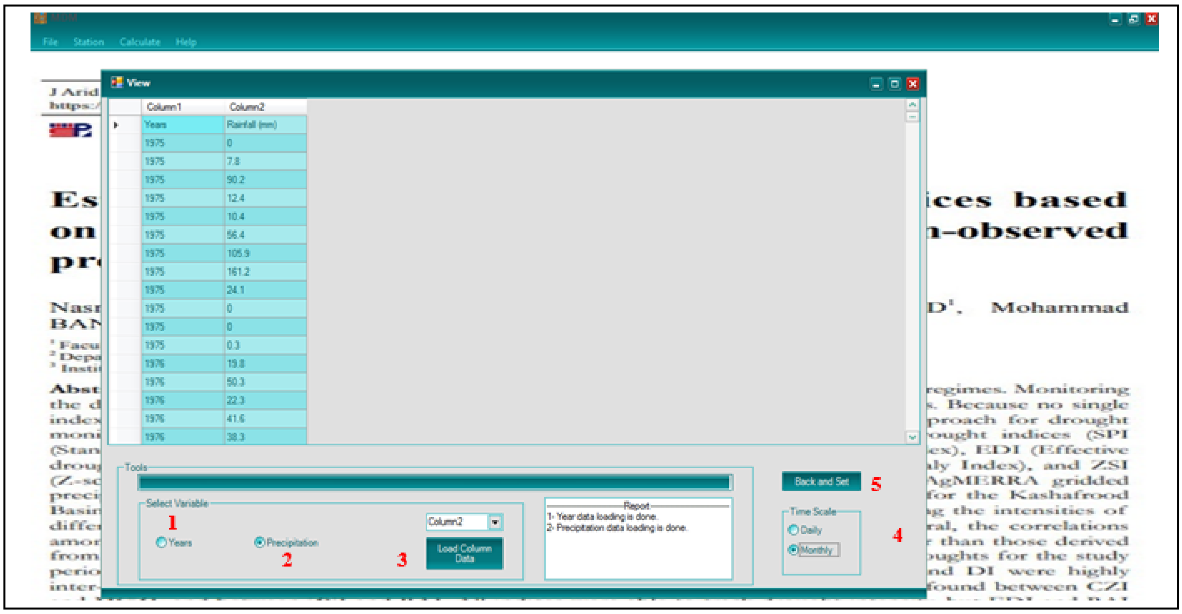


Figure 4-3: Assign the variables and time scale.

d. In this step, by selecting "Calculate" option. In the open window, there are eight rain-based drought indices should be calculating. In this example, we select "SPI". As we can view in the figure 4-4 there are different time steps for this index, namely “Yearly”, “Monthly”, and “Moving Average”.

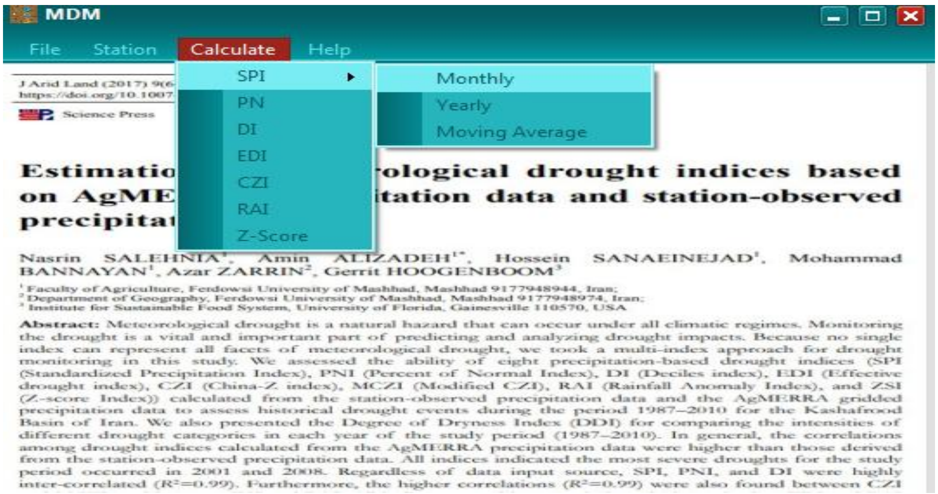


Figure 4-4 : Selection of rain-based indices.

e. In this example, by selecting the desirable index with proper time, we will face to the figure 4-5. We click “New station” because we load a data file of the station (Figure 4-5, Number 1).

f. In addition, press the “Calculate” button (Figure 4-5, Number 2).

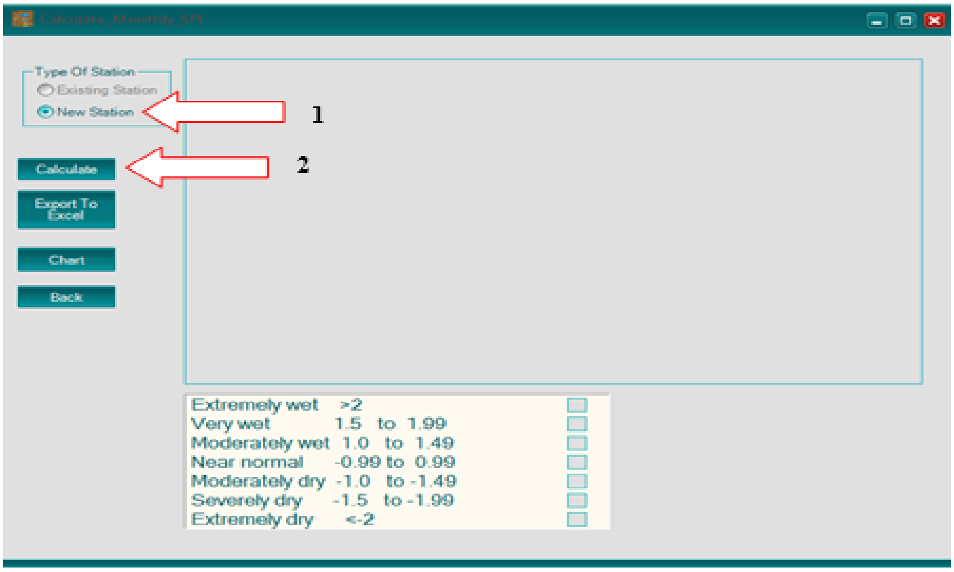


Figure 4-5 : Select the type of station

g. In the Figure 4-6, the values of SPI index in monthly scale was presented with different color in different class. In the table of results, if you can face a certain value of an index "1E+... ", it refers to a null value (not a number).

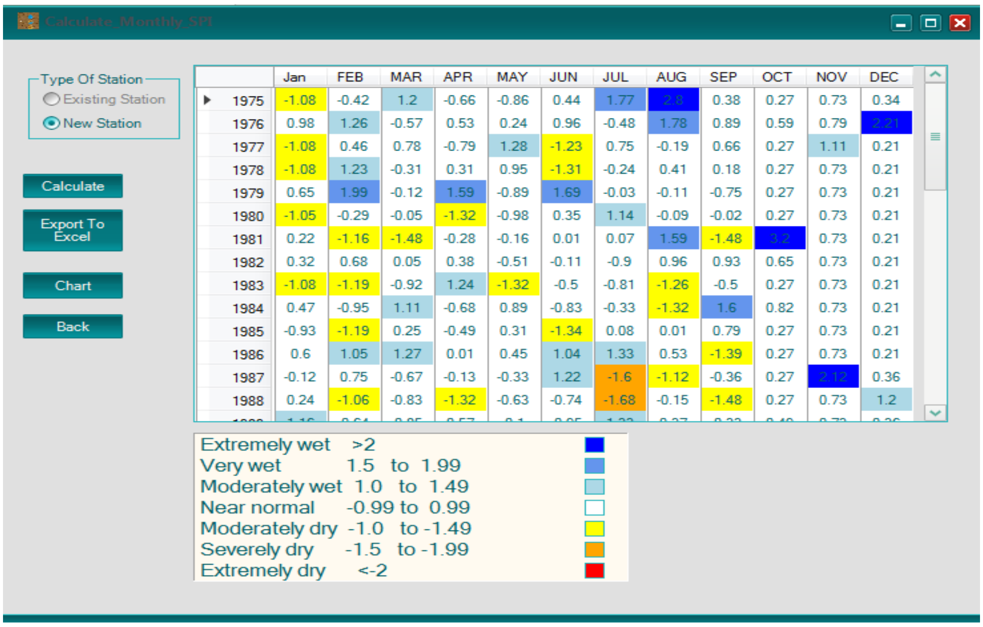


Figure 4-6: The values of SPI index in monthly scale.

h. For observing the graph of an index, select a desirable column of month to depict the amounts of the selected index.

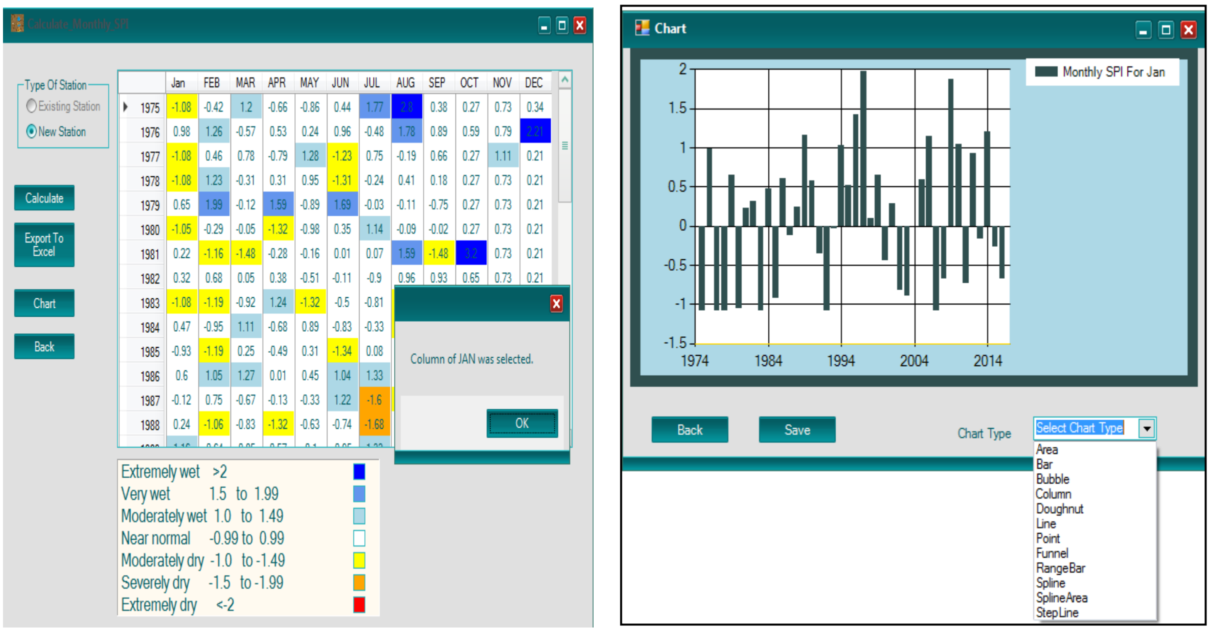


Figure 4-7: The selected chart of the SPI's value

4.1.2.1.2.1- Standardized Precipitation Index (SPI)

The SPI is the most popular drought index, which developed by (Mckee & al. 1993) for identifying wet and dry events and evaluate their intensity (Bartczak & al. 2014). The SPI output values vary between −2.0 and 2.0. A long-term precipitation data may be fitted by a gamma distribution, so, the SPI can be obtained using the following formula. (Salehnia and al, 2017)

$$\mathbf{G(x)} = \frac{1}{\beta^{\alpha}\gamma(\alpha)}\, x^{\alpha-1}\, e^{\frac{-x}{\beta}} \qquad \textbf{with } (\mathbf{x}>0) \qquad \text{(Equation 4-1)}$$

$\gamma\ (\alpha)$ **:** Gamma function,

x **:** The amount of precipitation (mm),

β : The scale parameter (β>0),

α :The shape parameter (α>0);

SPI used for monitoring dry and wet conditions. The drought event is continuously negative when the SPI reaches -1 or less, while, the greater value close to +1 or above indicates the wet event. (Djellouli & al., 2016)

Table 4-1: Classification of Standardized Precipitation Index (*SPI*) values. (Djellouli & al., 2016)

SPI value	Drought condition
≥ 2.0	Extremely wet
⟨1.5 to 1.99⟩	Very wet
⟨1.0 to 1.49⟩	Moderatly wet
⟨–0.99 to 0.99⟩	Near normal
⟨–1.0 to –1.49⟩	Moderatly dry
⟨–1.5 to –1.99⟩	Severly dry
≤ –2.0	Extremly dry

4.1.2.1.2.2- Percent of normal index 'PN'

In 1994, Willeke & al., described the PN as a percentage of normal precipitation. It is calculated using the formula below for different time scales (yearly, monthly, and seasonally).

$$PN\,(\%) = \frac{P_i}{P_n} * 100 \qquad \text{(Equation 4-2)}$$

Where:
P_i: Precipitation for the study period (mm).
P_n: Average precipitation for the same time period studied.
This index provides an estimation of rainfall relative to normal. Therefore, a drought period is identified when the rainfall is below normal, i.e. if PN value is less than 100% (Table 4-2)

Table 4-2: Classification of PN index values.

Degree of PN index	Description
> 100	Wet
80 to 100	Normal
70 to 80	Weak drought
55 to 70	Moderate drought
40 to 55	Severe drought
< 40	Extreme drought

4.1.2.1.2.3- Deciles index (DI)

According to Gibbs & Maher, 1967 the method of deciles or 10% considers the monthly historical precipitation data divided into 10 equal categories (10 % parts).

4.1.2.1.2.4- Effective Drought Index (EDI)

The EDI index was developed by Byun & Wilhite in 1999. It can be calculated only in daily time step while its values are standardized in a similar way with that for calculating SPI values.

4.1.2.1.2.5- Rainfall Anomaly Index (RAI)

This index is defined by two equations. The rainfall data are arranged in descending order, while the RAI considers two anomalies: the 10 highest values form a threshold for positive anomaly, and the other hand form the threshold for negative anomaly (Salehnia. N & al, 2017).

$$\text{RAI}= 3* \left[\frac{(P-\bar{p})}{(\bar{m}-\bar{P})}\right] \qquad \textbf{Equation (4-4)}$$

$$\text{RAI}= -3* \left[\frac{(P-\bar{p})}{(\bar{m}-\bar{P})}\right]$$

Where:
P : Actual rainfall for each year (mm)
$\bar{P}$: The mean long term rainfall.
$\bar{m}$: The average of the negative anomaly values and the positive anomaly values.
A drought classification is carried out according to the RAI values. (Table 4-3)

Table 4-3: Classification of RAI index values.

Degree of RAI index	Description
> 0.3	Extremly wet
(0.3 to -0.3)	Moderatly wet
(-0.3 to -1.2)	Near normal
(-1.2 to -2.1)	Moderatly dry
(-2.1 to -3.0)	Severly dry
> -3.0	Extremly dry

4.1.2.1.2.6- Score Index

ZSI is defined for each time step as the difference between moving cumulative rainfall (**P**$_i$) in (mm), and the mean monthly rainfall ($\bar{P}$) divided by the standard deviation (σ) as it is mention in the equation below (Dogan. S & al, 2012), and its classification is done in the table 4-4

$$\text{Z – Score} = \frac{Pi * \bar{P}}{\sigma} \qquad \text{(Equation 4-5)}$$

Table 4-4: Classification of Z-score index values.

Degree of Z-score index	Description
> 0.25	No drought
0.25 to -0.25	Weak drought
(-0.25 to -0.52)	Slight drought
(-0.52 to -0.84)	Moderately Drought
(-0.84 to -1.25)	Severely Drought
<-1.25	Extremely Drought

4.1.2.1.2.7- China-Z Index "CZI" and Modified CZI (MCZI)

This index can be calculated by the following equation:

$$\mathbf{CZI}_{ij} = \frac{6}{Csi} * \left(\frac{Csi}{2} * \varphi_{ij} + 1 \right) \qquad \text{(Equation 4-6)}$$

Where:

CZI_{ij}: The CZI's amount of the current month (j) for period (i),
i: The time scale of interest and j is the current month,
C_{si}: The coefficient of skewness,
φ_{ij} : The standardized variation.

The MCZI can also be calculated using the formula above but substituting the median rainfall for mean rainfall. (Salehnia. N & al, 2017), and its classification is given in the table below

Table 4-5: Classification of CZI and MCZI index values.

Degree of CZI & MCZI indices	Description
> 2	Extremly wet
(1.5 to 1.99)	Very wet
(1 to 1.49)	Moderatly wet
(-0.99 to 0.99)	Near normal
(-1.0 to -1.49)	Moderatly dry
(-1.5 to -1.99)	Severely dry
< -2	Extremely dry

4.2- Hydrological modeling

4.2.1- Introduction

To simulate the water balance components of the catchment, HBV light model (Hydrologiska Byråns Vattenbalansavdelning) was used. It computes the daily rainfall, daily temperature, long term monthly potential evapotranspiration and runoff data (Abebe & Kebede, 2017). The total period of the data that was 14 years. From this period 9 years of data from the 1st of September 2001 until 31st of August 2010 were used for calibration and the remaining years of the data (from the 1st of September 2010 to 31st of August 2014) were applied for validation.

4.2.2- Model Set-up

4.2.2.1- Data input

Data input for the HBV light model was described previously, it contains several parameters most of them are mentioned according to Seibert. J (2005):

ptq.txt: file contains time series of daily precipitation (mm/day), temperature (ºC) and discharge (mm/day).

EVAP.txt: file of the mean potential-evapotranspiration, it contains 12 values (long-term monthly mean values). The potential evapotranspiration used was calculated by "Thornthwaite method" 1957 in (mm).

The development of the formula was given by the following equation:

$$PET_{no\ corrected} = 16\left(\frac{10t}{I}\right)^{a} \qquad \text{(Equation 4-7)}$$

With $I = \sum_{1}^{12} i$ and $i=\left(\frac{t}{5}\right)^{1,514}$

$$a = 675 \times 10^{-9} \times I^{3} - 771\times10^{-7} \times I^{2} + 1792 \times 10^{-5} \times I + 0,49239$$

$$PET_{corrected} = 16\left(\frac{10t}{I}\right)^{a} * K \qquad \text{(Equation 4-8)}$$

Where:

t= The average monthly temperature of the month in °C,

I: Sum of the 12 monthly thermal indices,

K : Correction factor linked to the latitude (maximum duration of sunshine) → cf. calculation chart

Table 4-6: The PET calculation for the calibration periods for the Boukiou watershed.

Months	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Jl**	**A**	
T ° (C)	23.6	20.4	15.1	12.1	11.1	12.1	14.3	15.9	19.1	23.3	26.6	26.8	
I (monthly)	10.5	8.4	5.3	3.8	3.3	3.8	4.9	5.8	7.6	10.3	12.6	12.7	**88.98**
a	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	
K	1.0	1.0	0.9	0.9	0.9	0.9	1.0	1.1	1.2	1.2	1.2	1.2	
PET (mm)	104.4	74.9	37.5	24.3	21.1	24.4	40.4	52.4	81.9	119.8	157.1	149.4	**887.7**

Table 4-7: the PET calculation for the validation periods for Boukiou watershed.

Months	S	O	N	D	J	F	M	A	M	J	Jl	A	
T ° (C)	23.8	20.4	15.6	12.5	11.4	11.4	13.5	16.4	19.3	22.9	26.0	27.5	
I (monthly)	10.62	8.42	5.61	3.99	3.49	3.49	4.48	6.04	7.72	9.99	12.12	13.19	**89.15**
a	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	
K	1.03	0.97	0.86	0.85	0.87	0.85	1.03	1.09	1.21	1.21	1.23	1.16	
PET (mm)	105.9	74.6	39.8	25.7	22.2	21.7	36.0	55.3	83.4	115.2	149.2	156.4	**885.5**

T_MEAN.txt: file of the mean temperature that contains long term mean values for the temperature in (°C).

4.2.2.2- Start-up period

Determination of initial system state is mandatory prior to implementation of rain-flow model. To start HBV light model there was a need to identify the start-up period, which could be the first one year from data input (Vis & al, 2015). This start-up period refers as a solution to the problem of arbitrary selection of initial tank levels at the beginning of the test period, according to Seibert. J, (2005) it allows the acclimatization of the input data set to the running conditions normal for the start of the system simulation.

In our study start-up period and initialization of the model variables starts from 1st of September 2000 to 31st of August 2001. This period was not used for evaluation of the model predictions.

4.2.2.3- Data output

The models provide the output with simulated discharges Q_{sim} that will be compared with the observed discharges Q_{obs}

4.2.3- Model Calibration

In this research, the HBV light model calibration was done with a daily time step for observed data for the period ranged from 1st of September 2001 until 31st of August 2010 for only one catchment (conceptual model). The calibration process is usually made by manual try and error technique, and it was repeated iteratively until the best fit between observed and simulated streamflow was achieved. A test is considered successful if it achieves the optimal solution (Performance Criteria and parameter set) within 1%.

A schematic representative of calibration process is summarized in the figure below:

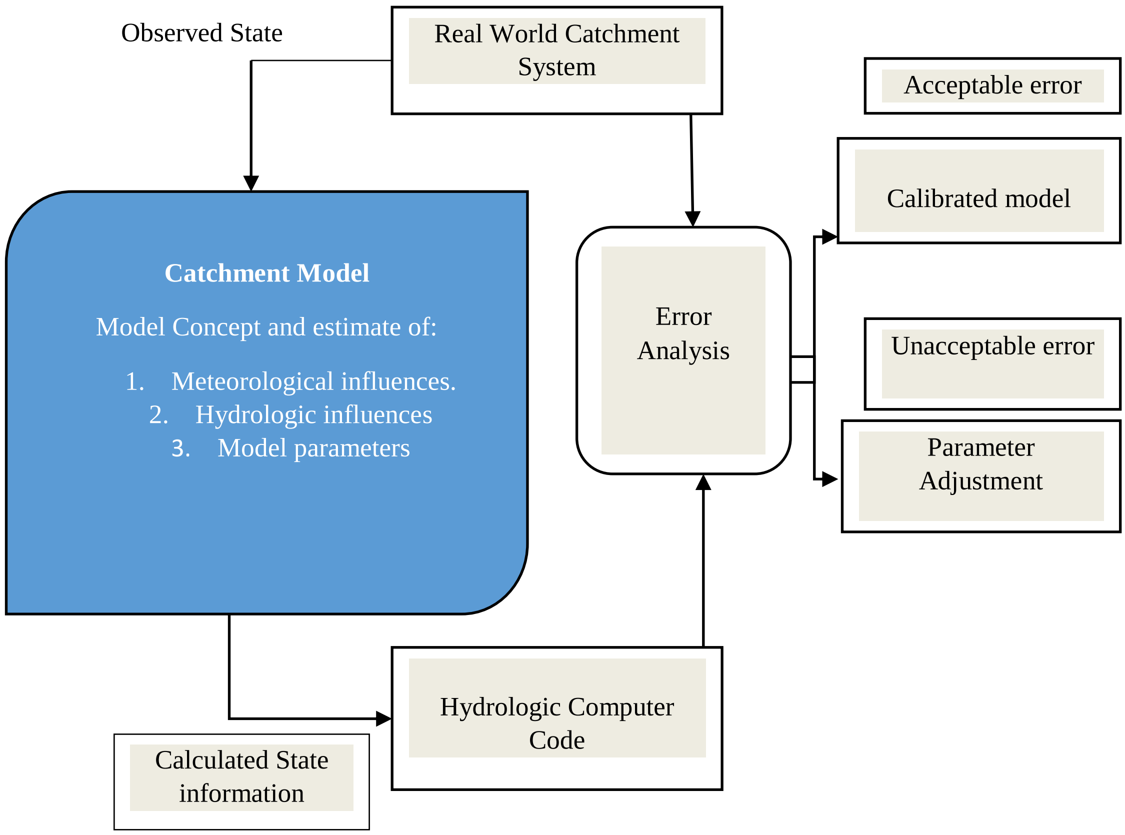


Figure 4-8: Flow diagram showing the model calibration model (Adapted from Birundu. A.M, 2016 in Rientijes, 2015).

According to Seibert. J (2005) differents criteria can be used to assess the fit of simulated runoff to observed runoff:

- ✓ Visual inspection of plots with Q_{sim} and Q_{obs}
- ✓ Accumulated difference.
- ✓ Statistical criteria.

4.2.4- Parameters Overview and their ranges

The ranges of parameters used in the HBV Light model which described in the chapter two of literature review are summarized in the Table 4-8 and Table 4-9. This is found in the help of the HBV Light model from (Seibert, 2005)

- **i. Catchment parameters**
- **ii. Vegetation zone parameters**

Table 4-8: The catchment parameters of HBV Light model and their ranges

		Catchment Prameters	
Name	**Unit**	**Valid range**	**Description**
PERC	mm/Δt	[0,inf)	treshold parameter
Alpha	-	[0,inf)	non-linearity coefficient
UZL	mm	[0,inf)	treshold parameter
K0	1/Δt	[0,1)	storage (or recession) coefficient 0
K1	1/Δt	[0,1)	storage (or recession) coefficient 1
K2	1/Δt	[0,1)	storage (or recession) coefficient 2
MAXBAS	Δt	[1,100]	length of triangular weighting function
Cet	1/°C	[0,1]	potential evaporation correction factor
PCALT	%/100m	(-inf,inf)	increase of precipitation with elevation
TCALT	°C/100m	(-inf,inf)	decrease of temperature with elevation
Pelev	m	(-inf,inf)	elevation of precipitation data in the PTQ file
Telev	m	(-inf,inf)	elevation of temperature data in the PTQ file
PART	-	[0,1]	portion of the recharge which is added to groundwater box 1
DELAY	Δt	[0,inf)	time period over which recharge is evenly distributed

Table 4-9: The vegetation zone parameters of HBV Light model and their ranges

		Vegetation zone parameters	
Name	**Unit**	**Valid range**	**Description**
TT	°C	(-inf,inf)	Threshold temperature
CFMAX	mm/Δt °C	[0,inf)	degree-Δt factor
SP	-	[0,1]	seasonal variability in degree-Δt factor
SFCF	-	[0,inf)	snowfall correction factor
CFR	-	[0,inf)	refreezing coefficient
CWH	-	[0,inf)	water holding capacity
CFGlacier	-	[0,inf)	glacier correction factor
CFSlope	-	(0,inf)	slope correction factor
FC	mm	(0,inf)	maximum soil moisture storage
LP	-	[0,1]	soil moisture value above which AET reaches PET
BETA	-	(0,inf)	Parameter that determines the relative contribution to runoff from rain or snowmelt

4.2.5- Model efficiency

During the calibration and validation steps, it is necessary to look at its efficiency. The Nash-Sutcliffe efficiency criteria R_{eff} was used to well evaluate the performance of HBV light model. Unfortunately, R_{eff} is often named R^2 in connection with the HBV model. (Seibert .J, 2005)

$$\text{NSE} = \left[1 - \frac{\sum_{t=1}^{T}(Qcalc\ (t) - Qobs\ (t))^2}{\sum_{t=1}^{T}(Qobs\ (t) - \bar{Q}\ obs)^2}\right]$$

Q_{calc} (t): Calculated or (simulated) discharge at time (t).

Q_{obs} (t): Observed discharge at time (t).

$\bar{Q}_{obs}$: The mean observed discharge.

4.2.6- Model Validation

The validation process based on setting the same simulation's parameters of calibration step, for different time step period which runs from the 1st September 2010 until 31st August 2014, in order to look at the new hydrologic response of that simulation during future period mostly used for future forecasting. The model efficiency was achieved using the same criteria of performance (NSE)

A simplified flow sheet for the HBV light processes is represented in the figure 4-9

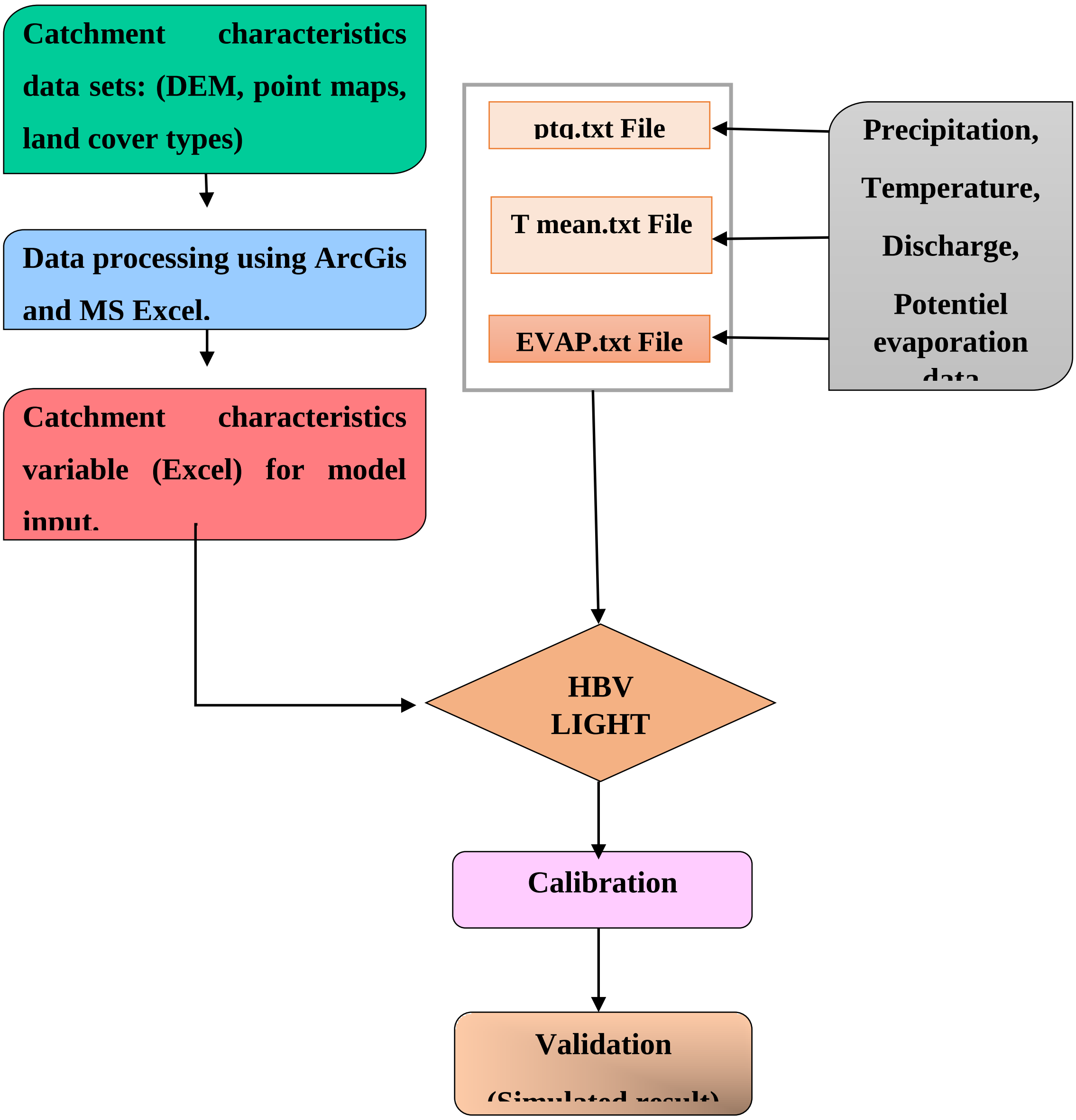


Figure 4-9: Flow diagram representing the Input and Output Process of the HBV Light Model.

5.1 Result of Climate Variability Study

5.1.1- Introduction

In this chapter first part, we use the Meteorological Drought Monitoring program to calculate and count the drought frequency of many years with differents time steps, for precipitation data during the period 1974/1975 until 2017/2018.

5.1.2- Standardized Precipitation Index 'SPI' result

5.1.2.1- SPI yearly result and interpretation

The yearly SPI index evolution in the basin was marked by alternating wet and dry sequences at the study station (Figure 5-1). Indeed, we can observe a wet period between 1974/1976 and 1980/1981, then, it is following by a sequence of drought with a shortage in rainfall from 1980/1981 until 2008/2009. Finally, we can see a return to a wetly period from 2008/2009 until 2017/2018.

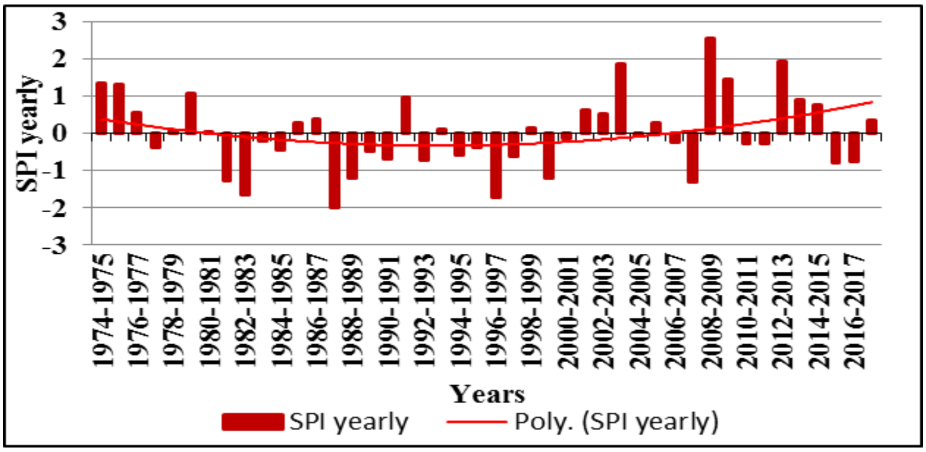


Figure 5-1: The yearly SPI changes of the Boukiou watershed (1974/1975-2017/2018)

According to the actual statistics of annual drought, (Table 5-1) the extreme dry event recorded during the year (1987/1988) with the minimum SPI value -2.01, while the severe dry events occurred in (1982/1983) and (1996/1997). The maximum SPI recorded during the year (2008/2009) reaches 2.55, which characterizes a relatively extreme wet event. These confirm the result in chapter three in the part of hydroclimatic context.

Table 5-1: Statistics of annual drought for SPI index (1974/1975-2017/2018)

Years	Yearly SPI	Years	Yearly SPI	Years	Yearly SPI
1974-1975	1.33	**1989-1990**	-0.50	**2004-2005**	-0.07
1975-1976	1.31	**1990-1991**	-0.68	**2005-2006**	0.27
1976-1977	0.56	**1991-1992**	0.95	**2006-2007**	-0.24
1977-1978	-0.39	**1992-1993**	-0.74	**2007-2008**	-1.32
1978-1979	0.07	**1993-1994**	0.11	**2008-2009**	2.55
1979-1980	1.08	**1994-1995**	-0.57	**2009-2010**	1.43
1980-1981	0.04	**1995-1996**	-0.39	**2010-2011**	-0.29
1981-1982	-1.26	**1996-1997**	-1.72	**2011-2012**	-0.29
1982-1983	-1.64	**1997-1998**	-0.63	**2012-2013**	1.93
1983-1984	-0.21	**1998-1999**	0.13	**2013-2014**	0.90
1984-1985	-0.44	**1999-2000**	-1.19	**2014-2015**	0.77
1985-1986	0.29	**2000-2001**	-0.14	**2015-2016**	-0.79
1986-1987	0.36	**2001-2002**	0.60	**2016-2017**	-0.75
1987-1988	-2.01	**2002-2003**	0.53	**2017-2018**	0.35
1988-1989	-1.20	**2003-2004**	1.87		

According to the calculation results (Figure 5-2 and Table 5-2), we can analyze drought occurrence frequency in our basin based on the yearly SPI. It showed that the “Near normal” class presents the maximum percentage with 68%, while the wet period and the dry period frequency had the similar percentage 16%.

Table 5-2: Drought Frequency of yearly SPI in differents Droughts Classes.

Droughts Categories	Number of years	Droughts Frequency %	Total %
Extremly wet	1	2	**16**
Very wet	2	5	
Moderatly wet	4	9	
Near normal	30	68	**68**
Moderatly dry	4	9	**16**
Severly dry	2	5	
Extremly dry	1	2	

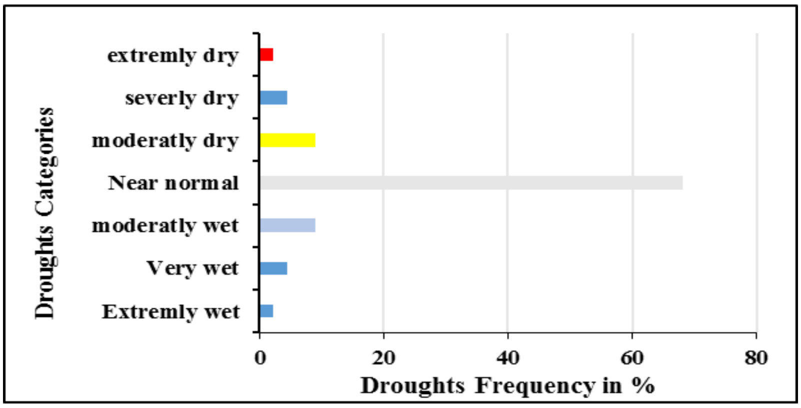
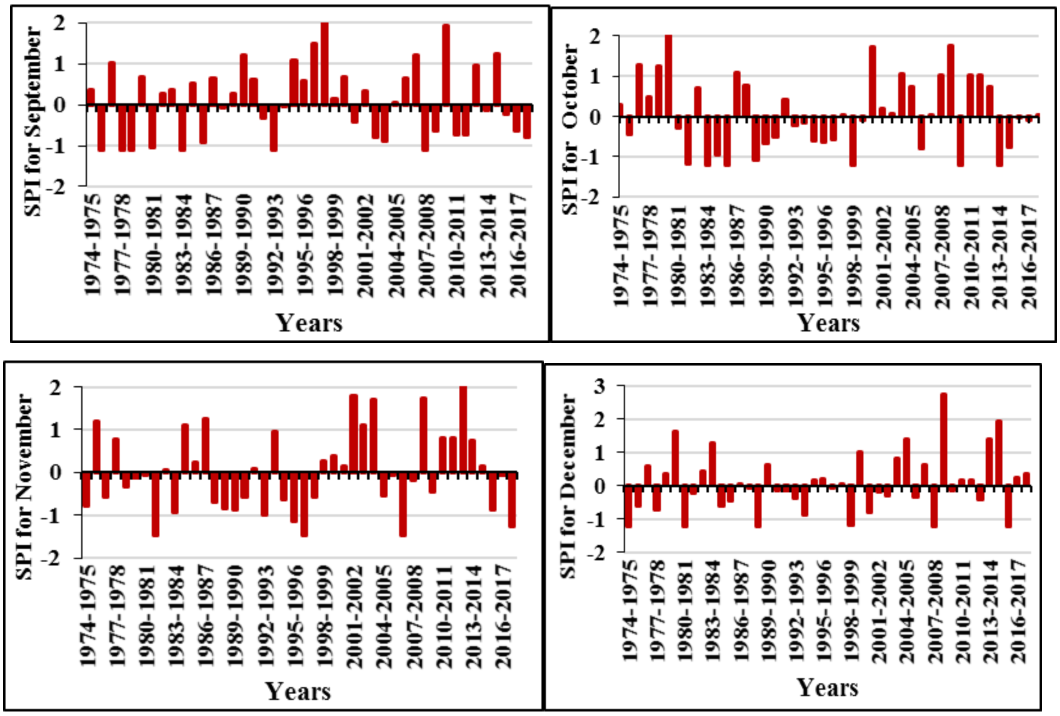


Figure 5-2: Droughts Frequency histogram of yearly SPI index.

5.1.2.1- Monthly SPI results and interpretation

The monthly SPI results (Figure 5-3) and (Table 5-3 in Appendix) show that the severe dry month detected in (March 1987, March 1988 and March 1997). While the extremely wet month occurred in June 1981, August 1976 with SPI value 3.4 and 2.86 respectively.



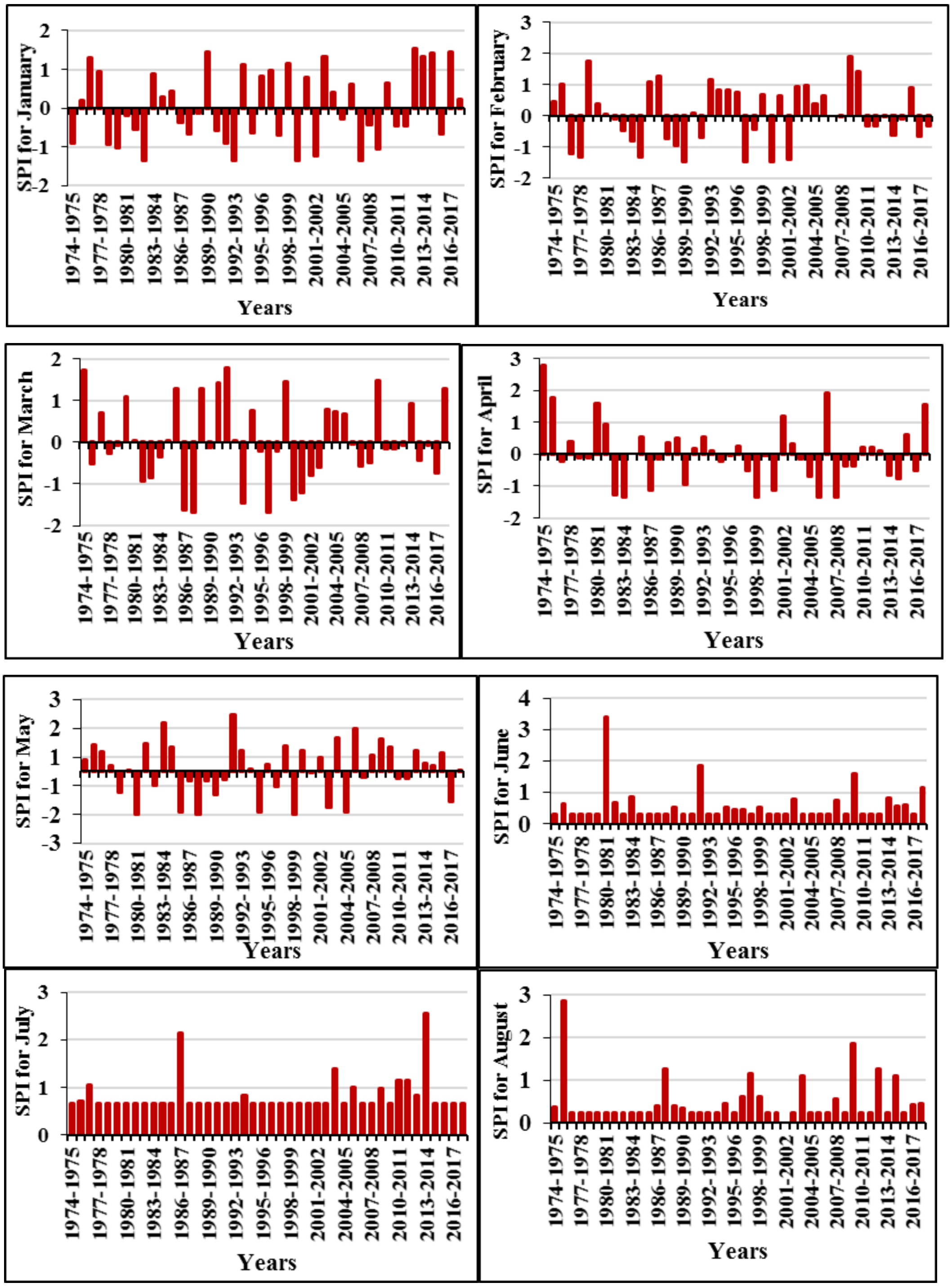


Figure 5-3: The monthly SPI results (1974/1975-2017/2018)

The drought occurrence frequency in our basin as given in the (Table 5-4) and the (figure 5-4) shows that the "Near normal" class is preponderant with a percentage of 72%, while the wet period and the dry period frequency are estimated respectively by 16% and 12%.

We observe that the month of January had the highest percentage of moderate wet month, however, the month of May reveals the highest percentage of the moderate dry month.

Table 5-4: Drought Frequency result of monthly SPI (1974/1975-2017/2018)

Droughts Categories	S	O	N	D	J	F	M	A	M	J	Jl	A	Number of month	Droughts frequency %	%
Extremly wet	1	1	1	1	0	0	0	1	0	1	2	1	9	**2**	**16**
Very wet	1	2	3	2	1	1	2	4	2	2	0	1	21	**4**	
moderatly wet	6	7	4	4	8	5	7	1	3	1	5	5	56	**11**	
Near normal	29	27	30	31	28	30	29	31	31	40	37	37	380	**72**	**74**
moderatly dry	7	7	6	6	7	7	3	7	8	0	0	0	58	**11**	**12**
severly dry	0	0	0	0	0	0	3	0	0	0	0	0	3	**1**	
extremly dry	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	

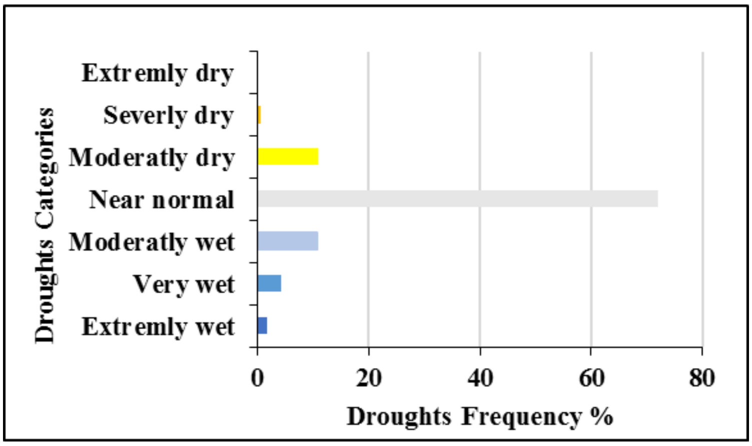


Figure 5-4: Droughts Frequency Histogram of monthly SPI index (1974/1975-2017/2018)

5.1.2.3- Moving average results for SPI and interpretation

A set of averaging periods are selected to determine a set of time scales of period j months for example, where j represent 3, 6, 9, 12, 18, 24, 48 or months. The data set is moving in the sense that each month a new value is determined from the previous "i" months. Then each of data sets is fitted to the gamma function to define the relationship of probability to precipitation. Once this process established from the historic records the probability of any observed rainfall data point is calculated and used along with an estimate of the inverse normal to calculate the rainfall deviation for a normally distributed probability density with a mean of zero and standard deviation of unity. Finally, this value represents the Precipitation Index for the specific rainfall data point. (Thomas. B & al, 1983)

5.1.2.3.1- For short term drought (SPI 3-month, SPI 6-months)

5.1.2.3.1.1- SPI 3-months

As shown in the (Table 5-5 in Appendix), the SPI index over 3 months ending at the end of November 1974 compares the cumulative precipitation, for the months of "September, October, November" of the year under study to the cumulative precipitation from September to November of all the years in the history of observations carried out at the Djebel Chouachi station.

The result in the figure 5-5 shows that the SPI moves frequently below and above zero, where the maximum value 2.68 occurred in April 1975, represents the extremely wet month and, the minimum value -3.92 which recorded in March 2000, characterizes the extremely drought month.

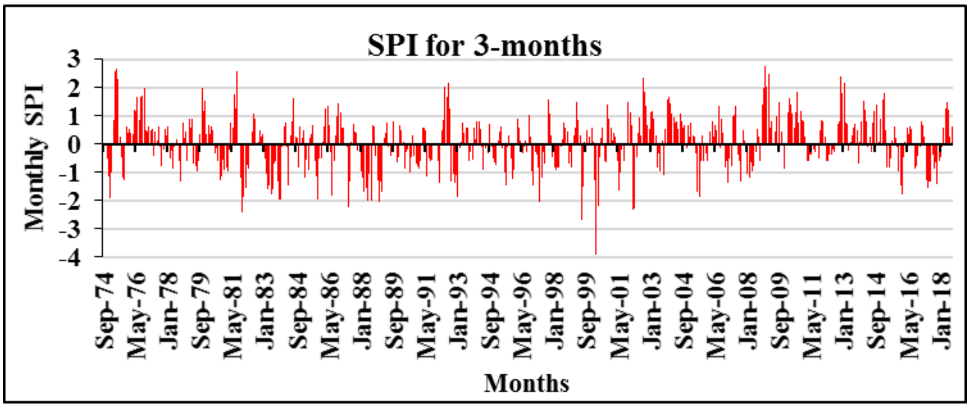


Figure 5-5: Standardized Precipitation Index time series calculated for Boukiou catchment during (1974/1975-2017/2018) using time scale 3 months

5.1.2.3.1.2- SPI 6-months

The result obtained by SPI 6-months (Table 5-6 in Appendix), reveals a succession of drought duration started in April 1983 ended in November 1984 and from February to August 1988. A succession of wetly duration observed from April to September 1975, and another one from November 2003 to July 2004, and from November 2008 until May 2009.

The result in the figure 5-6 shows that the SPI moves frequently below and above zero, where the maximum value 2.83 occurred in February 2009, determines the extremely wet month. Also, the minimum value -2.66 which recorded in October 1983, characterizes the extremely drought month.

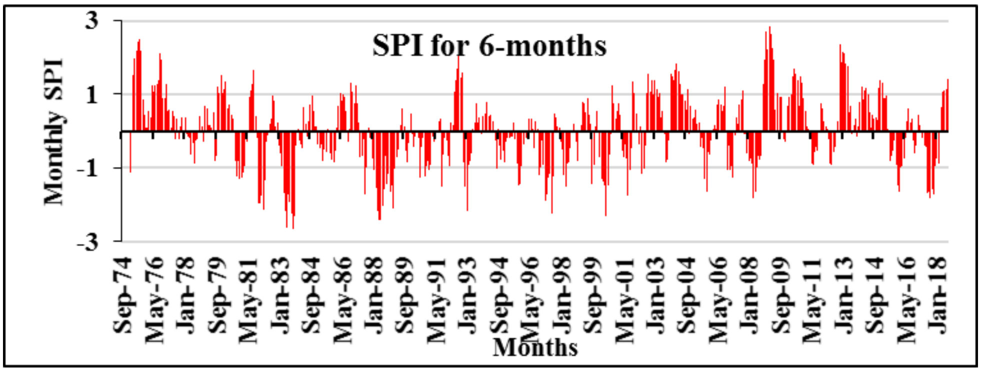


Figure 5-6: Standardized Precipitation Index time series calculated for Boukiou catchment during (1974/1975-2017/2018) using time scale 6 months.

5.1.2.3.2- For long term drought (SPI-9, 12, 18, 24, 48)

5.1.2.3.2.1- SPI 9-months

The result obtained by SPI 9-months (Table 5-7 in Appendix), reveals a succession of drought duration started in April 1983 ended in November 1984 and, from February to August 1988. A succession of wetly duration observed from May to December 1975, another one from December 2003 to October 2004, and from December 2008 until July 2009.

The figure 5-7 shows that the SPI moves slowly below and above zero, "that means the SPI responds slowly to changes in precipitations". The maximum value 2.82 occurred in February 2009 represents the extremely wet month and the minimum value -2.87 which recorded in September 1983 characterizes the extremely drought month.

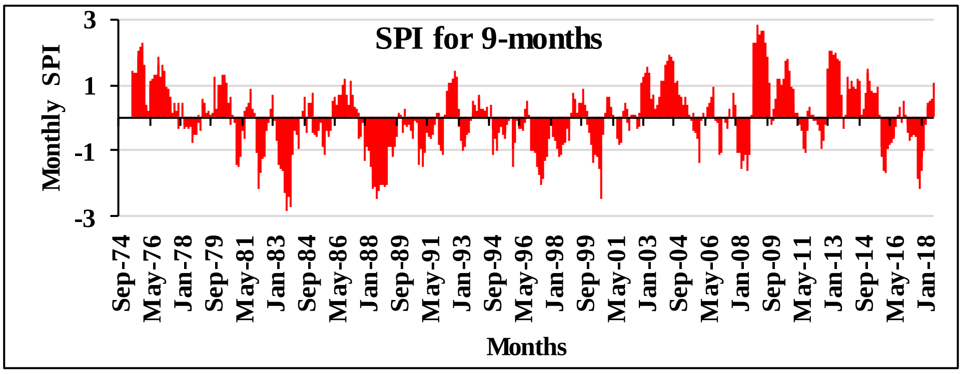


Figure 5-7: Standardized Precipitation Index time series calculated for Boukiou catchment during (1974/1975-2017/2018) using time scale 9- months.

5.1.2.3.2.2- SPI 12-months

The result obtained by SPI 12-months (Table 5-8 in Annex 1) reveals a succession of drought duration started in April 1983 ended in April 1984 and, from February to August 1988. A succession of wetly duration observed from August 1975 to April 1977, another wet long duration detected from December 2008 to November 2009.

The figure 5-8 shows that the SPI moves slowly below and above zero, "that means the SPI responds slowly to changes in precipitations". The maximum value 2.78 occurred in September 2009 represents the extremely wet month, the minimum value -2.97 recorded in November 1983 characterizes the extremely drought month.

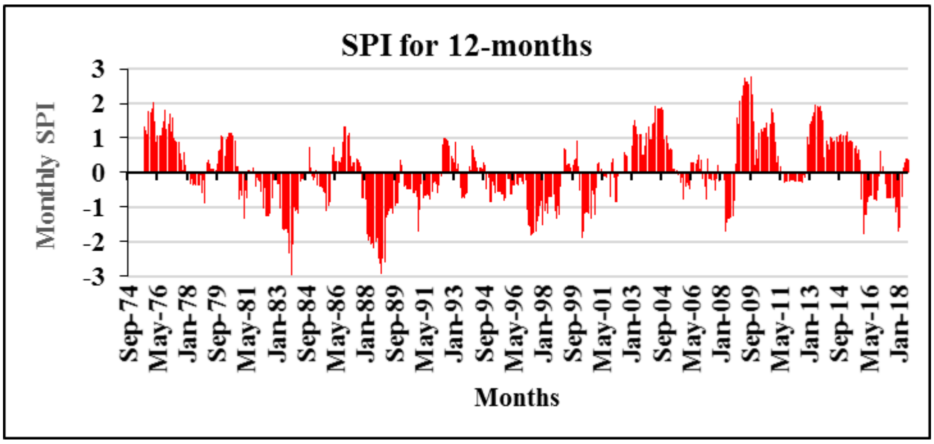


Figure 5-8: Standardized Precipitation Index time series calculated for Boukiou catchment during (1974/1975-2017/2018) using time scale 12- months.

5.1.2.3.2.3- SPI 18-months

The SPI 18-months (Table 5-9 in Appendix), shows a succession of long drought duration started in May 1988 ended in November 1989, then from March 1997 until August 1998. A succession of wetly duration observed from February 1976 to September 1977, then from September 2003 to April 2005. Another wet long duration detected from February 2009 to February 2011.

The SPI-18 (figure 5-9) moves slowly below and above zero, "that means the SPI responds slowly to changes in precipitations". The maximum value 2.58 occurred in August 1976 and October 2009, defines the extremely wet months. While the minimum value -2.66 in February 1989, characterizes the extremely drought month.

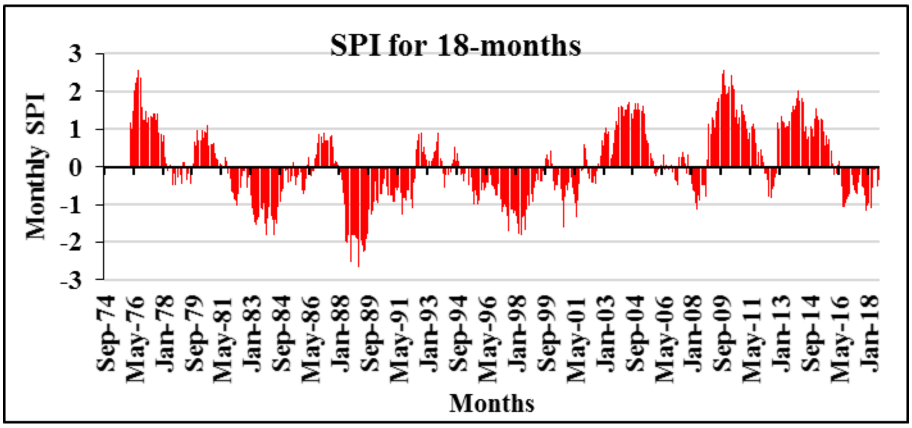


Figure 5-9: Standardized Precipitation Index time series calculated for Boukiou Catchment during (1974/1975-2017/2018) using time scale 18- months.

5.1.2.3.2.4- SPI 24-months

The SPI 24-months (Table 5-10 in Appendix) reveals a succession of drought duration from April 1983 to December 1984, and October 1988 to March 1990 identified as the longest duration, then, from January 1998 until January 1999. The longest wetly duration has been from December 2008 to January 2011.

The maximum value 2.52 of SPI-24 (figure 5-10) occurred in May, June, August and January 1977 corresponds to the extremely wet months. While the minimum value -2.01 in August 1989, determines the extremely drought month.

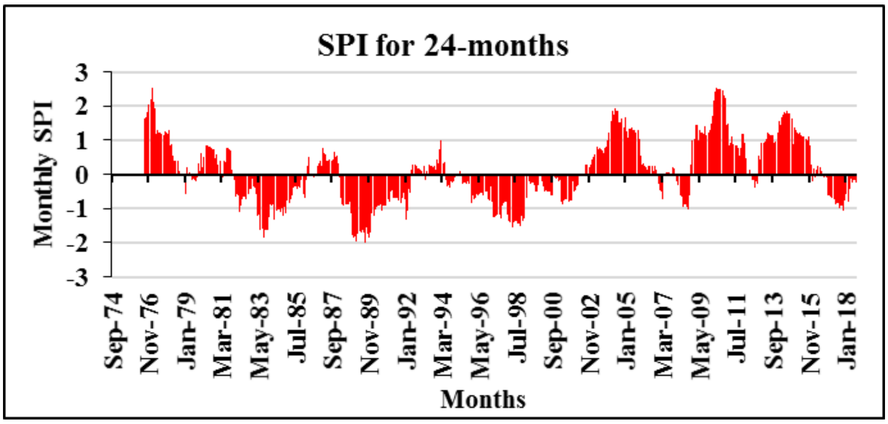


Figure 5-10: Standardized Precipitation Index time series calculated for Boukiou Catchment during (1974/1975-2017/2018) using time scale 24- months

5.1.2.3.2.5- SPI 48-months

The SPI index over 48- months (Table 5-11 in Appendix) permits to see a succession of drought period from April 1983 to December 1984 and from October 1988 to March 1990, which identified as the longest duration, then, in January 1998 to January 1999. The longest wetly period occurred from February 2010 to October 2016.

The result in the figure 5-11 shows that the maximum value 1.88 occurred in November 2012, defines a relatively very wet month. While the minimum value -1.43 that recorded in August 1991, indicates a relatively moderate drought month.

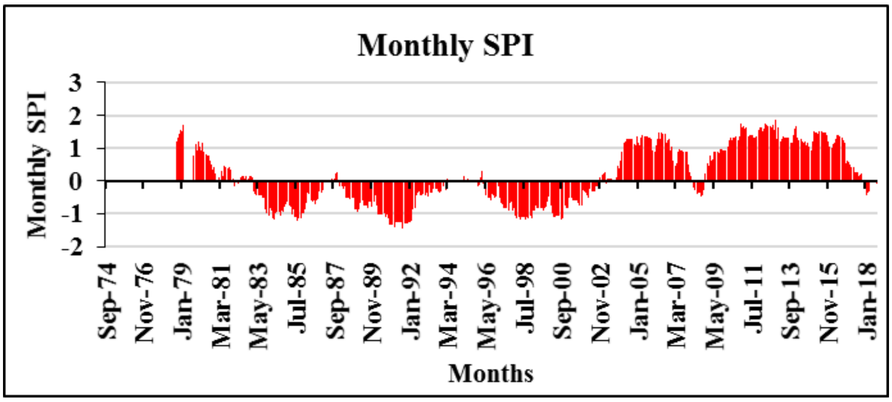


Figure 5-11: Standardized Precipitation Index time series calculated for Boukiou Catchment during (1974/1975-2017/2018) using time scale 48- months

5.1.2.3.3- Drought Frequency for SPI short and long-term drought

The drought frequency results detected for moving average Standardized Precipitations Index using differents Scales (SPI-3, 6, 9, 12, 18, 24, and 48 months) during (1974/1975-2017/2018) represented in the table and the figure below. It shows that the Near Normal class is the most frequent with 57% to 72.5% of years.

Table 5-12: Drought Frequency for SPI index using differents time-scales during (1974/1975-2017/2018)

Droughts Categories	SPI- 3 months	SPI -6 months	SPI- 9 months	SPI -12 months	SPI -18 months	SPI- 24 months	SPI -48 months
Extremly wet	2.5	2.5	2.5	1.9	2.5	2.5	0.0
Very wet	3.4	3.6	4.4	4.7	5.5	4.5	5.3
Moderatly wet	7.2	10.0	9.3	10.8	10.2	11.6	18.2
Near normal	72.5	68.9	67.0	66.1	65.7	66.5	57.2
Moderatly dry	8.1	6.6	8.5	7.8	7.8	6.4	10.2
Severly dry	3.8	4.7	3.4	4.4	4.0	4.0	0.0
Extremly dry	2.1	2.7	3.4	2.3	1.1	0.2	0.0

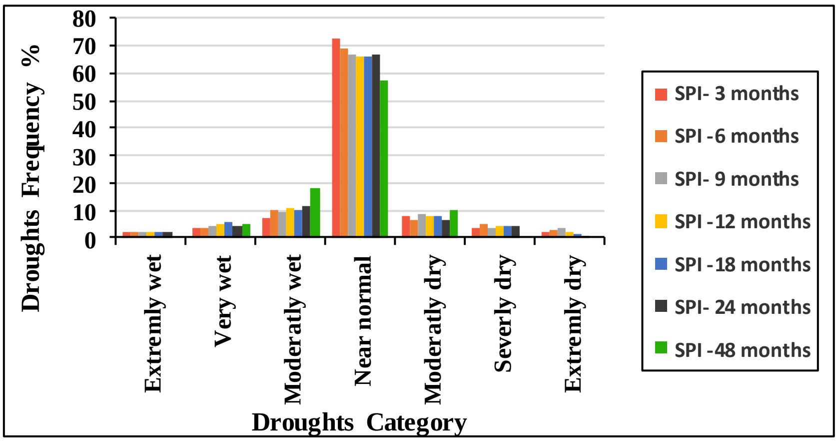


Figure 5-12: Droughts frequency Histogram for SPI index using differents time-scales during (1974/1975-2017/2018)

5.1.3- Percent of normal index result

5.1.3.1- Yearly PN result and interpretation

The yearly PN index evolution in our catchment (figure 5-13) and (Table 5-13) shows that the maximum PN value recorded during the year (2008/2009) reaches 191.3 characterizing a relatively wet event. The moderate dry event occurred during (1988/1989) and (1999/2000), while the weak drought event was detected in 1987/1988 with the minimum PN value 49.80

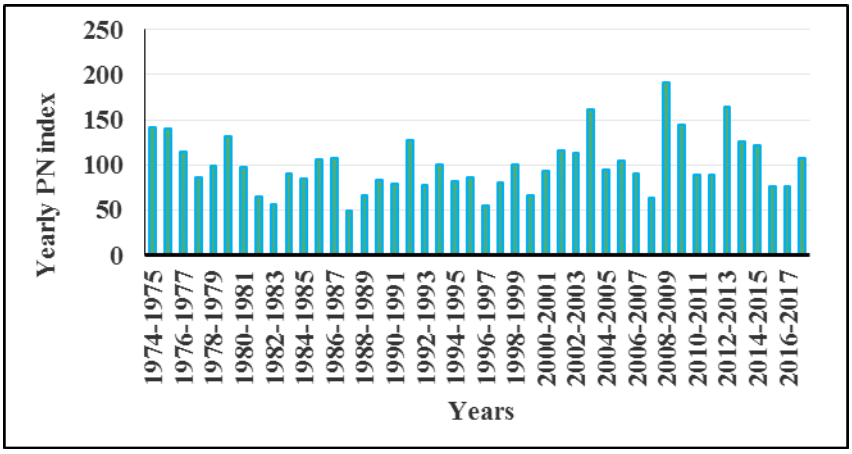


Figure 5-13: Yearly PN changes of the Boukiou catchment (1974/1975-2017/2018)

Table 5-13: Statistics of annual drought for PN index (1974/1975-2017/2018)

Years	PN	Years	PN	Years	PN
1974-1975	141.0	1989-1990	83.3	2004-2005	95.1
1975-1976	140.4	1990-1991	78.6	2005-2006	105.2
1976-1977	114.2	1991-1992	127.5	2006-2007	90.3
1977-1978	86.2	1992-1993	77.1	2007-2008	63.6
1978-1979	99.0	1993-1994	100.4	2008-2009	191.3
1979-1980	132.1	1994-1995	81.4	2009-2010	144.9
1980-1981	98.3	1995-1996	86.2	2010-2011	89.0
1981-1982	64.8	1996-1997	55.2	2011-2012	89.0
1982-1983	56.8	1997-1998	80.0	2012-2013	164.6
1983-1984	91.1	1998-1999	100.8	2013-2014	125.6
1984-1985	84.9	1999-2000	66.4	2014-2015	121.1
1985-1986	105.7	2000-2001	93.0	2015-2016	75.8
1986-1987	108.1	2001-2002	115.8	2016-2017	76.9
1987-1988	49.8	2002-2003	113.2	2017-2018	107.7
1988-1989	66.2	2003-2004	162.2		

The result of yearly drought frequency detected by PN index represented in the table 5-14 and the figure 5-14 shows that the wet class is the frequentest class with 43%, while 32 % are obtained for the Normal events. The rest represents the total of dry events reaches 25% where the moderate drought class recorded the highest percentage.

Table 5-14: Droughts Frequency results for PN index (1974/1975-2017/2018)

Drought Categories	Number of years	Drought Frequency %	Total %
Wet	19	43	**43**
Normal	14	32	**32**
Weak drought	5	11	**25**
Moderate drought	6	14	
Severe drought	0	0	
Extreme drought	0	0	

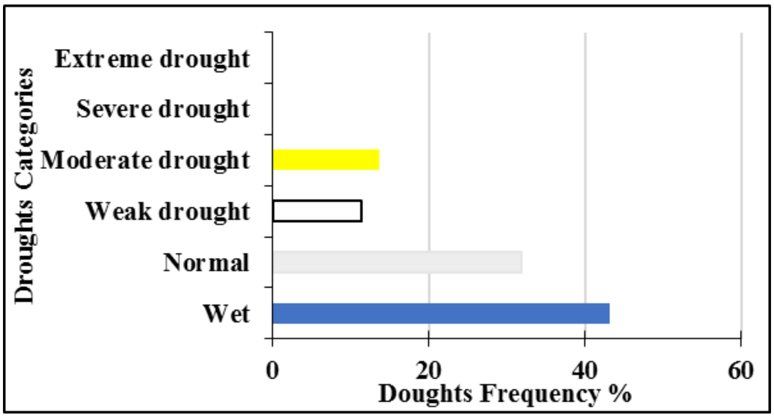
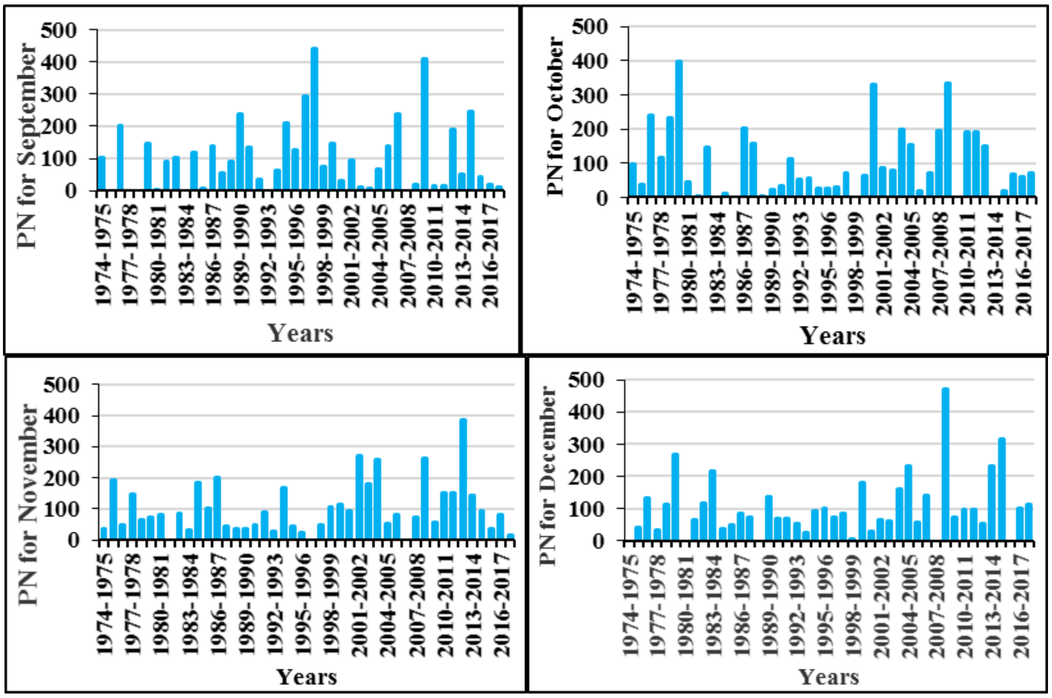


Figure 5-14: Drought frequency histogram of yearly PN index (1974/1975-2017/2018)

5.1.3.1- Monthly PN index result and interpretation

The monthly PN result represented in the (figure 5-15) and the (table 5-15 in Appendix) showed that the wet month occurred in June 1981 with the maximum PN intensity 1927.4. While, the extreme drought month is recorded in summer duration with the maximum PN intensity reaches 0, and the severe drought month in January 1995 with PN value 40.3.

The result shows also a succession of wetly periods varies from 1 month minimum to 6 months maximum during the years 1975/1976 and 2003/2004. However, we can observe a succession of dry months, varies from 1 month minimum to 9 months maximum as well as in the years 1982/1983 and 1987/1988.



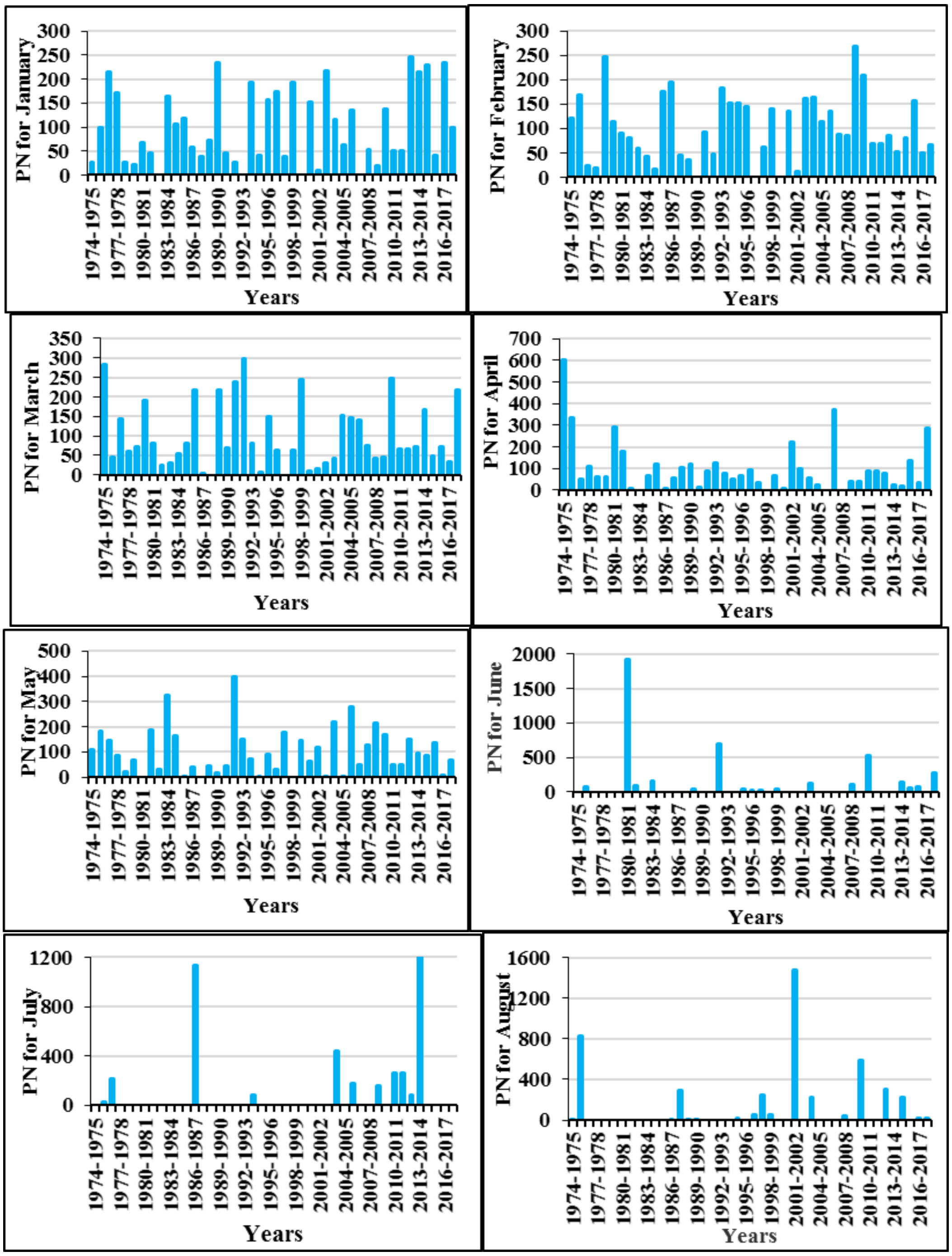


Figure 5-15: The monthly PN result (1974/1975-2017/2018)

The monthly drought frequency result obtained by the PN index (figure 5-16) reveals that 60% corresponds to the dry period, where the extreme drought class represents the highest percentage reaches 39%, and as we can see in the table5-16 “July and August “ are the most extremely drought months. While, 33 % define the wet period, where “January and February” are the most wetly months.

Table 5-16: Droughts Frequency results of monthly PN index (1974/1975-2017/2018)

Droughts Categories	S	O	N	D	J	F	M	A	M	J	Jl	A	Number of months	Droughts Frequency %	Total %
Wet	18	16	16	15	19	19	15	13	18	8	8	8	173	33	**33**
Normal	3	2	6	6	2	6	2	5	4	1	0	0	37	7	**7**
Weak drought	1	4	3	3	1	1	5	2	1	1	3	0	25	5	**60**
Moderate drought	2	4	2	6	3	5	6	7	3	1	0	0	39	7	
Severe drought	3	2	6	3	6	5	6	4	6	4	0	3	48	9	
Extreme drought	17	16	11	11	13	8	10	13	12	29	33	33	206	39	

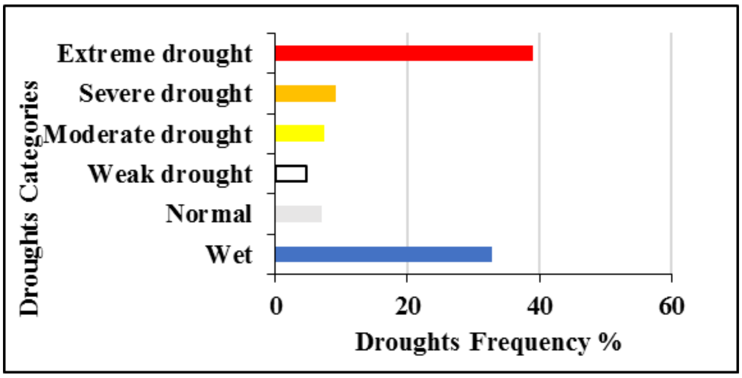
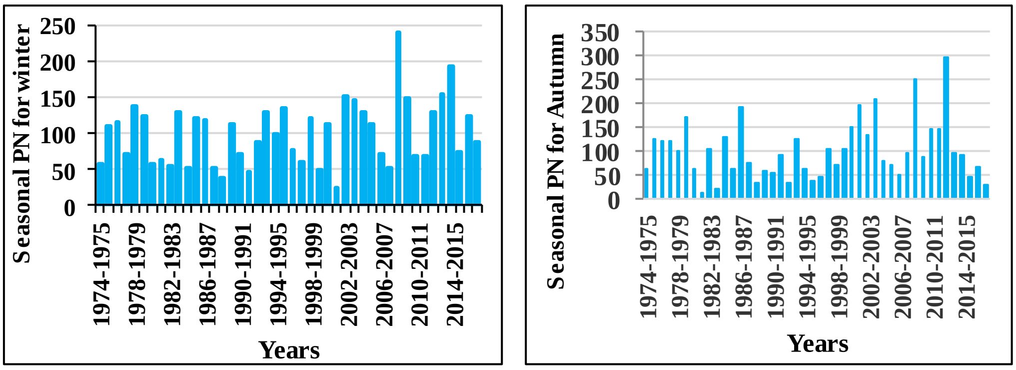


Figure 5-16: Drought Frequency Histogram for the monthly PN index.

5.1.3.2- Seasonal PN result and interpretation

The seasonal PN index in the Boukiou catchment (Figure 5-17) and (Table 5-17 in Appendix) shows that the maximum PN value '792' recorded during the summer season in (1980/1981) gives the wetly period . The table indicate also a succession of wetly period (the all season) in 1975/1976 and 2003/2004, while a succession of dry periods from severe to extreme drought during the year 1996/1997 started in Fall season ended in summer.



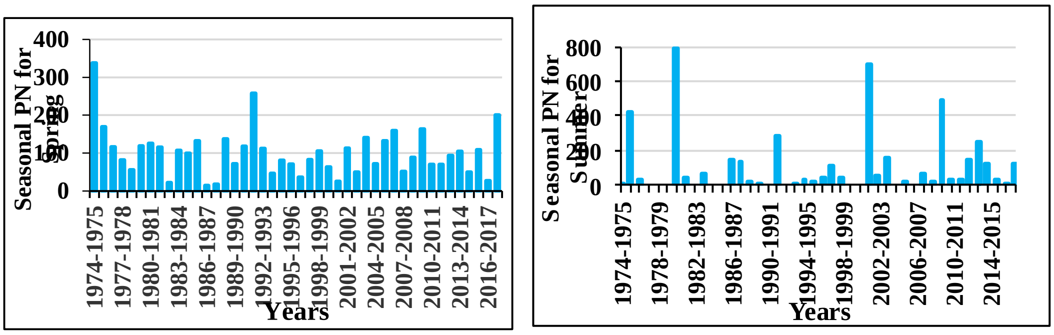


Figure 5-17: Seasonal drought Histogram for PN index (1974/1975-2017/2018)

Refering to the table 5-18 and the figure 5-18 below, we can say that the total of dry squence had the highest percentage with 48.9%, and 42.6 % is estimated for the total of wetly part, while only 8.5% is recorded for the Normal class.

Winter and Spring are identified as the most wetly seasons. Autumn was the most moderate season, and summer as the most extreme drought season.(Table 5-18)

Table 5-18: Droughts Frequency result of seasonal PN index (1974/1975-2017/2018)

Drought Categories	Autumn	Winter	Spring	Summer	Number of months	Drought Frequency %
Wet	19	22	21	13	**75**	**42.6**
Normal	6	3	6	0	**15**	**8.5**
Weak drought	3	7	3	0	**13**	**7.4**
Moderate drought	6	4	3	2	**15**	**8.5**
Severe drought	4	6	5	2	**17**	**9.7**
Extreme drought	6	2	6	27	**41**	**23.3**

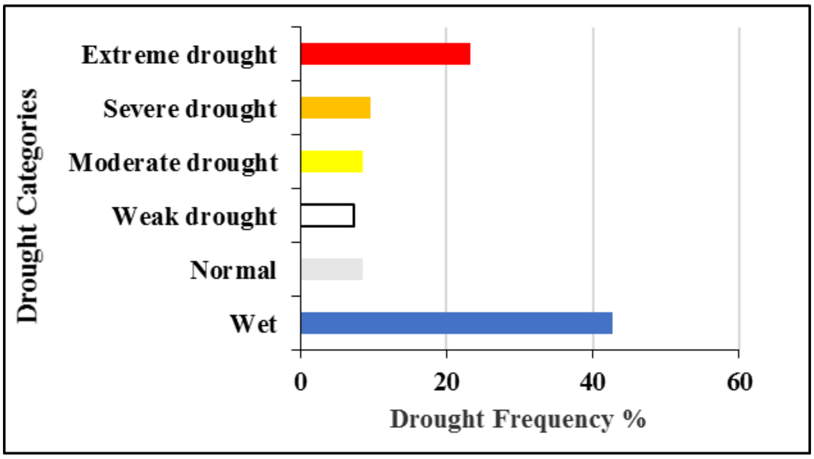


Figure 5-18: Droughts Frequency Histogram for seasonal PN index

5.1.4- Deciles index result

5.1.4.1- Yearly DI index results and interpretation

The yearly DI index evolution in our catchment (Figure 5-19), and according to the statistical drought results (Table 5-19) shows that the maximum DI index detected during 2003/2004, 2008/2009, 2009/2010, and 2012/2013 with value 10, testifies to the absence of dry period. While the minimum DI index reaches1 during 1982/1983, 1988/1987, 1996/1997, 2007/2008, expressing the extreme drought period.

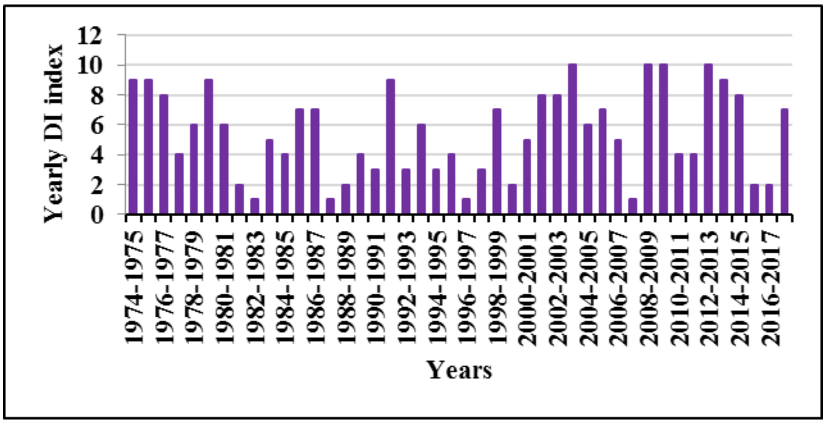


Figure 5-19: The yearly DI index changes of the Boukiou catchment (1974/1975-2017/2018)

Table 5-19: Statistics of annual drought for DI index (1974/1975-2017/2018)

Years	DI	Years	DI	Years	DI
1974-1975	9	1989-1990	4	2004-2005	6
1975-1976	9	1990-1991	3	2005-2006	7
1976-1977	8	1991-1992	9	2006-2007	5
1977-1978	4	1992-1993	3	2007-2008	1
1978-1979	6	1993-1994	6	2008-2009	10
1979-1980	9	1994-1995	3	2009-2010	10
1980-1981	6	1995-1996	4	2010-2011	4
1981-1982	2	1996-1997	1	2011-2012	4
1982-1983	1	1997-1998	3	2012-2013	10
1983-1984	5	1998-1999	7	2013-2014	9
1984-1985	4	1999-2000	2	2014-2015	8
1985-1986	7	2000-2001	5	2015-2016	2
1986-1987	7	2001-2002	8	2016-2017	2
1987-1988	1	2002-2003	8	2017-2018	7
1988-1989	2	2003-2004	10		

The figure5-20 and Table 5-20 indicate that the total of no dry events was the most highest percentage with 57 % than the dry events percentage 43 %.

Table 5-20: Droughts Frequency results of the yearly DI index (1974/1975-2017/2018)

Droughts Categories	Number of years	Droughts Frequency %	Total %
Extreme Drought	4	9.1	43
Severe Drought	5	11.4	
Moderate Drought	4	9.1	
Weak Drought	6	13.6	
No Drought	25	56.8	57

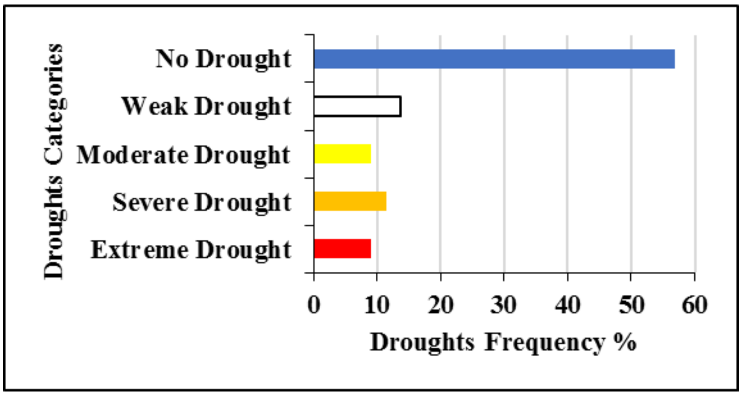
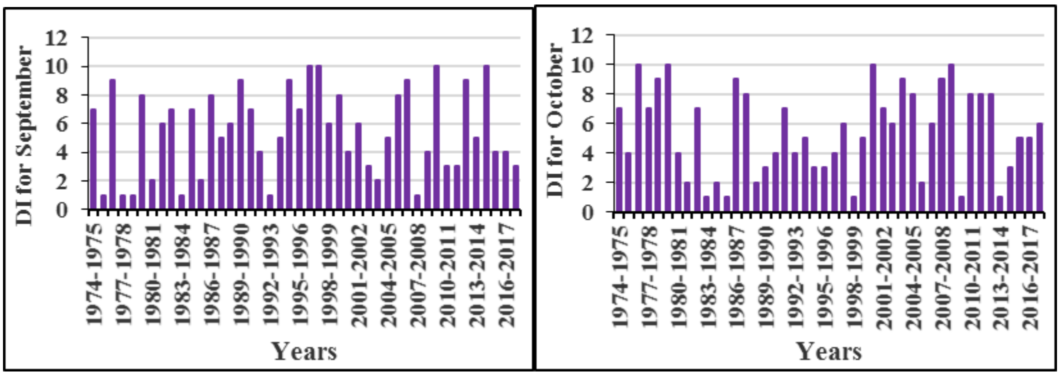


Figure 5-20: Droughts Frequency Histogram for DI index (1974/1975-2017/2018)

5.1.4.2- Monthly DI index results and interpretation

According to (Figure 5-21) and (Table 5-21 in Appendix), we observe a succession of No drought sequence varies from 1month minimum to 8 months maximum as well as from September 1986 to February 1987 (5 months), and from October 2003 until May 2004 (8 months). While, the succession of dry months varies from 1 to 11 months with different droughts classes, as well as from January 1983 to November 1984.



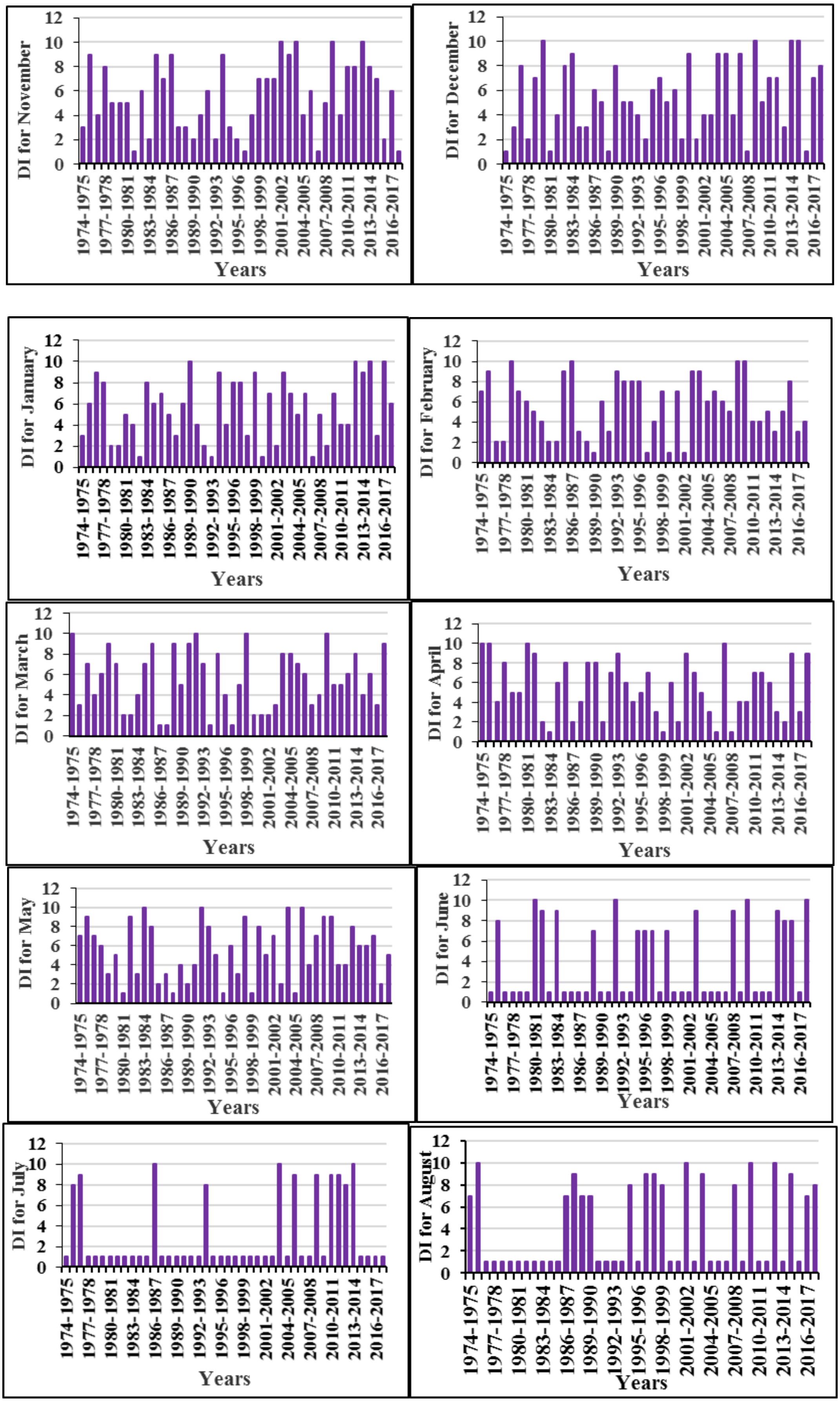


Figure 5-21: Monthly Drought result for DI index (1974/1975)-(2017/2018)

The monthly drought frequency (Table 5-22) and (Figure 5-22) reveals that the 47% occurred for the “dry period where we can see July was the most “extreme drought month”. While, the rest estimated for 53% with “No drought”

Table 5-22: Drought Frequency results for the monthly DI index (1974/1975-2017/2018)

Drought Categories	S	O	N	D	J	F	M	A	M	J	Jl	A	Number of months	Drought Frequency %	%
Extreme Drought	6	5	4	5	4	4	4	4	5	27	**33**	26	127	24	**47**
Severe Drought	3	4	5	4	5	5	5	5	4	0	0	0	40	8	
Moderate Drought	4	4	4	4	4	4	4	4	4	0	0	0	36	7	
Weak Drought	5	5	5	5	5	5	5	5	5	0	0	0	45	9	
No Drought	26	26	26	26	26	26	26	26	26	17	10	18	279	53	**53**

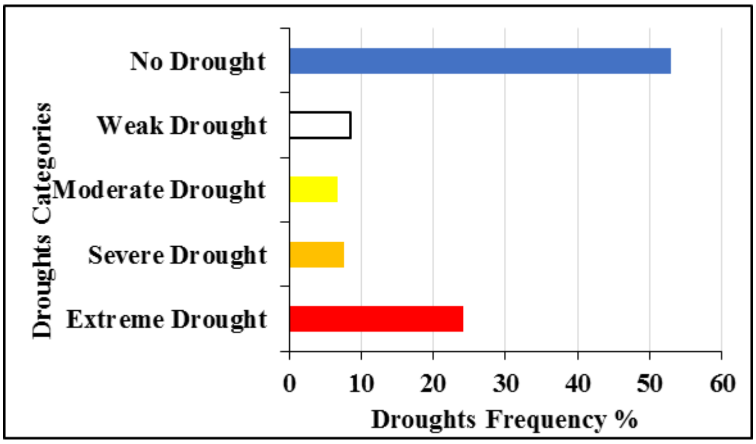


Figure 5-22: Drought Frequency Histogram for the monthly DI index

5.1.4.3- Seasonal Drought results for DI index and interpretation

The seasonal drought by DI index in the Boukiou catchment (Figure 5-23) and (Table 5-23 in Appendix). It indicates a succession of dry period with long duration from the winter season of 1982/1983 until the Autumn season in 1983/1984 from severe to extreme drought. While, we can observe a succession of no drought period with a long duration from Autumn 1975/1976 to Summer 1977/1978.

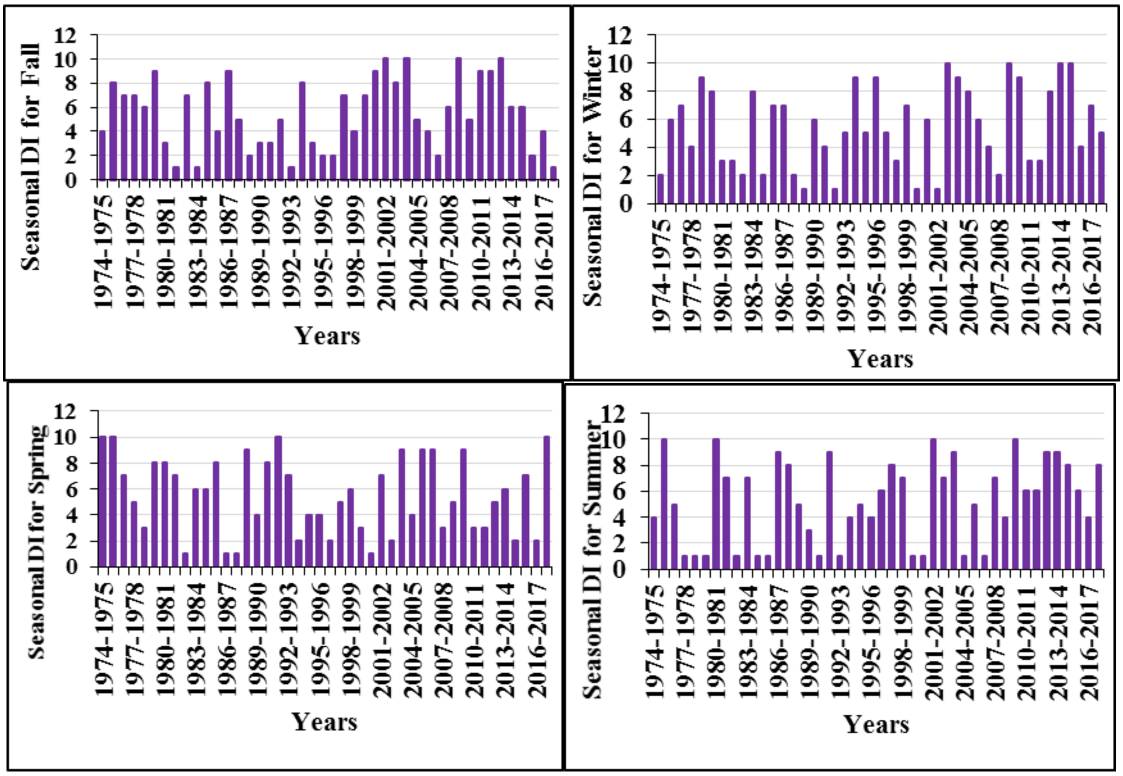


Figure 5-23: The Seasonal Drought results for DI index (1974/1975-2017/2018)

The drought frequency result as shows in the table and the figure below, expresses that the total of no drought events constitutes the highest percentage with 60% than the total of dry events with 40%, with 14 % for the extreme drought class. The Summer season is identified as the most extreme drought season, however, for No drought season all the season had the same percentage.

Table 5-24: Drought Frequency result of seasonal DI index (1974/1975-2017/2018)

Droughts Categories	Autumn	Winter	Spring	Summer	Number of months	Drought Frequency %	%
Extreme Drought	4	4	4	**12**	**24**	14	**40**
Severe Drought	5	5	5	0	**15**	9	
Moderate Drought	4	4	4	1	**13**	8	
Weak Drought	4	4	4	4	**16**	9	
No Drought	26	26	26	26	**104**	60	**60**

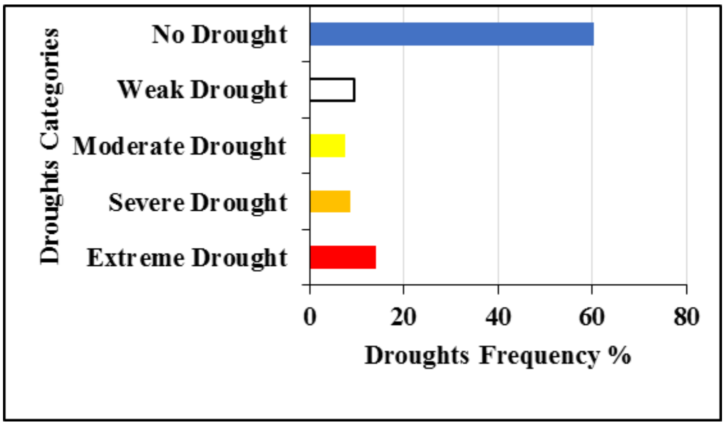
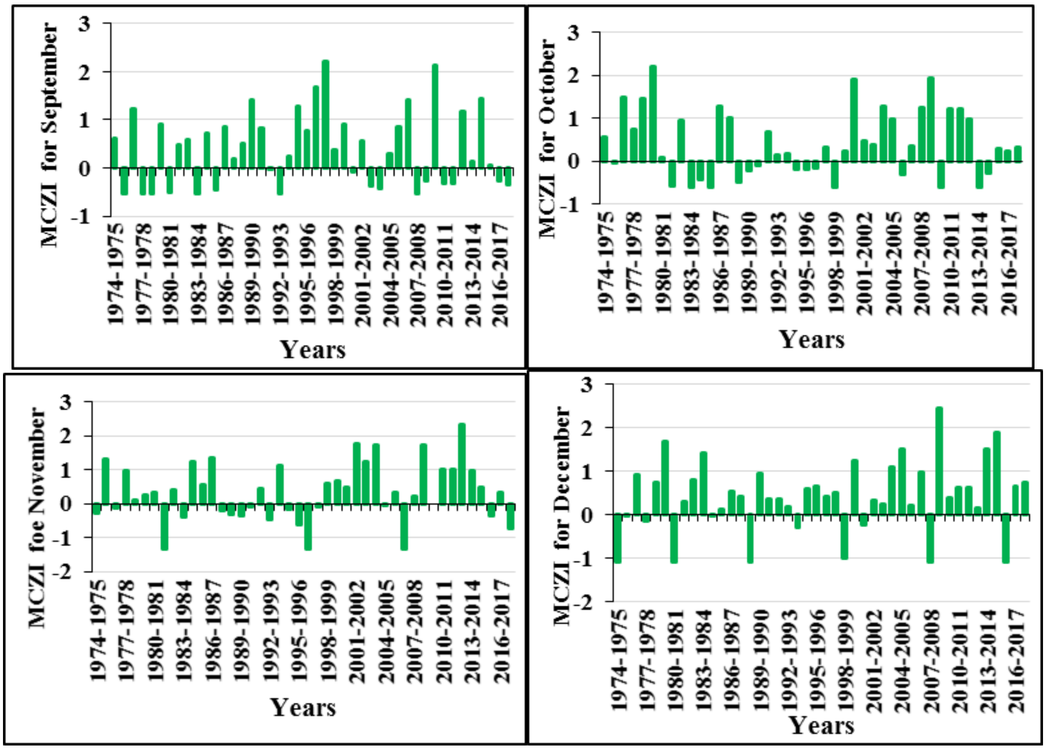


Figure 5-24: Drought Frequency Histogram % for the Seasonal DI index

5.1.5- Modified Chinese Z Index 'MCZI' results

5.1.5.1- Monthly "MCZI" results and interpretation

As shown in the (figure 5-25 and (table 5-25 in Appendix)), the maximum MCZI value with 2.65 recorded in June 1981, characterizes the extremely wet month. While, the severe drought months detected by monthly MCZI, occurred in (February, 1990- 1997-2000) reaches -1.57. The most moderate drought months with maximum intensity reaches -1.33 are identified in (November 1981, 1996, 2006)



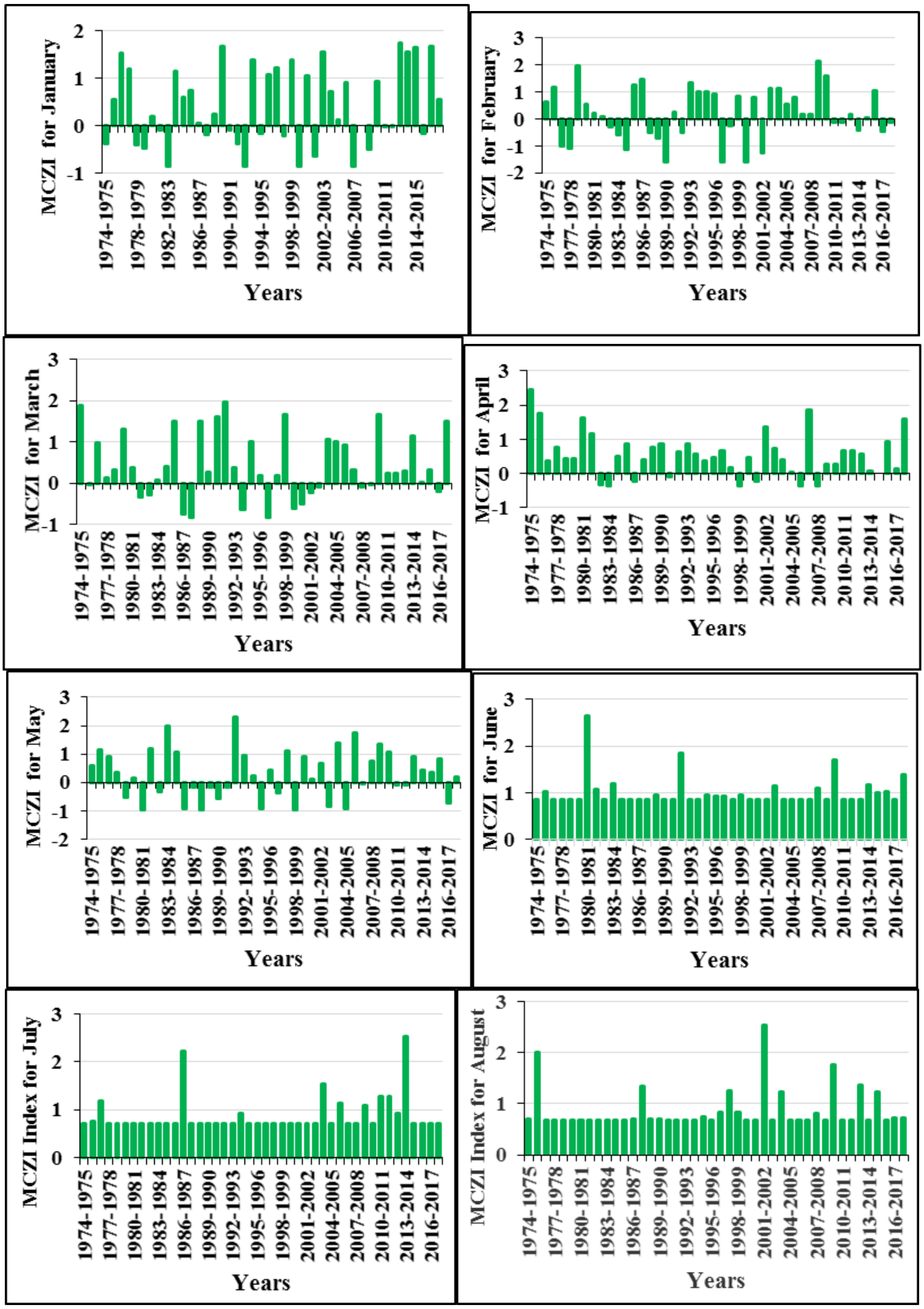


Figure 5-25: The monthly MCZI results (1974/1975-2017/2018)

According to this results, we can analyze drought occurrence frequency in our basin as shown in the table (Table 5-26) and the figure (Figure 5-26). The "Near Normal" class represents the highest percentage than the others classes with 74%. While, 23 % identified for the wet period where 15 % for the moderatly wet class and only 3% for the dry period.

The table of drought frequency results showed that "January" is the most frequently of the very wet month, and four months represents the highest percentage of the moderate wet months "October, February, March, June". Therefore, "December" constitutes the highest percentage of the moderate dry month.

Table 5-26: Drought Frequency results of monthly MCZI index (1974/1975-2017/2018)

Droughts Categories	S	O	N	D	J	F	M	A	M	J	Jl	A	Number of months	Droughts Frequency %	Total %
Extremly wet	2	1	1	1	0	1	0	1	1	1	2	2	13	**2**	**23**
Very wet	1	2	3	2	**7**	2	5	4	2	2	1	1	32	**6**	
moderatly wet	6	**8**	7	6	7	**8**	**8**	2	7	**9**	5	5	78	**15**	
Near normal	35	33	30	30	30	27	31	37	34	32	36	36	391	**74**	**74**
moderatly dry	0	0	3	**5**	0	3	0	0	0	0	0	0	11	**2**	**3**
severly dry	0	0	0	0	0	**3**	0	0	0	0	0	0	3	**1**	
extremly dry	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	

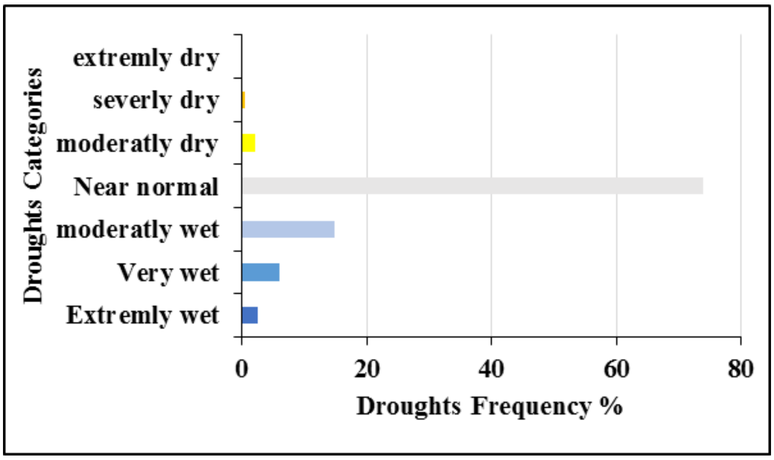


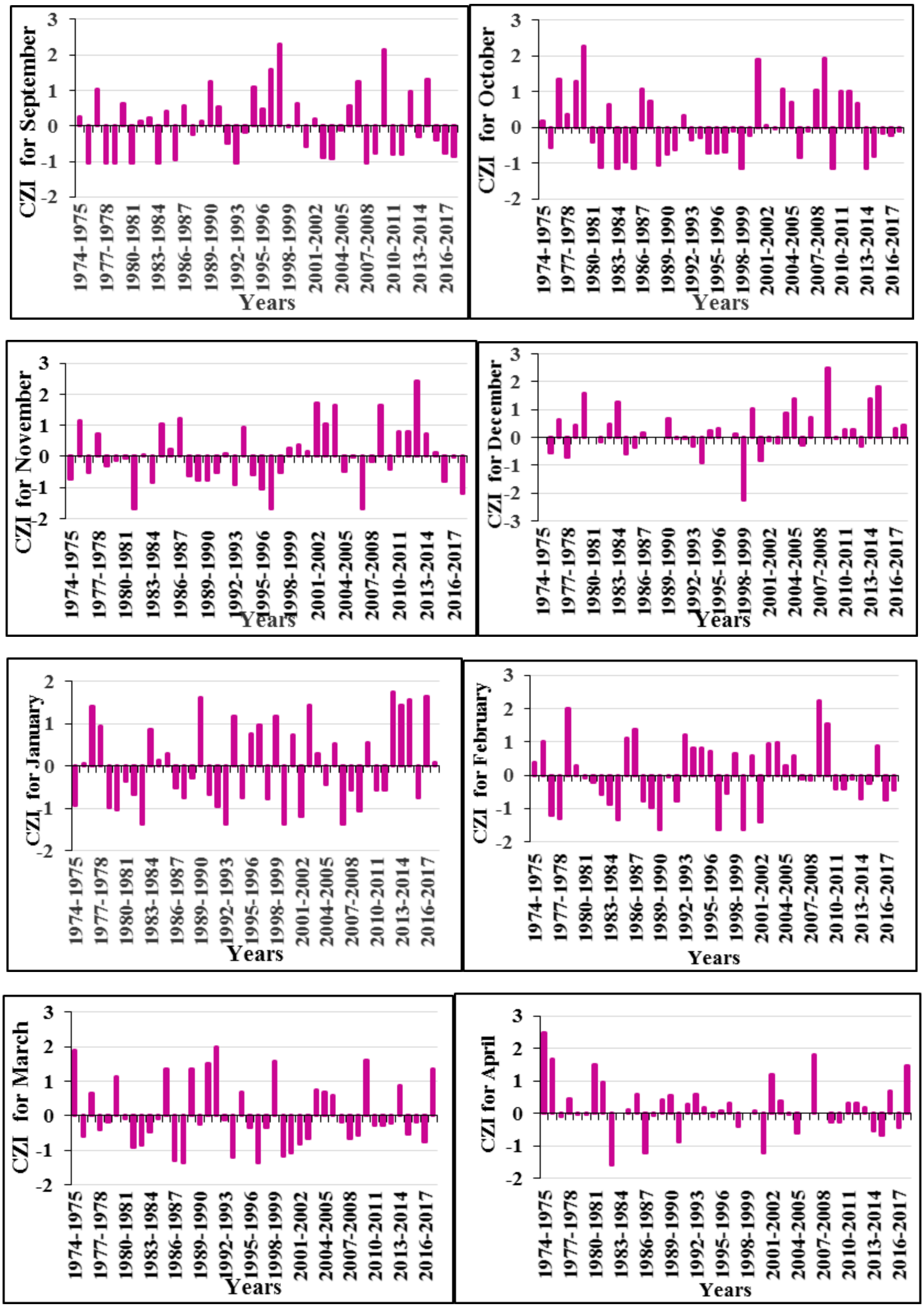
Figure 5-26: Drought Frequency Histogram for MCZI index .

5.1.6- Chinese Z Index 'CZI' results

5.1.6.1- Monthly "CZI" result and interpretation

The monthly drought result obtained by CZI index as showed in the Table 5-27 in (Appendix) and the figure 5-27 indicates that December 1998 is the most extremly dry month with the intensity -2.25, and the most severe dry months are identified in (November 1996, and February 1997, February 2000). The maximum CZI value reaches 2.64 in June 1981 characterizes a relatively extreme wet month, and the very wet month is occurred in February 1979 with the value 1.99

The result of calculation of monthly CZI index, gives 9 values of "NaN", which refer to a null value (not a number) like in December, 1974-1980-1988-2007-2015, then in April, 1984-1999-2006-2008.



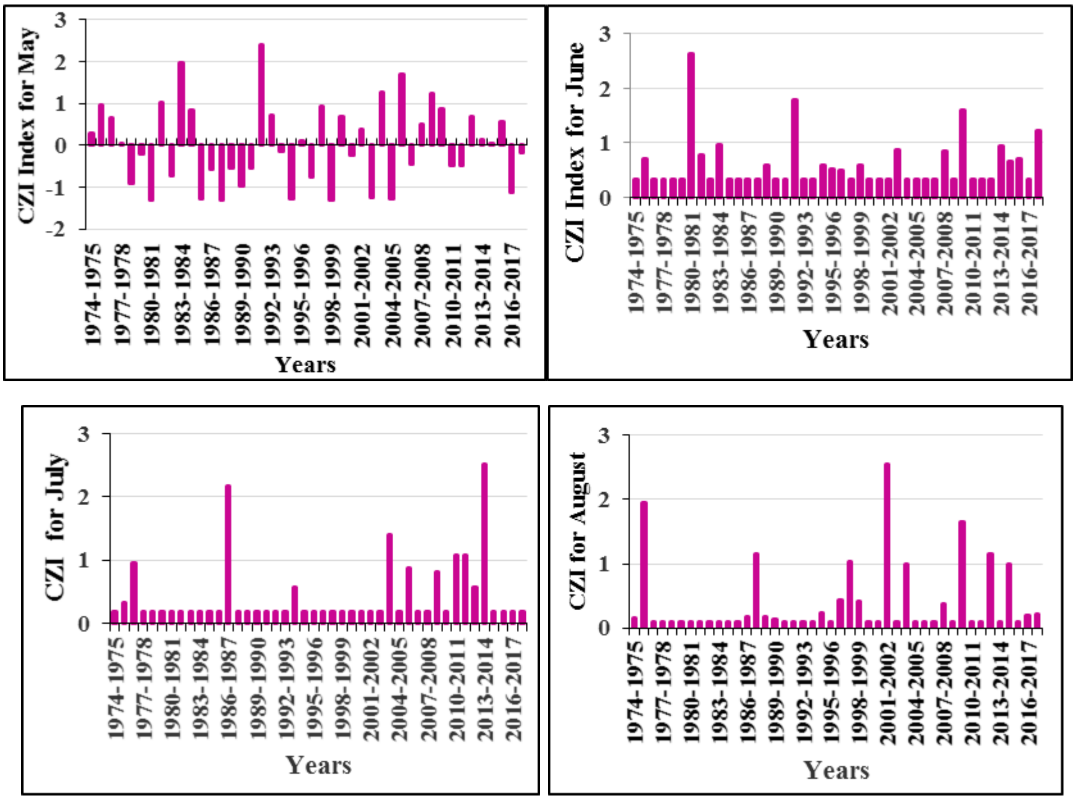


Figure 5-27: Monthly Drought result for CZI index (1974/1975-2017/2018)

According to this result, we can analyze drought occurrence frequency in our basin as shown in the table and the figure below, we obtain 9% for the total dry frequency, in other hand the total wet frequency is estimated by 16% while 73% corresponds to the total of Near Normal class which is the most frequent.

Table 5-28: Droughts Frequency results for CZI index (1974/1975-2017/2018)

Droughts Categories	S	O	N	D	J	F	M	A	M	J	Jl	A	Number of months	Droughts Frequency %	%
Extremly wet	2	1	1	1	0	**1**	**1**	**1**	1	1	**2**	**1**	13	3	
Very wet	1	2	3	2	4	2	4	2	2	**2**	**0**	**2**	26	5	**16**
moderatly wet	5	7	4	3	5	4	4	3	1	**1**	**3**	**4**	44	9	
Near normal	29	27	31	31	28	30	29	31	40	40	39	37	392	76	**73**
moderatly dry	7	7	2	1	7	4	6	2	0	0	0	0	36	7	
severly dry	0	0	3	0	0	3	0	1	0	0	0	0	7	1	**9**
extremly dry	0	0	0	1	0	0	0	0	0	0	0	0	1	0	

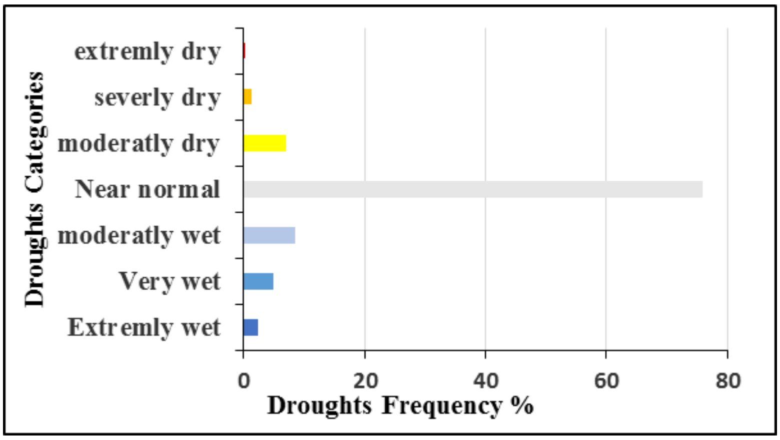


Figure 5-28: Droughts Frequency Histogram result for the monthly CZI index

5.1.7- Z-Score Statistics Index results

5.1.7.1- Yearly Z-Score results and interpretation

The yearly Z-Score index evolution in the basin is marked by alternating wet and dry sequences at the study station (figure 5-29). Indeed, we observe the wet period revealed between 1974/1975 and 1980/1981, then, it followed by a sequence of drought with a shortage in rainfall from 1980/1981 until 2008/2009. Finally, we can see a return to the wetly period from 2008/2009 until 2017/2018.

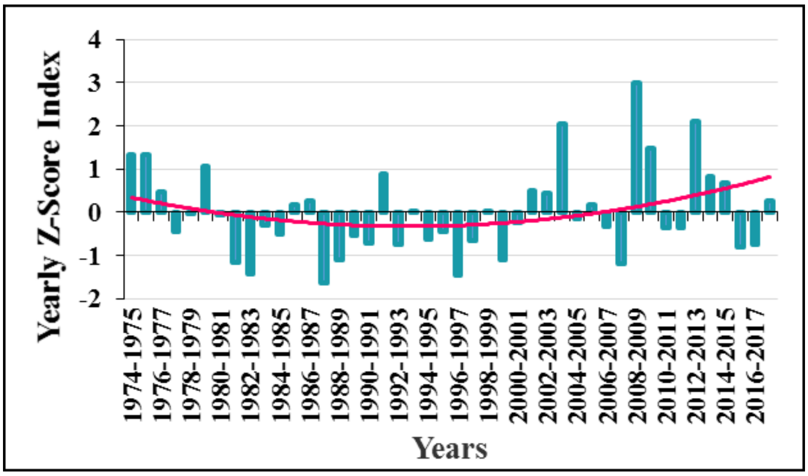


Figure 5-29: The yearly Z-Score index changes of the Boukiou watershed

(1974/1975-2017/2018)

According to the actual statistics of annual drought, (Table5-29) the extremely drought period occurred in the Boukiou River Basin during 1987/1988 reaches -1.65. While, the maximum Z-Score recorded during the year 2008/2009 reaches 3.00, this characterizes a relatively the No drought period.

Table 5-29: Yearly drought result for Z-Score index (1974/1975-2017/2018)

Years	Yearly Z-score	Years	Yearly Z-score	Years	Yearly Z-score
1974-1975	1.35	**1989-1990**	-0.55	**2004-2005**	-0.16
1975-1976	1.33	**1990-1991**	-0.70	**2005-2006**	0.17
1976-1977	0.47	**1991-1992**	0.90	**2006-2007**	-0.32
1977-1978	-0.45	**1992-1993**	-0.75	**2007-2008**	-1.19
1978-1979	-0.03	**1993-1994**	0.01	**2008-2009**	3.00
1979-1980	1.05	**1994-1995**	-0.61	**2009-2010**	1.47
1980-1981	-0.06	**1995-1996**	-0.45	**2010-2011**	-0.36
1981-1982	-1.15	**1996-1997**	-1.47	**2011-2012**	-0.36
1982-1983	-1.42	**1997-1998**	-0.66	**2012-2013**	2.12
1983-1984	-0.29	**1998-1999**	0.03	**2013-2014**	0.84
1984-1985	-0.49	**1999-2000**	-1.10	**2014-2015**	0.69
1985-1986	0.19	**2000-2001**	-0.23	**2015-2016**	-0.79
1986-1987	0.26	**2001-2002**	0.52	**2016-2017**	-0.76
1987-1988	-1.65	**2002-2003**	0.43	**2017-2018**	0.25
1988-1989	-1.11	**2003-2004**	2.04		

According to the calculation results (Figure 5-30 and Table 5-30), we can conclude that the total of drought period had the highest percentage with 68% than the total of No drought period with 32%.

Table 5-30: Droughts Frequency results for the yearly Z-Score index (1974/1975-2017/2018)

Droughts Categories	Yearly Z-Score	Droughts Frequency %	Total %
No Drought	14	31.8	**32**
Weak Drought	8	18.2	**68**
Slight Drought	8	18.2	
Moderatly Drought	7	15.9	
Severly Drought	4	9.1	
Extremly Drought	3	6.8	

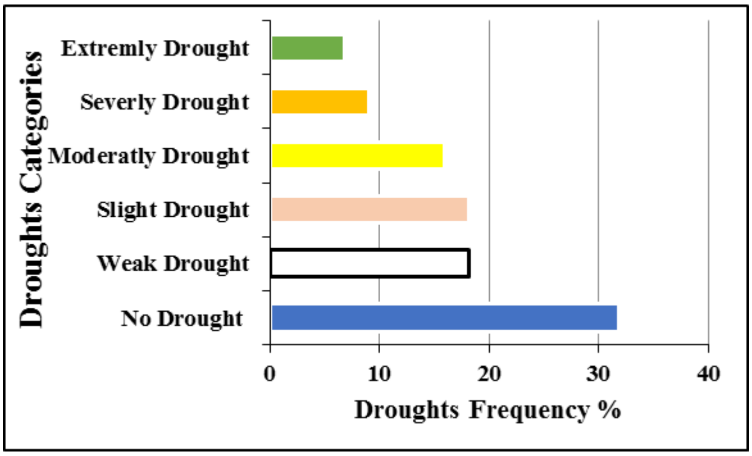
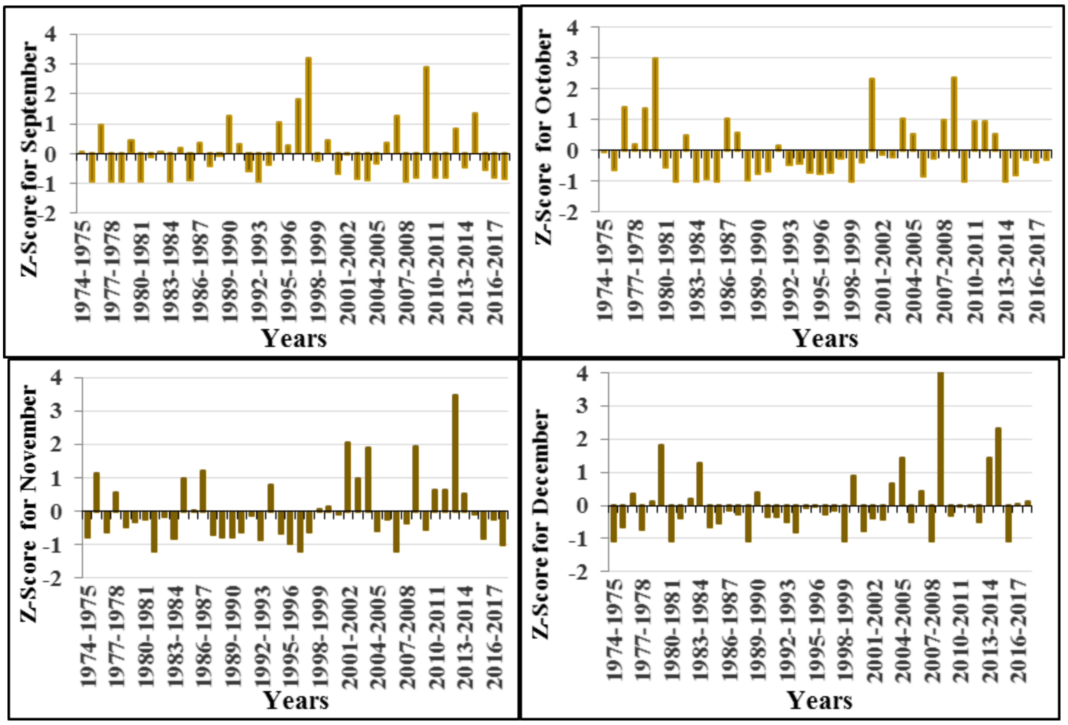


Figure 5-30: Droughts Frequency Histogram for the yearly Z-Score index

5.1.7.2- Monthly Z-Score results and interpretation

The (figure 5-31) and (Table 5-31 in Appendix) show that the maximum Z-Score value recorded in June 1981 with 5.9, and August 2001/2002 (5), July 2008/2009 (4.2). The severe drought period occurred during (February 1978, November 1981, March 1988, November 1996, March 1997, November 2006) with Z-score intensity equal to 1.2.



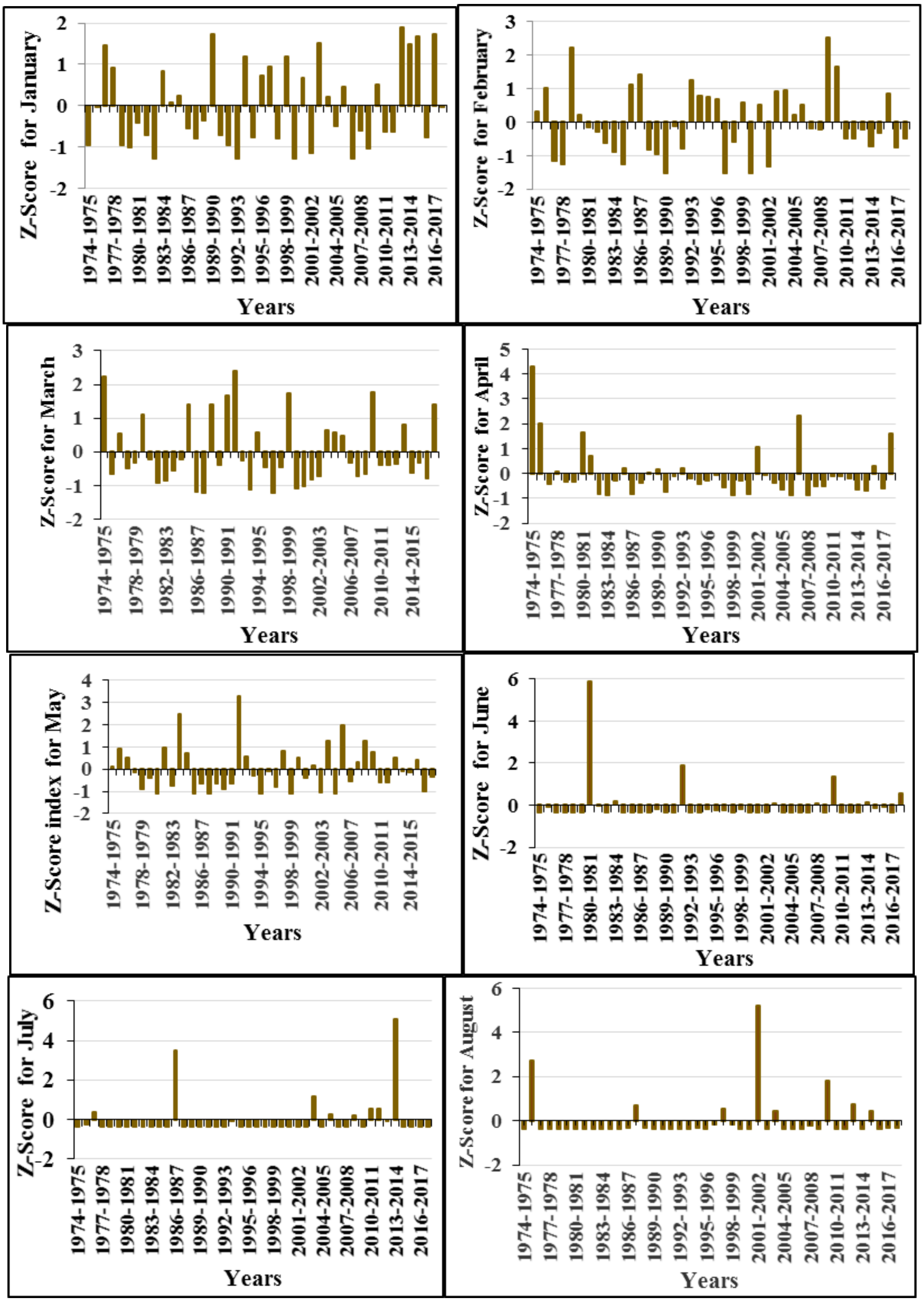


Figure 5-31: The monthly drought result for Z-Score index (1974/1975-2017/2018)

The monthly drought frequency detected by Z-Score index as showed in the (Table 5-32 and the Figure 5-32), present that in the total "drought period estimated by 73%, the slight drought constitutes the highest frequent class with 29%. In The total of "No drought period" with 27% We can observe that February was the most "no drought month". And July the most slight drought month

Table 5-32: Drought Frequency results for monthly Z-Score index (1974/1975-2017/2018)

Droughts Categories	S	O	N	D	J	F	M	A	M	J	Jl	A	Number of months	Droughts Frequency %	%
No Drought	15	14	13	11	16	17	15	8	16	4	7	8	144	27	**27**
Weak Drought	7	5	9	10	5	7	3	12	6	13	3	3	83	16	**73**
Slight Drought	4	8	4	11	3	5	10	11	4	**27**	**34**	**33**	154	29	
Moderatly Drought	8	8	**12**	6	10	6	8	9	8	0	0	0	75	14	
Severly Drought	**10**	9	6	6	6	4	8	4	10	0	0	0	63	12	
Extremly Drought	0	0	0	0	4	5	0	0	0	0	0	0	9	2	

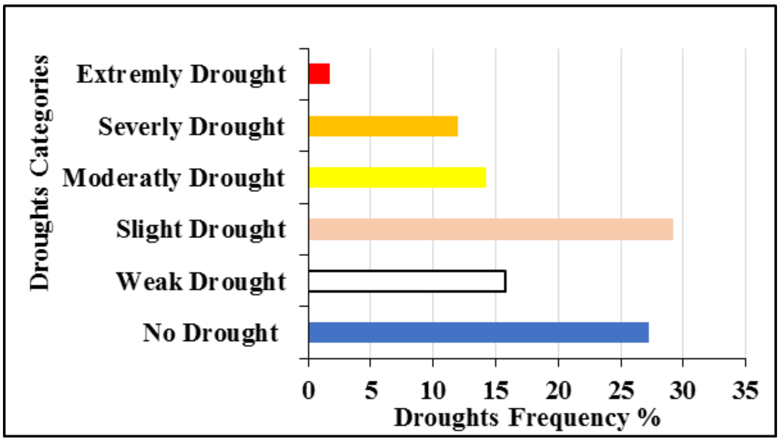


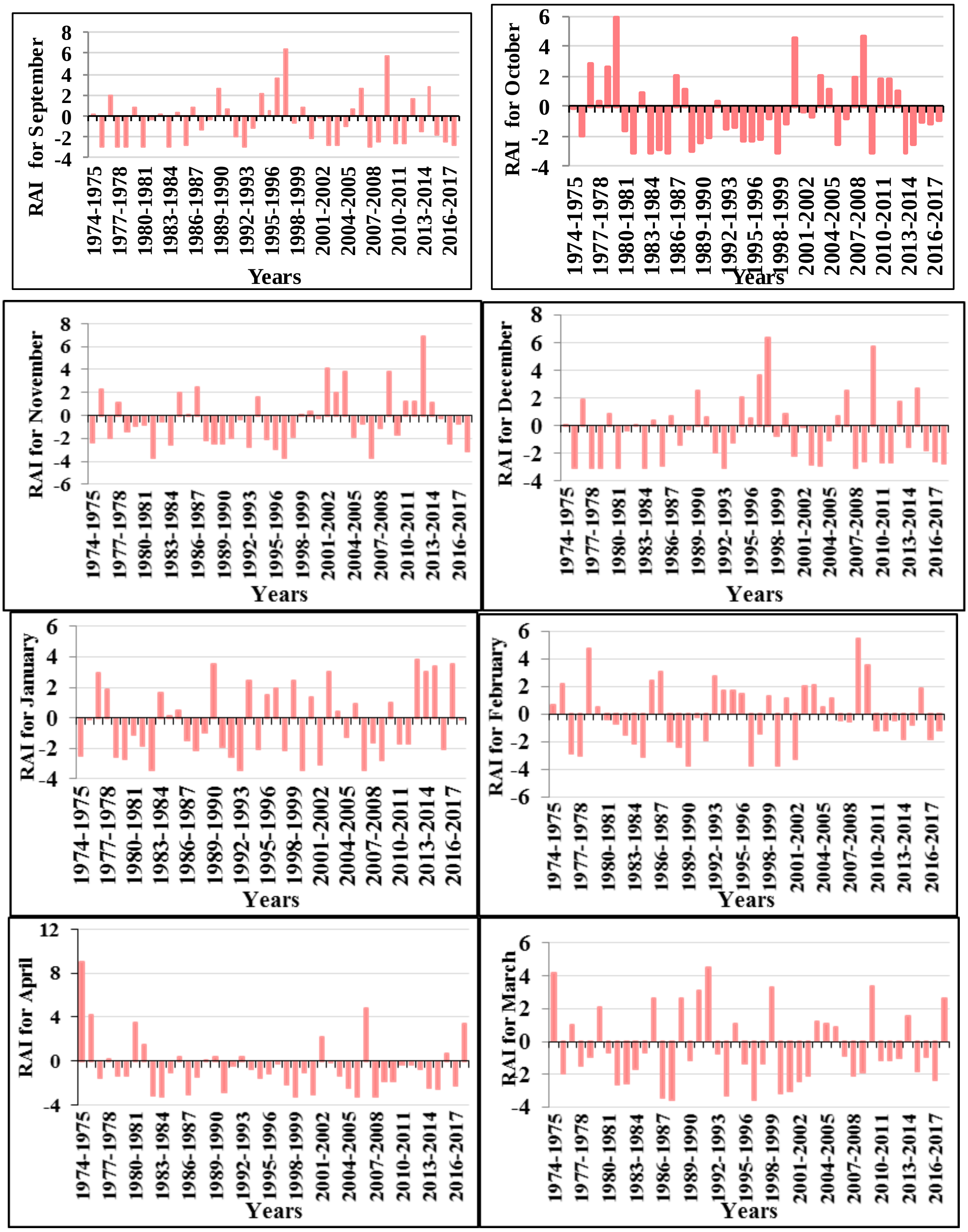
Figure 5-32: Drought Frequency Histogram for the monthly Z-Score index.

5.1.8- Rainfall Anomaly Index 'RAI' result

5.1.8.1- Monthly Drought results for RAI index and interpretation

The monthly drought results for RAI index (Figure 5-33 and (Table 5-33 in Appendix), it showed that the maximum RAI value observed in June 1981 reaches 17.69, which characterizes a relatively wet month. While, the extremly drought month identified in November 1996 and November 2006.

We observe a succession of wetly periods from 1 to 6 months. While for the drought periods vary from 1 to 7 months.


RAI for September
Years
RAI for October
Years
RAI for November
Years
RAI for December
Years
RAI for January
Years
RAI for February
Years
RAI for April
Years
RAI for March
Years
1974-1975
1977-1978
1980-1981
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2016-2017

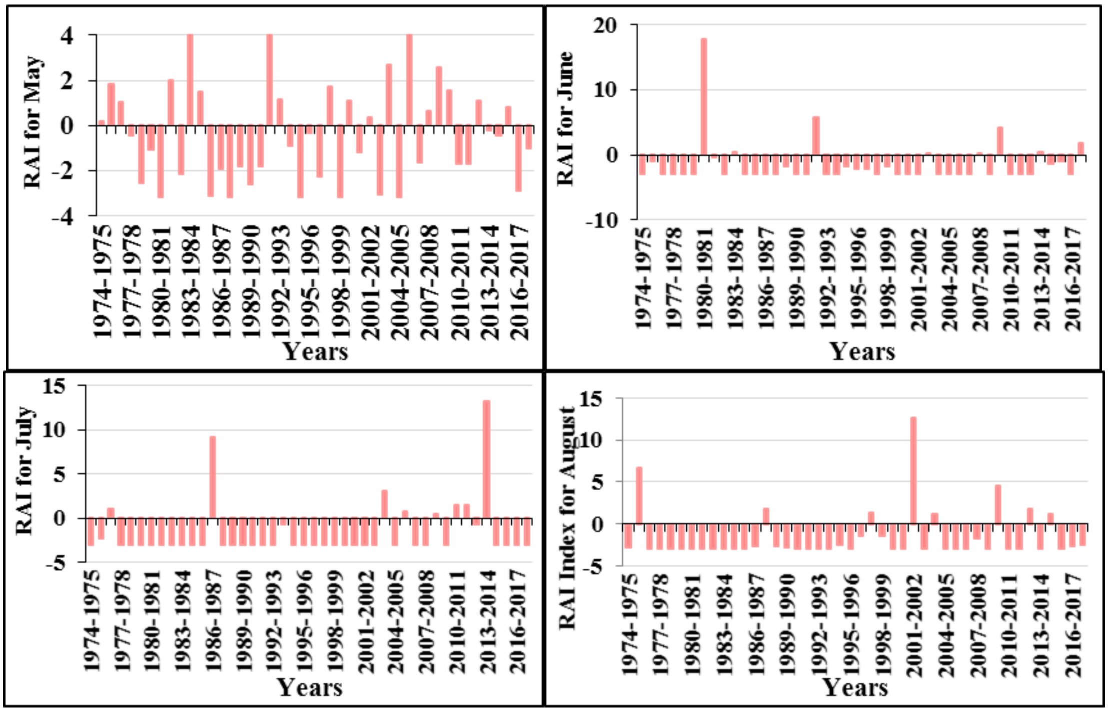

Figure 5-33: Monthly Drought results for RAI index (1974/1975-2017/2018)

The drought frequency (Table 5-34) and the (Figure 5-34) reveal that the dry period was estimated by 52%, and the wetly period by 36%. The rest of 12% represent the near normal period. In the wet category, the extremely wet occupy the highest level by 30%, in other hand the severly dry is identified as the highest percentage in the dry category by 29%.supprimer

February is the extremely wet month, January the moderate wet month, while July is the severe dry month.

Table 5-34: Drought Frequency results for monthly RAI index (1974/1975-2017/2018)

Droughts Categories	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Jl**	**A**	**Numbers of months**	**Droughts Frequency %**	**%**
Extremly wet	16	15	14	12	18	**19**	15	11	17	6	8	8	159	**30**	**36**
Moderatly wet	4	2	4	**7**	3	1	0	4	2	2	0	0	29	**5**	
Near normal	4	6	7	8	2	8	10	8	7	3	2	0	65	**12**	**12**
Moderatly dry	4	6	7	7	**9**	7	**8**	8	6	4	0	3	69	**13**	**52**
Severly dry	9	8	8	4	7	3	5	6	5	**29**	**34**	**33**	151	**29**	
Extremly dry	**7**	**7**	4	6	5	6	6	**7**	**7**	0	0	0	55	**10**	

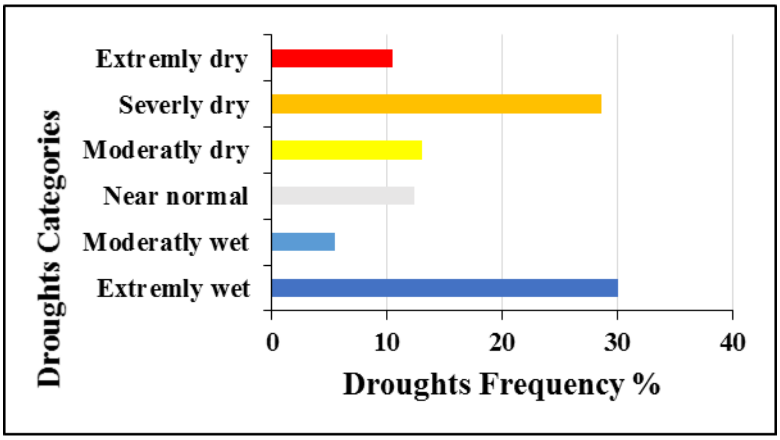

Figure 5-34: Droughts Frequency Histogram for RAI index (1974/1975-2017/2018)

5.1.9- Effective Drought Index 'EDI' results and interpretation

The figure 5-35 of the daily Effective Drought Index over the period (1974/1975-2017/2018 indicate that the moderate drought event relieved during the period 1980-1982 and 1983/1984 which represented a long duration of drought, then during 1992/1993, 1996/1997 . The extreme drought period occurred during 2017/2018.

While the moderatly wet event relieved during 2000/2001, 2012/2013, besides a very wet and extremly wet events relieved during the years 2003/2004, 2008/2009, 2011/2012.

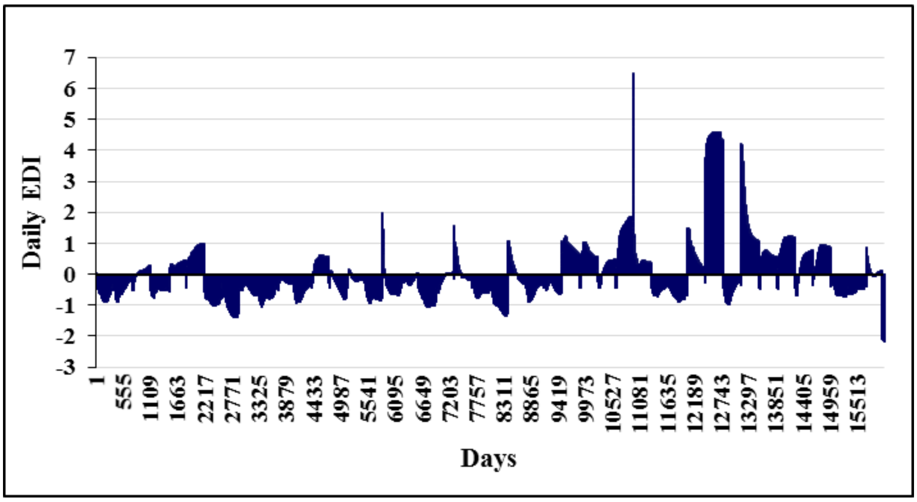

Figure 5-35: Daily EDI index Histogram for the Boukiou watershed during (1974/1975-2017/2018)

5.1.10- Conclusion

The following conclusion can be drawn from this study:

The application of climate indices SPI, PN, DI, EDI, RAI, CZI, MCZI, et Z-Score using the Meteorological Drought Monitoring Program have highlighted that the climate variability is characterized by alternating wet and dry sequences at the study station during the period (1974/1975-2017/2018). The meteorological drought events are from 1980/1981 until 2008/2009, while, the wet or no drought events observed from 1974/1975-1980/1981 and 2008/2009 until 2017/2018.

Generally, our basin had experienced a wet or No drought event during 1975/1977, 2003/2004 and 2008/2009. However, the drought event was indicated as the severe dry period during 1982/1983 and 1996/1997, while the extreme dry period detected during the year 1987/1988.

The monthly time step given that most of indices identifies “February” as the extreme wet month with the highest percentage, and January was a moderate wet month. While, “July” is identified as the extreme dry month. The seasonal time step result identifies the summer season as the extreme or severe dry season and “Winter and Spring” as the wetly seasons.

The drought frequency study for SPI, CZI, and MCZI indices indicate that the “Near Normal class” had the highest percentage of years, for PN and DI indices “No drought or wet class” and for both Z-Score, RAI indices, the “Dry class” had the maximum number of years.

Z-Score is an index easy to calculate, and the SPI is the complex index however it done a better result than the others indices.

The number of drought months grows with the increase of time step for Standardized Precipitations Index. When the time scales are small (3 or 6 months), the SPI moves frequently above and below zero. As the time scale is lengthened to 9, 12, 18, 24, 48 months, the SPI responds more slowly to changes in precipitation.

5.2- Result of HBV Light model

In this section, the results of successfully running the rainfall –runoff model are presented and discussed.

The Monte Carlo runs were used to evaluate the catchment response characteristics, and to explore the differences in the uncertainty for the different model's parameters. It is described in more detail by Seibert (2005). Moreover, this is found in the tools tab of HBV Light. The figure below show the possible parameter ranges of this procedure.

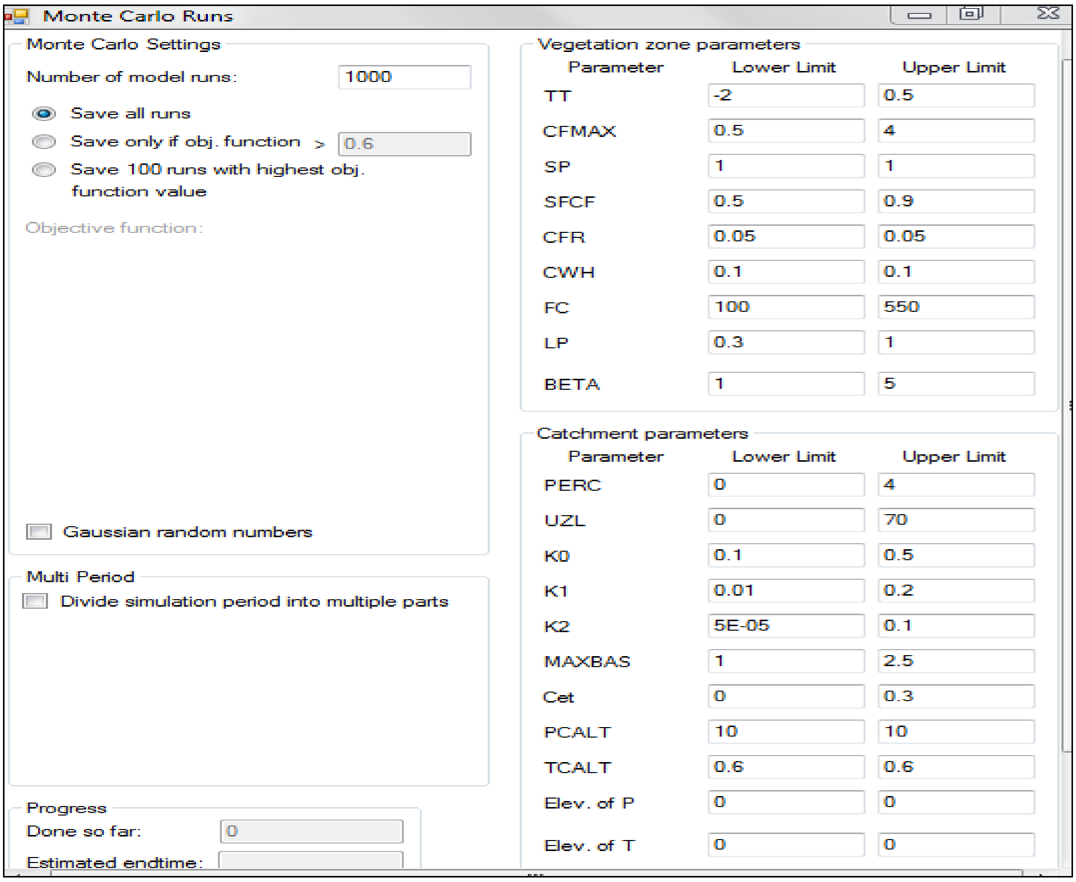

Figure 5-36: Parameters and their ranges applied during the Monte Carlo Simulations

The parameter uncertainty of the HBV model was studied by (Harline & Kung, 1992) using Monte Carlo procedure described by Hornberger, Cosby, & Galloway (1986).

The model calibration was carried out after passing through a number of simulations. Fifteen model parameters (TT, CFMAX, SFCF, CFR, CWH, FC, LP, BETA, PERC, UZL, K0, K1, K2, MAXBAS and Cet) were calibrated by applying changes to them while remaining within the limits of the interval space until an optimum Nash criterion equal to or greater than 70% and a more acceptable correlation coefficient between simulated and observed flows was obtained.

The values of the optimization parameters obtained during the calibration and validation over the different periods studied for the study area are presented in the Table 5-35. The optimized parameter values are those which give the best values of the model efficiency, coefficient of determination (R^2) and the mean difference between the observed and the simulated discharge values.

The analysis of the table shows us that the values of the optimization parameters obtained gives a good fit for both calibration and validation phases.

Table 5-35: Calibration and validation optimization parameters results of the daily time steps (2001-2014)

		Hydrological Parameters	Daily
Calibration and Validation Parameters		Calibration Period	1st September 2001 to 31st August 2010
		Validation Period	1st September 2010 to 31st August 2014
		TT (°C)	5
		(mm/(d °C))CFMAX	4
		SFCF[-]	0.9
		CFR[-]	0.05
		CWH[-]	0.1
		FC[-]	155
		LP[-]	0.11
		BETA[-]	3.59
		PERC [mm/d]	2.81
		UZL (mm)	1.69
		K0[d/1]	0.159
		K1 [d/1]	0.015
		K2 [d/1]	0.024
		MAXBAS [d]	5.2
		Cet [C°/1]	0.0801
The quality of fit	**Calibration**	Model Efficiency	**0.756**
		Coefficient of determination	**0.801**
	Validation	Model Efficiency	**0.758**
		Coefficient of determination	**0.917**

5.2.1- Graphics results of Calibration and validation phases

The PTQ plot type was generated from the simulation of the model , the table 5-36 describe their graphs result.

Table 5-36: The description of "PTQ" graph result by HBV Light model. (Seibert, 2005)

Plot type	Graph	Ploted variable (s)
PTQ	Top	Accumulated difference between simulated and observed discharge (black, right axis) and measured temperatures (red left axis)
	Middle	Measured precipitations (bleu, left axis) and simulated snow as water equivalent (green, right axis)
	Bottom	Observed (bleu) and simulated (red) discharge

5.2.1.1- Model Calibration

By analyzing the hydrographs of the observed and simulated discharge during the calibration period (1stSeptember 2001 to 31st August 2010) for the study catchment in the figure 5-37 we demonstrate that HBV Light model generally underestimate the peak values as well as during the periods 10 /11/2001 , 15/12/2008 , 05/02/2009. However, in 02nd 2009 of January shows overestimate the peak values. From the observed simulations, it seen that the low flow period is better simulated.

The scatter plot shows in the figure 5-38 illustrate the similar behavior of the observed and simulated discharges during the calibration. The visual inspection of the hydrographs (a good concordance of the two curves) and the coefficient of determination value 0.8, with the model efficiency value 0.75 obtained, and according to the description of the modeling evaluation criteria in the literature review those results demonstrate that the calibration performance of the HBV Light model is satisfactory.

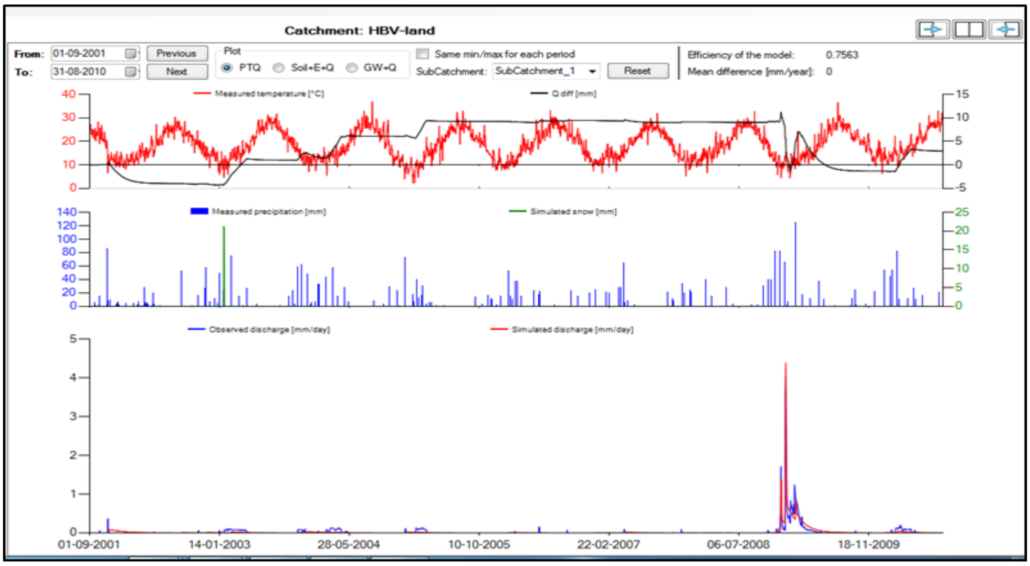

Figure 5-37: Visualizations of calibration quality for HBV Light model (1st September 2001-31st August 2010)

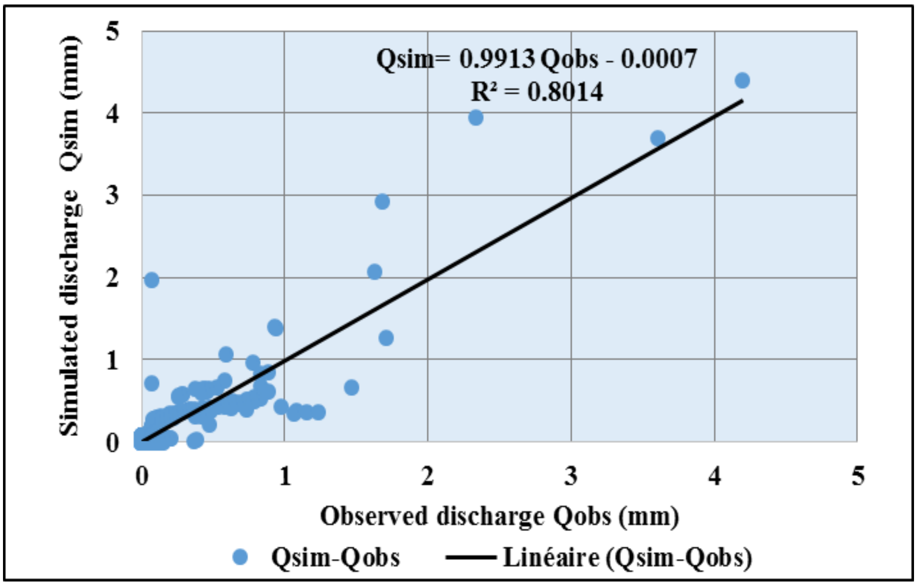

Figure 5-38: The correlation between Qsim and Qobs during calibration phase (1st September 2001-31st August 2010)

5.2.1.2- Model validation

The calibrated parameter sets were used for the representation of the catchment behavior using an independent data set for the validation period from 1st of September 2010 until 31st August 2014 (Table 5-35).The model tried to simulate the base flow hydrographs as shown in figure 5-4 above in order to have a good representation of the catchment characteristics that govern the water storage and delayed flow components generation. This showed the strength of the HBV Light model's soil routine and run-off generation routine. Also, the ability to reproduce good rainfall-run-off relation during mean and low flow periods.

The performance of the model validation results show in Table 5-35 and in both figures 5-39 &5-40. The model efficiency and the coefficient of determination are reaches 0.758 and 0.91 respectively. Those acceptable values, confirmed that the model was successfully validated.

The majority of the dots surround the line (Figure 5-40). The distant points below the line indicate that the observed discharge is greater than the simulated discharge and those above the line indicate the opposite.

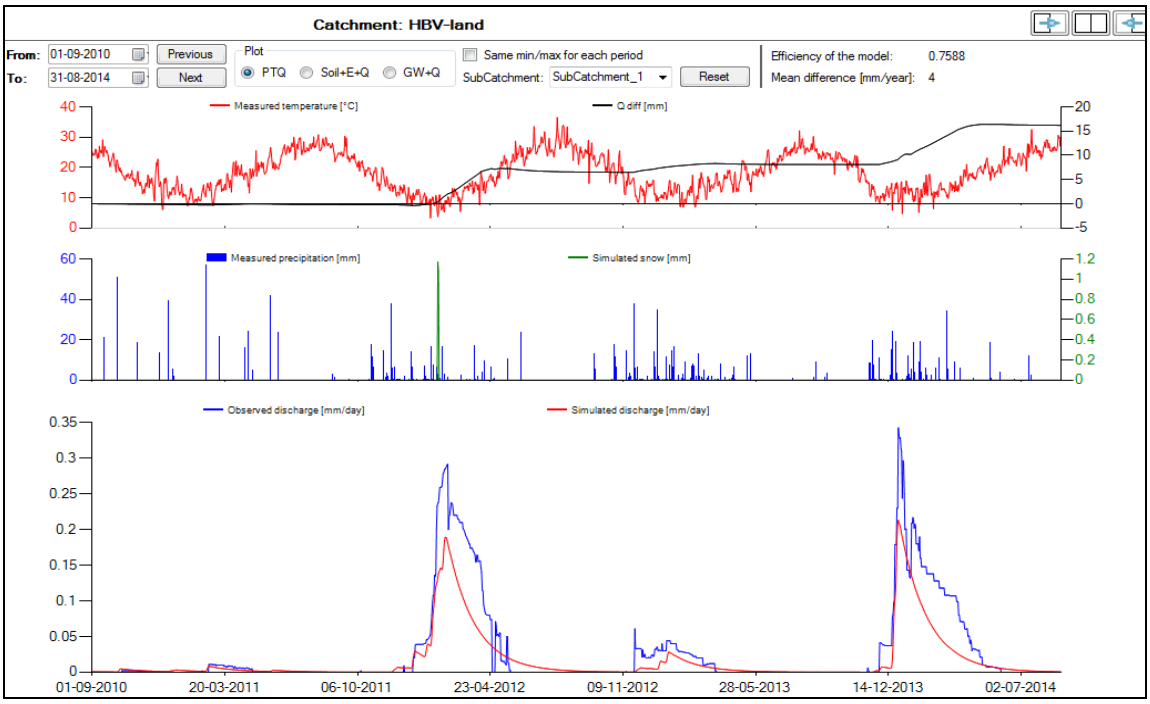

Figure 5-39: Visualizations of validation quality for HBV Light model

(1st September 2010-31st August 2014)

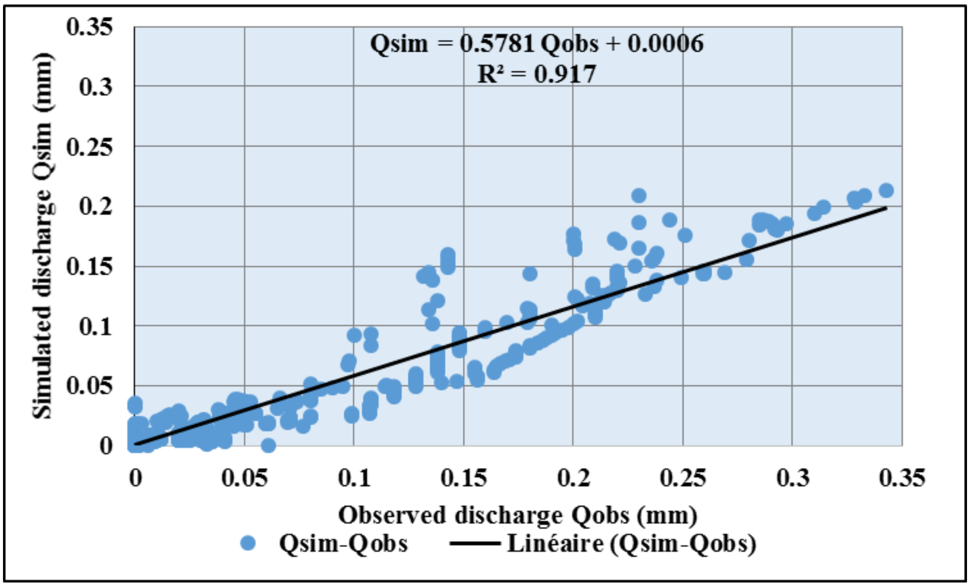

Figure 5-40: Correlation between Qsim and Qobs during validation phase

(1st September 2010-31st August 2014)

5.2.2- Water balance Analysis

A summary table 5-37 indicates the water balance result at the outlet of wadi Boukiou catchment obtained by calibration and validation process using the HBV Light model. It shows a decrease in runoff by 3 mm from the calibration to the validation periods.

Table 5-37: Water balance closure of the Boukiou catchment.

Boukiou catchment		
Water Balance [mm/y]	**Calibration**	**Validation**
Sum Qsim	9	6
Sum Q obs	12	12
Sum P	351	346
Sum AET	436	441
Sum PET	17726	17722
contribution of Q0	0.256	0.002
Contribution of Q1	0.028	0.001
Contribution of Q2	0.716	0.996

5.2.3- Conclusion

The modeling of the hydrological behavior of the Wadi Boukiou watershed has been attempted in this part by using the HBV Light model at the daily time step. The model performance is highly sensitive on the choice of values of parameter sets, the generation of a large number of parameter sets runs helps in prioritizing the important parameters to be used during calibration. The HBV light model has been proven to be effective to simulate the simulated discharge and the observed discharge in our study area where, both calibration and validation steps done a satisfactory results, producing of Nash –Sutcliffe coefficient 75% - 76% respectively. In addition, the values of coefficient of determination R^2 during the two steps are 0.80 -0.91 respectively.

6.1- Conclusion

This study is part of the research on the characterization of meteorological drought, the quantification of its impact on water resources in our study area and control of the water balance of the watershed by simulating the hydrological processes. To do that, two types of data were used: meteorological (rainfall, temperature) and hydrological (flow) data.

The results obtained can be summarized as follows:

- **The morphometric study** allowed us to identify the average altitudes and the most

frequent altitudes of our basin. The surface area and it perimeter, enabled us to quantify the Gravelius Compactness index (K_c) =1.50 which provides that it has an elongated shape.

The high value of the specific high difference D_s=247m and the global slope index I_g=0.0228 show that Boukiou watershed having a fairly high relief.

- **Geological study** based on previous work, in particular that of P. Guardia (1970-1975) illustrate that the study area shared between two large geological domains that are clearly different:

- The primary and secondary massif occupying the high altitudes.
- The Mio-plio-Quaternary occupying the plain at low altitude.
- The distribution of interannual precipitations at the climatic station of ’’Djebel Chouachi” is characterized by an irregularity regime from one year to another with an average equal to 290 mm/yr, while the evolution of seasonal precipitations identified winter as the wettest season, and summer as the driest season.

The corresponding temperature is equal 18 °C. In general, maximum temperatures are recorded in the months of July and August, and minimum temperatures are observed in the months of December to February.

The analysis of the climatic parameters (1974/1975-2017/2018) shows that our basin has a semi-arid Mediterranean climate with a temporary runoff.

Two seasons are distinguished:

- A wet season, from November to mid of April with irregular precipitations.
- A dry season, covering the rest of the months of the year when the precipitations is relatively low.

As for flows, the hydrological study during the period (1974/1975-2013/2014) showed that this watershedis characterized by an irregular flow regime due to the irregularity of the rainfall regime. The evolution of the seasonal flows has shown that in Spring, most of the runoff occurs, which means that the intensity of rainfall is high during this season.

- The statistical analysis highlights the adjustment of the precipitations series that follows a normal law distribution. While, the adjustment of the flow rate series follows a log normal distribution. In other hand, it helps for the estimation of the rainfall and the flow rate for a given return period:
    - The rainfall for the return periods: for the wet periods, it ranging from 350 to 750 mm, and for the dry periods, it ranging from 200 to 100 mm.
    - The flow rate for the return periods: for the wet periods, it ranging from 50 to 450 mm, while for the dry periods, it is equal zero (indicating a deficit period).
- **Climate variability study:** the application of climate indices SPI, PN, DI, EDI, RAI,

CZI, MCZI, and Z-Score using the Meteorological Drought Monitoring Program have highlighted that the climate variability is characterized by alternating wet and dry sequences at the study station during the period (1974/1975-2017/2018). The meteorological drought events are from 1980/1981 to 2008/2009, while, the wet or no drought events observed from 1974/1975-1980/1981 and 2008/2009 to 2017/2018.

Generally, our basin had experienced a wet or No drought event during 1975/1977, 2003/2004 and 2008/2009. However, the drought event was indicated as the severe dry period during 1982/1983 and 1996/1997, while the extreme dry period detected during the year 1987/1988.

The drought frequency study for SPI, CZI, and MCZI indices indicate that the “Near Normal class” had the highest percentage of years, for PN and DI indices was “No drought or wet class”, and for both Z-Score, RAI indices, the “Dry class” represented the maximum number of years.

Z-Score is an index easy to calculate, and the SPI is the complex index however it done a better result than the others indices which confirm that the extreme dry event recorded during the year (1987/1988) with the minimum SPI value -2.01, while the severe dry events occurred in (1982/1983) and (1996/1997). The maximum SPI recorded during the year (2008/2009) reaches 2.55, which characterizes a relatively extreme wet event.

- The modeling of the hydrological behavior of the Wadi Boukiou watershed has been attempted in this part by using the HBV Light model at the daily time step. The model performance is highly sensitive on the choise of values of parameter sets, the generation of a large number of parameter sets helps in prioritizing the important parameters to be used during calibration.

The HBV light model has been effective in estimating the simulated discharge in our study area where, both stages done a satisfactory results, producing of Nash –Sutcliffe coefficient 75% - 76% respectively. In addition, the values of coefficient of determination R^2 during the two steps are 0.80 -0.91 respectively.

6.2- Recommendations

As a conclusion, we propose some recommendations to improve and enrich the results of this research:

-Use satellite imagery to continuously detect and monitor drought at the regional scale of the Wadi Boukiou watershed through applied and other new indices to highlight drought.

-Combining this aspect with the use of other semi-distributed or distributed rainfall-flow models so that they can better simulate flows at the watershed level.

-Further, the use of climate change scenarios is recommended to assess the uncertainty of climate change impact studies that arise due to the use of different future climate data.

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Table 5-3: Monthly SPI index results (1974/1975-2017/2018)												
Years	S	O	N	D	J	F	M	A	M	J	Jl	A
1974-1975	0.4	0.3	-0.8	-1.2	-0.9	0.5	1.7	2.8	0.4	0.3	0.7	0.4
1975-1976	-1.1	-0.4	1.2	-0.6	0.2	1.0	-0.5	1.8	0.9	0.6	0.7	2.9
1976-1977	1.0	1.3	-0.6	0.6	1.3	-1.2	0.7	-0.2	0.7	0.3	1.1	0.2
1977-1978	-1.1	0.5	0.8	-0.7	1.0	-1.3	-0.3	0.4	0.2	0.3	0.7	0.2
1978-1979	-1.1	1.3	-0.3	0.4	-0.9	1.7	-0.1	-0.1	-0.7	0.3	0.7	0.2
1979-1980	0.7	2.0	-0.1	1.6	-1.0	0.4	1.1	-0.1	0.0	0.3	0.7	0.2
1980-1981	-1.1	-0.3	-0.1	-1.2	-0.2	0.0	0.0	1.6	-1.5	3.4	0.7	0.2
1981-1982	0.3	-1.2	-1.5	-0.2	-0.6	-0.1	-0.9	0.9	1.0	0.7	0.7	0.2
1982-1983	0.4	0.7	0.0	0.4	-1.3	-0.5	-0.8	-1.3	-0.5	0.3	0.7	0.2
1983-1984	-1.1	-1.2	-0.9	1.3	0.9	-0.8	-0.4	-1.3	1.7	0.9	0.7	0.2
1984-1985	0.5	-1.0	1.1	-0.6	0.3	-1.3	0.1	0.0	0.8	0.3	0.7	0.2
1985-1986	-0.9	-1.2	0.2	-0.4	0.4	1.1	1.3	0.5	-1.4	0.3	0.7	0.2
1986-1987	0.7	1.1	1.3	0.1	-0.4	1.3	-1.6	-1.1	-0.3	0.3	2.2	0.4
1987-1988	-0.1	0.8	-0.7	-0.1	-0.7	-0.7	-1.7	-0.2	-1.5	0.3	0.7	1.3
1988-1989	0.3	-1.1	-0.9	-1.2	-0.1	-0.9	1.3	0.4	-0.3	0.5	0.7	0.4
1989-1990	1.2	-0.7	-0.9	0.6	1.5	-1.5	-0.1	0.5	-0.8	0.3	0.7	0.3
1990-1991	0.6	-0.5	-0.6	-0.2	-0.6	0.1	1.4	-0.9	-0.3	0.3	0.7	0.2
1991-1992	-0.3	0.4	0.1	-0.2	-0.9	-0.7	1.8	0.2	2.0	1.8	0.7	0.2
1992-1993	-1.1	-0.2	-1.0	-0.4	-1.3	1.2	0.0	0.5	0.7	0.3	0.7	0.2
1993-1994	0.0	-0.2	1.0	-0.9	1.1	0.8	-1.5	0.1	0.1	0.3	0.8	0.2
1994-1995	1.1	-0.6	-0.6	0.2	-0.7	0.8	0.8	-0.2	-1.4	0.5	0.7	0.5
1995-1996	0.6	-0.6	-1.2	0.2	0.8	0.8	-0.2	0.0	0.3	0.5	0.7	0.2
1996-1997	1.5	-0.6	-1.5	-0.1	1.0	-1.5	-1.7	0.2	-0.5	0.5	0.7	0.6
1997-1998	2.0	0.0	-0.6	0.0	-0.7	-0.4	-0.2	-0.5	0.9	0.3	0.7	1.1
1998-1999	0.1	-1.2	0.3	-1.2	1.1	0.7	1.5	-1.3	-1.5	0.5	0.7	0.6
1999-2000	0.7	-0.1	0.4	1.0	-1.3	-1.5	-1.4	0.0	0.7	0.3	0.7	0.2
2000-2001	-0.4	1.7	0.1	-0.8	0.8	0.6	-1.2	-1.1	0.0	0.3	0.7	0.2
2001-2002	0.3	0.2	1.8	-0.2	-1.2	-1.4	-0.8	1.2	0.5	0.3	0.7	1E+300
2002-2003	-0.8	0.1	1.1	-0.3	1.3	0.9	-0.6	0.3	-1.3	0.8	0.7	0.2
2003-2004	-0.9	1.1	1.7	0.8	0.4	1.0	0.8	-0.1	1.2	0.3	1.4	1.1
2004-2005	0.0	0.8	-0.5	1.4	-0.3	0.4	0.7	-0.7	-1.4	0.3	0.7	0.2
2005-2006	0.6	-0.8	-0.1	-0.4	0.6	0.6	0.7	-1.3	1.5	0.3	1.0	0.2
2006-2007	1.2	0.0	-1.5	0.6	-1.3	0.0	0.0	1.9	-0.2	0.3	0.7	0.2
2007-2008	-1.1	1.0	-0.2	-1.2	-0.4	0.0	-0.6	-1.3	0.6	0.7	0.7	0.6
2008-2009	-0.7	1.8	1.7	2.7	-1.1	1.9	-0.5	-0.4	1.1	0.3	1.0	0.2
2009-2010	1.9	-1.2	-0.5	-0.1	0.7	1.4	1.5	-0.4	0.9	1.6	0.7	1.9
2010-2011	-0.7	1.0	0.8	0.2	-0.5	-0.3	-0.1	0.2	-0.2	0.3	1.1	0.2
2011-2012	-0.7	1.0	0.8	0.2	-0.5	-0.3	-0.1	0.2	-0.2	0.3	1.1	0.2
2012-2013	1.0	0.7	2.5	-0.4	1.5	0.0	-0.1	0.1	0.7	0.3	0.8	1.3
2013-2014	-0.1	-1.2	0.7	1.4	1.3	-0.6	0.9	-0.7	0.3	0.8	2.6	0.2
2014-2015	1.3	-0.8	0.1	1.9	1.4	-0.1	-0.4	-0.8	0.2	0.6	0.7	1.1
2015-2016	-0.2	0.0	-0.9	-1.2	-0.7	0.9	-0.1	0.6	0.6	0.6	0.7	0.2
2016-2017	-0.7	-0.1	-0.1	0.2	1.5	-0.7	-0.7	-0.5	-1.1	0.3	0.7	0.4
2017-2018	-0.8	0.0	-1.3	0.4	0.2	-0.3	1.3	1.6	0.0	1.2	0.7	0.4

Table 5-5: Monthly SPI 3- months index results (1974/1975-2017/2018)												
Years	S	O	N	D	J	F	M	A	M	J	Jl	A
1974-1975	NaN	NaN	-0.52	-1.16	-1.94	-1.00	0.85	2.58	2.68	2.29	0.25	-0.45
1975-1976	-1.20	-1.29	0.60	0.38	0.53	0.37	0.33	1.20	1.14	1.65	0.85	1.67
1976-1977	1.71	2.00	0.50	0.44	0.61	0.48	0.52	-0.43	0.45	0.12	0.60	-0.11
1977-1978	-0.81	-0.20	0.52	0.28	0.60	-0.54	-0.24	-0.87	-0.13	0.16	0.04	-0.60
1978-1979	-1.32	0.74	0.22	0.42	-0.60	0.89	0.59	0.88	-0.68	-0.77	-0.98	-0.60
1979-1980	0.35	1.96	1.16	1.54	0.34	0.67	0.33	0.64	0.49	-0.35	-0.17	-0.60
1980-1981	-1.28	-1.14	-0.56	-0.91	-0.84	-0.96	-0.21	0.77	0.59	1.74	1.27	2.58
1981-1982	-0.03	-1.21	-2.41	-1.89	-1.57	-0.76	-0.87	-0.08	0.44	1.07	0.89	0.01
1982-1983	0.06	0.46	0.27	0.35	-0.52	-1.07	-1.62	-1.47	-1.80	-1.60	-0.70	-0.60
1983-1984	-1.32	-1.99	-1.95	-0.09	0.61	0.76	-0.13	-1.45	0.31	0.79	1.60	0.24
1984-1985	0.19	-0.84	0.62	0.20	0.49	-1.19	-0.58	-0.94	0.19	0.34	0.68	-0.60
1985-1986	-1.14	-1.98	-0.53	-0.50	0.05	0.62	1.25	1.33	0.68	-0.27	-1.85	-0.60
1986-1987	0.31	0.96	1.42	1.10	0.56	0.55	0.04	-0.13	-2.24	-1.34	0.05	0.69
1987-1988	0.45	0.39	-0.24	-0.22	-0.95	-1.21	-1.68	-1.55	-2.01	-1.05	-2.00	0.68
1988-1989	0.62	-0.42	-1.30	-2.04	-1.35	-1.71	0.22	0.41	0.74	-0.10	-0.41	-0.14
1989-1990	0.82	-0.01	-0.64	-0.47	0.66	0.46	0.09	-0.90	-0.31	-0.18	-1.04	-0.49
1990-1991	0.30	-0.44	-0.69	-0.79	-0.87	-0.59	0.55	0.56	0.48	-1.16	-0.50	-0.60
1991-1992	-0.56	-0.08	0.02	0.00	-0.59	-1.38	0.48	0.85	2.03	1.67	2.16	1.26
1992-1993	-1.32	-1.05	-1.40	-1.09	-1.86	-0.15	0.07	0.74	0.38	0.58	0.58	-0.60
1993-1994	-0.27	-0.56	0.56	0.17	0.79	0.78	0.54	-0.10	-0.91	-0.15	-0.07	-0.34
1994-1995	0.72	-0.12	-0.54	-0.65	-0.76	0.12	0.44	0.63	-0.14	-1.01	-1.46	-0.10
1995-1996	0.29	-0.53	-1.23	-0.92	-0.07	0.88	0.58	0.14	-0.33	-0.10	0.12	-0.29
1996-1997	1.04	0.25	-0.95	-1.48	-0.27	-0.40	-0.82	-2.05	-1.22	-0.31	-0.68	0.00
1997-1998	1.59	1.07	0.28	-0.47	-0.82	-0.92	-0.84	-0.82	-0.10	0.16	0.74	0.55
1998-1999	0.45	-0.68	-0.30	-0.84	0.29	0.58	1.48	0.85	0.29	-2.71	-1.51	0.05
1999-2000	0.46	0.01	0.26	0.57	0.07	-1.29	-3.92	-2.19	-0.49	0.22	0.55	-0.60
2000-2001	-0.65	1.38	0.91	0.55	0.10	0.41	0.26	-0.60	-1.65	-1.02	-0.22	-0.60
2001-2002	0.02	-0.06	1.46	1.12	0.66	-2.33	-2.31	-0.45	0.40	0.94	0.31	2.34
2002-2003	1.83	1.33	0.67	0.52	1.12	1.17	0.87	0.29	-0.83	-0.34	-0.96	0.12
2003-2004	-1.11	0.53	1.59	1.65	1.43	1.07	0.92	0.76	0.79	0.53	1.09	0.78
2004-2005	0.58	0.67	-0.14	0.65	0.24	0.74	0.32	0.24	-0.32	-1.71	-1.90	-0.60
2005-2006	0.30	-0.61	-0.34	-0.60	0.03	0.44	0.78	0.24	0.68	0.49	1.35	-0.16
2006-2007	0.87	0.38	-0.83	-0.59	-1.36	-0.54	-0.80	1.00	1.03	1.34	-0.40	-0.60
2007-2008	-1.32	0.48	0.14	-0.25	-1.08	-1.19	-0.64	-0.96	-0.78	-0.31	0.52	0.24
2008-2009	-0.62	1.41	1.96	**2.76**	2.03	2.46	0.56	0.82	0.00	0.42	1.00	-0.20
2009-2010	1.48	0.44	-0.05	-0.87	-0.07	1.10	1.60	1.40	1.07	0.55	1.12	1.86
2010-2011	0.77	1.14	0.85	0.82	0.24	-0.61	-0.62	-0.36	-0.36	-0.22	-0.28	-0.04
2011-2012	-0.54	0.49	0.85	0.82	0.24	-0.61	-0.62	-0.36	-0.36	-0.22	-0.28	-0.04
2012-2013	0.71	0.79	2.38	1.80	2.15	0.77	0.72	-0.23	0.09	0.30	0.59	0.73
2013-2014	0.46	-0.71	0.09	0.82	1.52	1.21	0.82	-0.13	0.27	-0.31	0.76	1.14
2014-2015	1.38	-0.04	0.08	0.89	1.59	1.80	0.49	-0.82	-0.82	-0.52	0.11	0.62
2015-2016	0.21	-0.12	-0.98	-1.45	-1.80	-0.45	0.08	0.58	0.34	0.63	0.54	-0.08
2016-2017	-0.87	-0.78	-0.41	-0.11	0.79	0.67	0.24	-1.28	-1.55	-1.34	-1.35	-0.39
2017-2018	-0.89	-0.65	-1.42	-0.63	-0.45	-0.10	0.57	1.26	1.48	1.20	0.24	0.60

Table 5-6: Monthly SPI 6- months index results (1974/1975-2017/2018)												
Years	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Jl**	**A**
1974-1975	NaN	NaN	NaN	NaN	NaN	-1.12	-0.02	1.51	1.96	2.18	2.41	2.51
1975-1976	2.17	0.84	0.44	0.10	0.09	0.54	0.38	1.24	1.05	1.25	1.28	1.38
1976-1977	2.11	1.95	0.90	0.89	1.26	0.55	0.58	0.08	0.55	0.39	-0.23	0.34
1977-1978	-0.23	0.13	0.38	0.02	0.38	-0.09	-0.16	-0.20	-0.65	-0.33	-0.88	-0.26
1978-1979	-0.24	0.40	0.02	0.14	-0.31	0.67	0.63	0.17	0.17	0.10	0.52	-0.81
1979-1980	-0.68	1.19	1.03	1.53	1.03	1.12	1.34	0.62	0.73	-0.03	0.43	0.35
1980-1981	-0.81	-1.22	-0.82	-1.32	-1.26	-1.12	-0.97	-0.08	-0.29	0.93	1.11	1.27
1981-1982	1.66	0.42	-0.19	-1.96	-1.98	-1.76	-2.15	-1.35	-0.31	-0.12	0.21	0.34
1982-1983	0.97	0.82	0.14	0.22	-0.39	-0.59	-0.95	-1.69	-2.19	-2.63	-1.73	-1.93
1983-1984	-2.25	-2.66	-2.31	-0.41	0.06	-0.27	-0.35	-0.47	0.66	0.20	-0.17	0.25
1984-1985	0.71	0.95	0.54	0.11	0.13	-0.37	-0.47	-0.35	-0.81	-0.51	-0.58	0.05
1985-1986	-0.02	-0.62	-0.78	-0.85	-0.53	0.08	0.69	1.02	0.83	0.99	0.93	0.53
1986-1987	-0.28	0.06	1.30	1.06	0.74	1.23	0.75	0.22	-0.72	-0.68	-0.23	-1.71
1987-1988	-0.99	0.10	-0.20	-0.23	-0.76	-1.06	-1.56	-2.16	-2.41	-2.42	-2.05	-1.58
1988-1989	-0.68	-1.46	-1.16	-1.65	-1.47	-2.10	-1.01	-0.72	-0.51	-0.02	0.15	0.62
1989-1990	0.14	-0.53	-0.84	-0.32	0.49	-0.09	-0.43	-0.16	0.00	-0.20	-1.27	-0.44
1990-1991	-0.19	-1.25	-0.95	-0.83	-1.07	-0.93	-0.16	-0.31	-0.17	-0.05	0.28	0.33
1991-1992	-1.51	-0.64	-0.19	-0.25	-0.68	-0.96	0.23	0.15	1.07	1.38	1.69	2.08
1992-1993	1.46	1.58	-0.85	-1.51	-2.19	-0.92	-0.80	-0.60	0.04	0.23	0.77	0.24
1993-1994	0.38	-0.10	0.39	-0.02	0.48	0.80	0.41	0.45	-0.04	0.28	-0.25	-1.02
1994-1995	0.04	-0.40	-0.77	-0.52	-0.84	-0.31	-0.19	-0.18	-0.16	-0.14	0.22	-0.23
1995-1996	-0.90	-1.49	-1.45	-0.95	-0.35	0.03	-0.20	-0.13	0.35	0.34	0.04	-0.45
1996-1997	0.27	0.04	-1.20	-0.99	-0.26	-0.92	-1.89	-1.71	-1.28	-1.17	-2.24	-1.25
1997-1998	0.47	0.38	0.14	0.08	-0.28	-0.50	-1.21	-1.52	-0.90	-0.86	-0.45	-0.06
1998-1999	0.18	0.01	-0.31	-0.81	-0.04	0.16	0.79	0.75	0.51	0.88	0.45	0.20
1999-2000	-1.46	-0.92	0.13	0.55	-0.06	-0.72	-1.29	-1.39	-1.49	-2.33	-1.47	-0.63
2000-2001	-0.09	1.25	0.76	0.33	0.56	0.77	0.45	-0.53	-0.70	-0.35	-0.75	-1.77
2001-2002	-1.07	-0.46	1.35	1.02	0.48	-0.02	-0.35	0.11	-1.16	-1.01	-0.39	1.04
2002-2003	1.55	1.06	1.37	1.01	1.37	1.13	0.94	1.03	0.36	0.55	-0.07	-0.85
2003-2004	-0.79	-0.25	1.54	1.48	1.38	1.67	1.85	1.64	1.26	1.00	1.00	0.81
2004-2005	0.58	1.13	-0.07	0.67	0.35	0.37	0.58	0.21	0.24	-0.42	-0.19	-0.45
2005-2006	-1.32	-1.67	-0.58	-0.65	-0.27	0.04	0.17	0.04	0.71	0.85	0.73	0.56
2006-2007	0.68	1.20	-1.05	-0.40	-1.06	-0.97	-1.27	-0.11	0.38	0.18	0.72	0.87
2007-2008	1.09	-0.08	-0.07	-0.60	-0.80	-0.76	-0.89	-1.84	-1.65	-1.00	-0.69	-0.78
2008-2009	-0.66	1.26	1.94	2.71	2.21	2.83	2.63	2.24	1.94	0.59	1.02	-0.11
2009-2010	0.93	0.91	-0.24	-0.28	-0.01	0.69	0.91	1.00	1.50	1.71	1.57	1.38
2010-2011	0.69	1.49	1.30	0.89	0.55	0.13	0.07	-0.24	-0.89	-0.92	-0.56	-0.44
2011-2012	-0.54	-0.01	0.74	0.63	0.28	0.13	0.07	-0.24	-0.89	-0.92	-0.56	-0.44
2012-2013	-0.02	0.26	2.36	1.87	2.14	2.10	1.84	1.78	0.52	0.69	-0.08	0.16
2013-2014	0.32	-0.17	0.14	0.80	1.19	0.84	1.10	1.16	1.00	0.51	0.10	0.45
2014-2015	0.33	0.38	0.29	1.16	1.39	1.31	0.90	0.89	0.97	0.07	-0.81	-0.68
2015-2016	-0.55	-0.26	-0.92	-1.47	-1.66	-0.98	-0.96	-0.75	-0.20	0.27	0.61	0.23
2016-2017	0.33	-0.26	-0.59	-0.40	0.44	0.17	-0.04	-0.20	-0.41	-0.44	-1.70	-1.65
2017-2018	-1.82	-1.58	-1.72	-0.97	-0.75	-0.88	-0.05	0.64	1.08	1.11	1.13	1.43

Table 5-7: Monthly SPI 9- months index results (1974/1975-2017/2018)

Years	S	O	N	D	J	F	M	A	M	J	Jl	A
1974-1975	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	1.44	1.37	1.39	1.84
1975-1976	2.03	2.15	2.28	1.62	0.04	0.42	0.21	0.96	1.12	1.18	1.31	1.3
1976-1977	1.61	1.89	1.26	1.61	1.42	0.8	0.94	0.87	0.64	0.48	0.17	0.46
1977-1978	0.23	-0.35	0.47	-0.05	0.46	-0.2	-0.32	-0.3	-0.31	-0.21	-0.27	-0.76
1978-1979	-0.52	-0.51	-0.15	0.08	-0.43	0.56	0.45	0.37	0.16	0.24	-0.11	0.06
1979-1980	0.12	1.24	0.28	1.02	0.77	1.01	1.32	1.31	1.19	1.09	0.45	0.61
1980-1981	-0.22	0.08	-0.13	-1.41	-1.47	-1.29	-1.18	-0.38	-0.66	0.21	0.34	0.46
1981-1982	0.87	0.78	0.25	0.16	-1.06	-0.75	-2.18	-1.69	-1.25	-1.2	-0.92	-0.38
1982-1983	-0.16	0.29	0.32	0.72	-0.12	-0.7	-1	-1.43	-1.59	-1.6	-1.87	-2.29
1983-1984	-2.87	-2.43	-2.72	-1.12	-0.25	-0.42	-0.55	-0.94	-0.19	-0.03	0.21	0.61
1984-1985	0.18	-0.47	0.47	0.43	0.76	-0.44	-0.5	-0.6	-0.36	-0.41	-0.17	-0.91
1985-1986	-0.7	-1.15	-0.37	-0.58	-0.37	-0.05	0.53	0.65	0.38	0.45	0.68	0.72
1986-1987	0.98	1.15	1.2	0.71	0.39	1.13	0.72	0.5	0.34	0.26	0.12	-0.64
1987-1988	-0.6	-0.13	-1.32	-0.88	-0.88	-1.03	-1.47	-1.87	-2.17	-2.09	-2.48	-2.22
1988-1989	-2.07	-2.07	-2.05	-2.11	-2.05	-2.03	-0.9	-0.87	-1.17	-1.14	-0.88	-0.59
1989-1990	0.13	0.07	0.07	-0.46	0.26	-0.21	-0.3	-0.2	-0.43	-0.63	-0.43	-0.1
1990-1991	-0.18	-1.41	-0.85	-0.92	-1.51	-1.1	-0.17	-0.46	-0.61	-0.67	-0.5	-0.28
1991-1992	-0.19	0.18	0.16	-0.85	-0.99	-1.13	0.09	0.08	0.84	1.07	1.05	1.21
1992-1993	1.22	1.42	1.24	0.25	-0.29	-0.71	-1	-0.89	-0.67	-0.55	-0.44	-0.07
1993-1994	0.13	0.54	0.42	0.2	0.55	0.68	0.3	0.27	0.19	0.2	0.32	-0.13
1994-1995	0.39	-0.34	-1.16	-0.66	-1.01	-0.45	-0.1	-0.25	-0.52	-0.67	-0.49	-0.23
1995-1996	-0.12	0	-0.94	-1.47	-0.78	-0.08	-0.21	-0.31	-0.32	-0.37	-0.18	0.25
1996-1997	0.54	0.06	-0.99	-0.99	-0.36	-1.08	-1.53	-1.55	-1.72	-2.07	-1.88	-1.32
1997-1998	-0.53	-1.19	-0.67	-0.22	-0.61	-0.61	-0.69	-0.95	-0.67	-1.19	-1.14	-0.85
1998-1999	-0.77	-0.72	-0.33	-0.69	0.12	0.14	0.79	0.55	0.18	0.19	0.43	0.44
1999-2000	0.9	0.37	0.2	-0.23	-0.46	-0.83	-1.22	-1.36	-1.13	-1.21	-1.13	-1.59
2000-2001	-2.47	-0.53	0.15	0.27	0.61	0.66	0.31	0.04	-0.06	0	-0.65	-0.8
2001-2002	-0.39	-0.79	0.21	0.46	0.3	-0.15	-0.41	0.05	0.1	0.07	0.1	-0.33
2002-2003	-0.27	0.18	1.08	1.25	1.36	1.57	1.3	1.39	0.58	0.68	0.73	0.3
2003-2004	0.39	0.06	0.63	1.1	1.15	1.62	1.7	1.71	1.9	1.89	1.76	1.27
2004-2005	1.04	1.11	0.46	0.72	0.65	0.39	0.61	0.38	0.02	0.03	-0.12	0.13
2005-2006	-0.4	-0.44	-0.65	-1.39	-0.72	-0.1	0.15	-0.16	0.35	0.27	0.48	0.62
2006-2007	0.97	0.75	-0.07	-0.14	-0.37	-1.11	-1.06	-0.02	-0.15	-0.35	-0.29	0.27
2007-2008	0	0.78	0.66	0.39	-1.09	-0.93	-1.1	-1.54	-1.34	-1.14	-1.53	-1.64
2008-2009	-1.14	0.01	0.98	2.32	2.29	**2.82**	2.52	2.56	2.68	2.64	2.29	1.84
2009-2010	0.92	1.05	-0.22	-0.11	0.28	0.59	1.16	1.07	1.19	0.99	1.21	1.77
2010-2011	1.77	1.8	1.45	0.92	0.86	0.48	0.16	0.17	-0.24	-0.15	-0.39	-0.95
2011-2012	-1.05	-0.38	0.21	0.33	0.07	0.03	-0.07	-0.1	-0.24	-0.15	-0.39	-0.95
2012-2013	-0.73	-0.23	1.47	1.5	2.05	2.05	1.87	1.92	1.96	1.81	1.73	0.56
2013-2014	0.71	-0.35	0.07	0.72	1.26	0.86	1.1	0.96	0.81	0.86	1.21	1.11
2014-2015	0.81	0.01	0.29	0.79	1.52	1.4	1.12	0.83	0.77	0.59	0.77	0.97
2015-2016	0.06	-0.86	-1.2	-1.64	-1.7	-0.97	-0.97	-0.81	-0.75	-0.66	-0.59	-0.27
2016-2017	0.11	0.33	-0.15	-0.05	0.49	0.07	-0.21	-0.44	-0.69	-0.59	-0.5	-0.51
2017-2018	-0.61	-1.89	-2.18	-1.6	-1.21	-1.03	-0.22	0.44	0.34	0.5	0.57	1.08

Table 5-8: Monthly SPI 12- months index results (1974/1975-2017/2018)

Years	S	O	N	D	J	F	M	A	M	J	Jl	A
1974-1975	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	1.33
1975-1976	1.22	1.10	1.78	1.73	1.86	2.03	1.48	0.90	1.09	1.09	1.08	1.31
1976-1977	1.47	1.83	1.27	1.41	1.69	1.18	1.59	1.01	0.94	0.90	0.90	0.56
1977-1978	0.35	0.06	0.58	0.22	0.05	0.03	-0.35	-0.18	-0.36	-0.35	-0.36	-0.39
1978-1979	-0.37	-0.07	-0.58	-0.23	-0.88	0.31	0.38	0.27	0.10	0.10	0.10	0.07
1979-1980	0.24	0.61	0.68	1.08	1.02	0.48	0.95	1.04	1.16	1.14	1.13	1.08
1980-1981	0.93	0.17	0.19	-0.80	-0.54	-0.68	-1.35	-0.52	-0.74	0.07	0.07	0.04
1981-1982	0.15	0.05	-0.41	-0.14	-0.22	-0.26	-0.55	-1.03	-0.44	-1.27	-1.25	-1.26
1982-1983	-1.20	-0.76	-0.24	-0.02	-0.21	-0.32	-0.35	**-1.06**	-1.65	-1.66	-1.63	-1.64
1983-1984	-1.76	-2.33	-2.97	-2.07	-1.00	-1.11	-1.08	**-1.18**	-0.26	-0.19	-0.18	-0.21
1984-1985	-0.05	-0.03	0.75	0.14	-0.10	-0.23	-0.14	0.09	-0.37	-0.42	-0.41	-0.44
1985-1986	-0.56	-0.58	-1.13	-0.98	-0.87	-0.01	0.53	0.74	0.33	0.32	0.32	0.29
1986-1987	0.44	0.87	1.34	1.32	1.08	1.16	0.49	0.18	0.28	0.28	0.39	0.36
1987-1988	0.28	0.17	-0.76	-0.73	-0.78	**-1.78**	-1.96	-1.87	-2.08	-2.03	-2.20	-2.01
1988-1989	-1.88	-2.50	-2.64	-2.92	-2.50	-2.61	-1.32	-1.23	-1.10	-1.05	-1.03	**-1.20**
1989-1990	-0.95	-0.89	-0.91	-0.29	0.37	0.21	-0.42	-0.39	-0.48	-0.48	-0.47	-0.50
1990-1991	-0.61	-0.58	-0.51	-0.72	-1.72	-1.07	-0.33	-0.76	-0.68	-0.67	-0.65	-0.68
1991-1992	-0.78	-0.55	-0.31	-0.27	-0.34	-0.58	-0.36	-0.13	0.80	1.01	1.00	0.95
1992-1993	0.91	0.78	0.49	0.41	0.30	0.88	0.12	0.26	-0.45	-0.73	-0.72	-0.74
1993-1994	-0.63	-0.61	0.18	0.08	0.78	0.66	0.43	0.34	0.14	0.14	0.14	0.11
1994-1995	0.29	0.22	-0.47	-0.16	-0.84	-0.85	-0.26	-0.37	-0.59	-0.56	-0.56	-0.57
1995-1996	-0.65	-0.65	-0.83	-0.73	-0.17	-0.20	-0.63	-0.63	-0.37	-0.36	-0.35	-0.39
1996-1997	-0.16	-0.15	-0.28	-0.34	-0.24	-1.07	-1.53	-1.55	-1.82	-1.77	-1.74	-1.72
1997-1998	-1.43	-1.28	-0.96	-0.83	-1.52	-1.11	-0.88	-1.19	-0.72	-0.71	-0.70	-0.63
1998-1999	-1.10	-1.33	-0.96	-1.23	-0.41	-0.01	0.70	0.67	0.23	0.24	0.24	0.13
1999-2000	0.21	0.36	0.41	0.92	0.19	-0.51	-1.88	-1.71	-1.18	-1.17	-1.15	-1.19
2000-2001	-1.33	-0.52	-0.65	-1.24	-0.43	0.25	0.28	0.11	-0.12	-0.12	-0.11	-0.14
2001-2002	-0.05	-0.69	0.31	0.41	-0.16	-0.84	-0.84	-0.11	0.04	0.04	0.04	0.60
2002-2003	0.51	0.49	0.04	0.03	0.79	1.38	1.51	1.34	1.11	1.12	1.11	0.53
2003-2004	0.52	0.79	1.15	1.33	0.96	0.97	1.42	1.45	1.92	1.84	1.85	1.87
2004-2005	1.89	1.80	0.95	1.08	0.86	0.67	0.69	0.66	0.11	0.11	0.06	-0.07
2005-2006	0.03	-0.31	-0.15	-0.80	-0.42	-0.31	-0.38	-0.50	0.29	0.29	0.30	0.27
2006-2007	0.38	0.51	0.10	0.37	-0.18	-0.42	-0.79	0.42	-0.20	-0.20	-0.21	-0.24
2007-2008	-0.51	-0.18	0.21	-0.28	-0.05	-0.05	-0.21	-1.72	-1.44	-1.35	-1.33	-1.32
2008-2009	-1.25	-0.82	0.27	1.59	1.42	2.06	2.24	2.54	2.73	2.64	2.62	2.55
2009-2010	**2.78**	2.26	1.50	0.22	0.65	0.40	1.15	1.26	1.17	1.31	1.28	1.43
2010-2011	1.05	1.42	1.84	1.75	1.43	0.90	0.30	0.48	0.17	-0.03	0.00	-0.29
2011-2012	-0.27	-0.26	-0.27	-0.24	-0.22	-0.22	-0.25	-0.27	-0.27	-0.27	-0.26	-0.29
2012-2013	-0.06	-0.16	1.03	0.83	1.41	1.49	1.62	1.74	1.98	1.93	1.89	1.93
2013-2014	1.78	1.51	0.43	0.94	0.80	0.66	1.05	1.01	0.89	0.92	1.05	0.90
2014-2015	1.07	1.11	0.90	1.06	1.06	1.18	0.87	0.94	0.93	0.88	0.72	0.77
2015-2016	0.56	0.66	0.38	-0.78	-1.79	-1.24	-1.22	-0.85	-0.70	-0.67	-0.66	-0.79
2016-2017	-0.80	-0.81	-0.53	-0.11	0.64	0.17	0.01	-0.34	-0.74	-0.75	-0.74	-0.75
2017-2018	-0.73	-0.69	-1.14	-0.99	-1.71	-1.59	-0.71	0.13	0.30	0.39	0.39	0.35

Table 5-9: Monthly SPI 18- months index results (1974/1975-2017/2018)

Years	S	O	N	D	J	F	M	A	M	J	Jl	A
1974-1975	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
1975-1976	NaN	NaN	NaN	NaN	NaN	1.17	1.02	1.47	2.01	2.23	2.37	2.58
1976-1977	2.36	1.58	1.23	1.23	1.49	1.16	1.31	1.36	1.30	1.43	1.43	1.23
1977-1978	1.41	0.91	0.88	0.65	0.83	0.27	0.09	-0.11	0.06	-0.06	-0.49	-0.18
1978-1979	-0.48	-0.05	-0.29	-0.21	-0.47	0.11	0.12	0.02	-0.36	-0.19	-0.46	-0.12
1979-1980	0.08	0.68	0.56	0.96	0.69	0.69	0.98	0.76	0.94	0.90	1.11	0.56
1980-1981	0.61	0.61	0.64	0.36	0.24	0.18	0.10	0.04	-0.06	-0.03	0.25	0.17
1981-1982	-0.19	-0.33	-0.67	-0.70	-0.86	-0.91	-1.04	-0.73	-0.55	-0.25	-0.13	-0.13
1982-1983	-0.06	-0.55	-0.30	-0.77	-1.10	-1.27	-1.46	-1.53	-1.40	-1.34	-1.10	-1.12
1983-1984	-0.95	-1.51	-1.80	-1.36	-1.05	-1.30	-1.41	-1.80	-1.41	-1.50	-1.05	-0.93
1984-1985	-0.65	-0.60	0.03	-0.12	-0.09	-0.43	-0.38	-0.26	0.13	-0.24	-0.49	-0.27
1985-1986	-0.20	-0.16	-0.62	-0.74	-0.63	-0.31	0.05	0.26	-0.26	-0.11	-0.12	0.22
1986-1987	0.34	0.64	0.88	0.80	0.64	0.90	0.71	0.71	0.69	0.81	0.82	0.54
1987-1988	0.10	0.15	0.11	0.06	-0.14	-0.36	-0.69	-0.99	-1.97	-2.01	-1.81	-2.54
1988-1989	-1.81	-1.82	-1.80	-1.87	-1.90	-2.66	-1.94	-2.08	-2.24	-2.22	-1.92	-1.77
1989-1990	-1.15	-1.26	-1.18	-0.94	-0.40	-0.91	-0.96	-0.72	-0.72	-0.44	-0.33	-0.08
1990-1991	-0.53	-0.75	-0.76	-0.77	-0.93	-0.94	-0.56	-0.62	-0.54	-0.70	-1.27	-0.84
1991-1992	-0.83	-0.91	-0.63	-0.64	-0.87	-1.09	-0.41	-0.31	0.46	0.71	0.87	0.92
1992-1993	0.41	0.54	0.32	0.19	-0.14	0.16	0.16	0.21	0.38	0.44	0.68	0.89
1993-1994	0.22	0.15	-0.18	-0.57	-0.21	-0.02	-0.20	-0.15	0.08	0.19	0.53	0.17
1994-1995	0.37	0.14	-0.21	-0.18	-0.37	-0.17	0.02	0.02	-0.50	-0.29	-0.65	-1.00
1995-1996	-0.61	-0.77	-0.99	-0.88	-0.63	-0.43	-0.62	-0.55	-0.42	-0.43	-0.20	-0.49
1996-1997	-0.51	-0.58	-0.75	-0.75	-0.44	-0.86	-1.19	-1.06	-1.00	-1.05	-1.30	-1.70
1997-1998	-1.13	-1.15	-1.23	-1.16	-1.32	-1.50	-1.78	-1.82	-1.35	-1.32	-1.68	-1.14
1998-1999	-0.77	-1.04	-0.71	-0.93	-0.54	-0.38	-0.19	-0.35	-0.39	-0.37	-0.13	0.02
1999-2000	0.22	0.31	0.20	0.43	0.10	-0.38	-0.62	-0.50	-0.50	-0.23	-0.59	-0.88
2000-2001	-1.61	-0.81	-0.48	-0.64	-0.42	-0.29	-0.57	-0.71	-0.98	-1.33	-0.89	-0.47
2001-2002	-0.13	-0.09	0.59	0.48	0.18	-0.17	-0.31	-0.42	-0.43	-0.24	-0.44	-0.13
2002-2003	0.10	0.30	0.71	0.58	0.90	1.03	0.88	0.94	0.22	0.33	0.62	0.98
2003-2004	**1.20**	1.12	1.57	1.61	1.60	1.35	1.51	1.52	1.64	1.73	1.40	1.28
2004-2005	1.53	1.67	1.51	1.68	1.53	1.47	1.61	**1.41**	0.86	0.69	0.63	0.37
2005-2006	0.24	0.16	-0.17	-0.26	-0.15	-0.09	0.06	-0.22	0.31	-0.09	0.06	-0.03
2006-2007	-0.08	0.06	-0.16	-0.01	-0.34	-0.39	-0.48	0.26	0.27	0.38	0.25	0.08
2007-2008	-0.17	0.31	-0.21	-0.46	-0.62	-0.66	-0.95	-1.14	-0.76	-0.90	-0.49	-0.48
2008-2009	-0.50	-0.81	0.18	1.13	0.86	**1.32**	1.24	1.05	1.49	1.71	1.82	1.93
2009-2010	2.46	2.58	2.15	1.94	1.97	2.14	2.45	2.16	2.05	1.32	1.53	1.13
2010-2011	1.32	1.65	1.49	1.39	1.20	**1.02**	0.72	0.89	1.08	1.14	1.02	0.62
2011-2012	0.04	0.39	0.45	0.29	0.13	-0.18	-0.19	-0.36	-0.78	-0.82	-0.59	-0.51
2012-2013	-0.30	-0.18	1.16	0.99	1.34	1.20	1.18	1.05	1.09	1.09	1.22	1.46
2013-2014	1.63	1.52	1.63	1.81	2.02	1.76	1.83	1.71	0.93	1.07	0.72	0.79
2014-2015	1.07	1.00	0.80	1.27	1.56	1.33	1.23	1.27	1.26	0.93	0.55	0.82
2015-2016	0.60	0.73	0.42	0.10	-0.22	-0.01	-0.19	0.04	0.14	-0.52	-1.05	-1.05
2016-2017	-0.97	-0.87	-0.81	-0.72	-0.21	-0.48	-0.61	-0.70	-0.71	-0.43	-0.20	-0.52
2017-2018	-0.54	-0.77	-1.16	-1.02	-0.96	-1.09	-0.57	-0.07	-0.07	-0.02	-0.53	-0.34

Table 5-10: Monthly SPI 24- months index results (1974/1975-2017/2018)

Years	S	O	N	D	J	F	M	A	M	J	Jl	A
1974-1975	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
1975-1976	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	1.63
1976-1977	1.66	1.84	2.03	2.2	2.52	2.14	1.93	1.19	1.28	1.24	1.24	1.17
1977-1978	1.15	1.26	1.23	1.17	1.31	0.83	0.89	0.55	0.41	0.39	0.39	0.11
1978-1979	-0.01	-0.02	0.03	-0.03	-0.59	0.21	0.03	0.06	-0.15	-0.14	-0.15	-0.22
1979-1980	-0.08	0.34	0.1	0.63	0.2	0.51	0.84	0.83	0.82	0.8	0.79	0.73
1980-1981	0.73	0.47	0.57	0.3	0.4	-0.1	-0.08	0.39	0.37	0.79	0.78	0.72
1981-1982	0.68	0.12	-0.15	-0.66	-0.58	-0.62	-1.12	-0.93	-0.71	-0.66	-0.65	-0.73
1982-1983	-0.58	-0.43	-0.44	-0.14	-0.35	-0.4	-0.56	-1.23	-1.19	-1.61	-1.59	-1.84
1983-1984	-1.62	-1.64	-1.64	-1.25	-0.86	-0.91	-0.86	-1.31	-1.08	-1.02	-1.01	-1.11
1984-1985	-0.99	-1.22	-0.95	-1.13	-0.78	-0.85	-0.73	-0.62	-0.38	-0.36	-0.36	-0.43
1985-1986	-0.37	-0.38	-0.15	-0.56	-0.7	-0.17	0.25	0.52	0	-0.04	-0.03	-0.1
1986-1987	-0.05	0.23	0.32	0.41	0.26	0.79	0.63	0.57	0.39	0.38	0.45	0.39
1987-1988	0.43	0.65	0.51	0.54	0.31	-0.1	-0.7	-0.89	-0.9	-0.87	-0.86	-0.86
1988-1989	-0.81	-1.15	-1.79	-1.87	-1.83	-1.96	-1.75	-1.68	-1.69	-1.64	-1.7	-2.01
1989-1990	-1.56	-1.74	-1.84	-1.71	-1.14	-1.2	-1.04	-0.95	-0.93	-0.9	-0.89	-1.07
1990-1991	-0.93	-0.9	-0.92	-0.72	-0.79	-0.52	-0.48	-0.7	-0.7	-0.69	-0.68	-0.76
1991-1992	-0.84	-0.7	-0.55	-0.71	-1.34	-1.06	-0.44	-0.53	0.14	0.3	0.3	0.23
1992-1993	0.16	0.19	0.13	0.08	-0.06	0.25	-0.15	0.08	0.27	0.26	0.26	0.2
1993-1994	0.24	0.15	0.43	0.31	0.74	1	0.34	0.37	-0.18	-0.34	-0.32	-0.39
1994-1995	-0.19	-0.23	-0.19	-0.09	0.02	-0.06	0.11	0	-0.26	-0.24	-0.23	-0.29
1995-1996	-0.2	-0.26	-0.85	-0.63	-0.74	-0.69	-0.56	-0.61	-0.58	-0.55	-0.55	-0.62
1996-1997	-0.5	-0.5	-0.73	-0.76	-0.34	-0.81	-1.26	-1.25	-1.22	-1.18	-1.17	-1.28
1997-1998	-0.91	-0.84	-0.81	-0.82	-1.18	-1.36	-1.4	-1.54	-1.42	-1.38	-1.37	-1.45
1998-1999	-1.44	-1.5	-1.23	-1.37	-1.29	-0.69	-0.04	-0.22	-0.27	-0.25	-0.25	-0.32
1999-2000	-0.49	-0.51	-0.31	-0.07	-0.19	-0.35	-0.51	-0.46	-0.52	-0.5	-0.49	-0.63
2000-2001	-0.6	-0.09	-0.14	-0.08	-0.2	-0.18	-0.82	-0.86	-0.75	-0.73	-0.72	-0.82
2001-2002	-0.78	-0.75	-0.21	-0.5	-0.46	-0.36	-0.32	0	-0.05	-0.04	-0.04	0.29
2002-2003	0.29	-0.09	0.22	0.28	0.44	0.51	0.59	0.82	0.75	0.76	0.75	0.69
2003-2004	0.63	0.79	0.82	0.99	1.21	1.55	1.85	1.75	1.93	1.86	1.87	1.53
2004-2005	1.54	1.64	1.39	1.68	1.26	1.07	1.34	1.33	1.36	1.3	1.28	1.21
2005-2006	1.28	1.05	0.56	0.3	0.34	0.25	0.22	0.14	0.25	0.25	0.23	0.11
2006-2007	0.25	0.13	-0.05	-0.28	-0.46	-0.5	-0.72	-0.02	0.07	0.07	0.07	0.01
2007-2008	-0.06	0.2	0.18	0.04	-0.21	-0.33	-0.61	-0.65	-0.94	-0.88	-0.88	-0.96
2008-2009	-1.03	-0.61	0.3	1.01	1.02	1.46	1.45	1.01	1.28	1.24	1.24	1.17
2009-2010	1.4	1.16	1.21	1.31	1.47	1.7	2.17	2.42	2.52	2.51	2.49	2.5
2010-2011	2.45	2.32	2.23	1.44	1.47	0.85	0.92	1.1	0.87	0.85	0.85	0.78
2011-2012	0.53	0.79	1.17	1.18	0.92	0.47	0.03	0.15	-0.05	-0.17	-0.15	-0.38
2012-2013	-0.21	-0.27	0.54	0.42	0.91	0.92	0.96	1.03	1.21	1.17	1.15	1.15
2013-2014	1.15	0.91	0.97	1.21	1.56	1.43	1.69	1.73	1.84	1.8	1.86	1.78
2014-2015	1.78	1.64	0.88	1.38	1.3	1.21	1.2	1.21	1.15	1.12	1.11	1.02
2015-2016	1.01	1.1	0.84	0.3	-0.22	0.16	-0.09	0.15	0.23	0.21	0.1	0.04
2016-2017	-0.1	-0.04	-0.09	-0.63	-0.6	-0.64	-0.7	-0.71	-0.87	-0.85	-0.84	-0.99
2017-2018	-0.92	-0.92	-1.07	-0.76	-0.56	-0.81	-0.43	-0.12	-0.24	-0.17	-0.17	-0.23

Table 5-11: Monthly SPI 48- months index results (1974/1975-2017/2018)												
Years	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Jl**	**A**
1974-1975	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
1975-1976	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
1976-1977	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
1977-1978	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	1.25
1978-1979	1.20	1.34	1.45	1.55	1.52	1.70	1.43	0.84	0.77	0.76	0.76	0.71
1979-1980	0.78	1.12	0.92	1.21	1.06	0.92	1.18	0.90	0.81	0.79	0.78	0.60
1980-1981	0.52	0.34	0.43	0.22	-0.05	0.10	-0.01	0.31	0.16	0.45	0.44	0.39
1981-1982	0.44	0.34	0.02	0.06	-0.17	-0.02	-0.08	0.02	0.13	0.15	0.15	0.09
1982-1983	0.16	0.08	0.15	0.14	0.10	-0.30	-0.38	-0.45	-0.44	-0.43	-0.43	-0.50
1983-1984	-0.52	-0.88	-0.99	-1.04	-0.81	-0.91	-1.12	-1.18	-0.99	-0.96	-0.96	-1.07
1984-1985	-0.92	-0.95	-0.77	-0.71	-0.63	-0.75	-0.77	-1.02	-0.88	-1.11	-1.1	-1.23
1985-1986	-1.13	-1.14	-0.99	-1.00	-0.87	-0.65	-0.34	-0.41	-0.61	-0.62	-0.61	-0.7
1986-1987	-0.61	-0.56	-0.32	-0.36	-0.26	0.05	0.00	0.02	0.03	0.04	0.09	0.03
1987-1988	0.08	0.24	0.28	0.05	-0.18	-0.15	-0.25	-0.17	-0.52	-0.53	-0.53	-0.55
1988-1989	-0.51	-0.51	-0.85	-0.88	-0.93	-0.85	-0.66	-0.61	-0.75	-0.73	-0.73	-0.82
1989-1990	-0.64	-0.62	-0.78	-0.64	-0.43	-0.76	-1.01	-1.01	-1.02	-1.01	-1.00	-1.11
1990-1991	-1.01	-1.14	-1.35	-1.35	-1.35	-1.4	-1.25	-1.25	-1.26	-1.25	-1.27	-1.43
1991-1992	-1.28	-1.30	-1.28	-1.27	-1.27	-1.23	-0.87	-0.84	-0.44	-0.34	-0.33	-0.45
1992-1993	-0.44	-0.4	-0.42	-0.34	-0.47	-0.13	-0.37	-0.34	-0.23	-0.23	-0.23	-0.3
1993-1994	-0.34	-0.30	-0.01	-0.18	-0.26	0.08	-0.02	-0.06	0.00	0.00	0.00	-0.06
1994-1995	0.01	0.01	0.01	0.04	0.03	0.15	0.01	0.07	0.03	0.04	0.04	-0.02
1995-1996	0.05	-0.03	-0.18	-0.14	0.10	0.30	-0.09	-0.11	-0.44	-0.53	-0.52	-0.6
1996-1997	-0.41	-0.43	-0.51	-0.47	-0.15	-0.52	-0.67	-0.70	-0.84	-0.82	-0.82	-0.91
1997-1998	-0.66	-0.64	-0.91	-0.82	-1.05	-1.15	-1.11	-1.16	-1.09	-1.08	-1.08	-1.17
1998-1999	-1.1	-1.12	-1.05	-1.14	-0.91	-0.89	-0.76	-0.83	-0.84	-0.83	-0.83	-0.92
1999-2000	-0.82	-0.79	-0.62	-0.49	-0.76	-0.99	-1.09	-1.09	-1.07	-1.06	-1.05	-1.17
2000-2001	-1.15	-0.92	-0.75	-0.81	-0.83	-0.52	-0.51	-0.61	-0.59	-0.58	-0.58	-0.67
2001-2002	-0.75	-0.74	-0.28	-0.3	-0.35	-0.43	-0.5	-0.25	-0.32	-0.32	-0.31	-0.16
2002-2003	-0.16	-0.08	0.1	0.18	0.21	0.26	-0.08	0.06	0.06	0.08	0.08	0.01
2003-2004	-0.03	0.12	0.45	0.4	0.6	0.91	1.17	1.2	1.29	1.28	1.29	1.28
2004-2005	1.29	1.14	1.10	1.35	1.18	1.09	1.34	1.4	1.37	1.36	1.35	1.31
2005-2006	1.31	1.27	0.92	0.88	1.08	1.27	1.48	1.27	1.46	1.44	1.44	1.18
2006-2007	1.26	1.27	0.94	1.03	0.63	0.46	0.54	0.89	0.96	0.93	0.93	0.88
2007-2008	0.88	0.89	0.52	0.26	0.14	-0.02	-0.21	-0.28	-0.38	-0.35	-0.37	-0.47
2008-2009	-0.44	-0.26	0.21	0.55	0.46	0.76	0.62	0.67	0.90	0.89	0.89	0.85
2009-2010	0.97	0.96	0.95	0.94	0.93	1.05	1.25	1.34	1.26	1.32	1.31	1.36
2010-2011	1.25	1.37	1.74	1.63	1.69	1.59	1.63	1.36	1.39	1.38	1.38	1.34
2011-2012	1.33	1.35	1.57	1.65	1.62	1.52	1.61	**1.76**	1.73	1.69	1.69	1.65
2012-2013	1.70	1.56	1.88	1.27	1.62	1.21	1.29	1.37	1.34	1.33	1.32	1.32
2013-2014	1.16	1.18	1.41	1.59	1.69	1.32	1.25	1.27	1.22	1.16	1.21	1.08
2014-2015	1.17	1.03	0.95	1.22	1.50	1.46	1.48	1.45	1.52	1.51	1.49	1.48
2015-2016	1.48	1.39	1.20	1.03	0.99	1.13	1.17	1.27	1.39	1.38	1.36	1.32
2016-2017	1.23	1.17	0.56	0.61	0.58	0.49	0.44	0.41	0.27	0.27	0.27	0.16
2017-2018	0.17	0.24	-0.03	-0.22	-0.43	-0.37	-0.3	0.04	0.02	0.04	-0.03	-0.09

Table 5-15: Monthly PN index results (1974/1975-2017/2018)

Years	S	O	N	D	J	F	M	A	M	J	Jl	A
1974-1975	102.1	98.7	37.3	0.0	26.8	120.9	283.9	603.2	108.4	0.0	0.0	8.4
1975-1976	0.0	37.2	193.2	39.4	98.8	167.5	45.0	333.1	181.3	70.4	22.0	823.9
1976-1977	202.2	239.8	47.8	132.3	213.7	22.5	143.4	52.8	145.3	0.0	209.0	0.0
1977-1978	0.0	117.3	147.8	32.4	171.1	17.8	58.7	107.8	86.4	0.0	0.0	0.0
1978-1979	0.0	233.6	62.5	110.7	25.3	247.0	72.9	59.1	19.8	0.0	0.0	0.0
1979-1980	146.0	396.1	74.7	268.7	20.9	114.5	191.4	60.2	66.6	0.0	0.0	0.0
1980-1981	1.0	46.2	79.0	0.0	67.9	89.9	80.7	292.3	0.0	**1927.4**	0.0	0.0
1981-1982	88.8	1.4	0.0	63.3	45.7	81.7	25.5	180.4	187.1	89.6	0.0	0.0
1982-1983	101.1	145.9	86.5	117.7	0.0	58.5	28.9	1.9	31.9	0.0	0.0	0.0
1983-1984	0.0	0.0	31.1	217.5	164.1	41.4	53.6	0.0	323.4	153.7	0.0	0.0
1984-1985	119.5	9.5	182.1	38.5	105.3	16.3	81.2	68.9	165.5	0.0	0.0	0.0
1985-1986	5.1	0.0	101.5	49.6	118.2	175.2	216.3	122.4	1.3	0.0	0.0	0.0
1986-1987	138.9	202.6	200.7	85.2	56.8	193.6	3.2	6.0	40.5	0.0	**1133.0**	11.2
1987-1988	54.1	156.4	43.0	74.1	39.0	45.9	0.0	56.1	0.0	0.0	0.0	291.5
1988-1989	90.9	5.2	34.9	0.0	72.3	36.0	216.6	103.7	42.7	41.6	0.0	11.2
1989-1990	236.9	23.8	34.3	136.8	234.3	0.0	68.6	120.5	17.5	0.0	0.0	5.6
1990-1991	134.8	31.9	48.4	69.3	44.9	93.1	237.0	13.1	43.2	0.0	0.0	0.0
1991-1992	35.7	113.0	90.0	69.4	26.3	47.8	297.3	85.7	398.5	691.6	0.0	0.0
1992-1993	0.0	52.0	28.1	52.8	0.0	183.1	79.9	122.7	150.7	0.0	0.0	0.0
1993-1994	61.3	56.7	166.6	24.2	192.8	151.8	7.8	77.8	72.4	0.0	77.0	0.0
1994-1995	210.3	26.7	45.6	94.1	40.3	151.0	147.7	52.8	0.9	41.6	0.0	19.6
1995-1996	127.6	25.3	21.4	98.6	156.1	144.5	61.9	65.9	90.4	28.8	0.0	0.0
1996-1997	295.1	28.6	0.0	74.1	173.7	0.0	0.0	91.7	29.2	25.6	0.0	53.2
1997-1998	440.1	72.0	48.8	84.2	37.9	61.3	62.5	33.3	175.0	0.0	0.0	241.0
1998-1999	75.6	0.0	104.1	1.6	193.3	139.6	243.7	0.0	0.0	41.6	0.0	50.4
1999-2000	146.0	62.0	112.9	181.3	0.0	0.0	10.5	66.6	147.1	0.0	0.0	0.0
2000-2001	29.6	328.9	94.0	27.7	153.0	134.9	15.5	6.0	62.5	0.0	0.0	0.0
2001-2002	96.0	86.3	269.0	66.2	10.6	12.0	31.6	223.0	116.1	0.0	0.0	1479.7
2002-2003	9.2	76.7	181.6	59.2	217.0	161.9	40.7	98.8	4.0	118.5	0.0	0.0
2003-2004	6.1	199.7	257.9	159.7	116.1	163.6	153.3	58.0	216.8	0.0	440.0	224.2
2004-2005	65.3	153.5	50.5	232.2	62.4	114.1	147.4	23.6	0.9	0.0	0.0	0.0
2005-2006	137.8	17.2	80.1	55.3	136.2	134.5	138.8	0.0	279.8	0.0	176.0	0.0
2006-2007	235.9	72.5	0.0	139.6	0.0	87.3	74.5	369.0	49.5	0.0	0.0	0.0
2007-2008	0.0	195.4	71.3	0.0	52.6	85.8	41.3	0.0	128.2	105.7	0.0	42.0
2008-2009	16.3	333.2	260.2	472.0	19.1	268.1	46.4	42.3	213.2	0.0	154.0	0.0
2009-2010	409.4	0.0	55.3	70.9	138.6	209.3	246.3	41.9	168.2	525.1	0.0	588.5
2010-2011	13.3	191.6	151.9	95.7	51.4	68.4	67.3	90.2	47.2	0.0	264.0	0.0
2011-2012	13.3	191.6	151.9	95.7	51.4	68.4	67.3	90.2	47.2	0.0	264.0	0.0
2012-2013	190.9	151.1	385.7	52.2	246.2	86.4	71.6	77.1	148.9	0.0	77.0	297.1
2013-2014	50.0	0.0	144.6	232.5	216.0	51.3	167.5	25.4	93.1	140.9	**1584.0**	0.0
2014-2015	245.1	19.5	93.6	314.5	229.4	79.6	49.0	20.6	85.5	54.4	0.0	221.4
2015-2016	41.9	67.8	33.7	0.0	40.0	156.8	72.8	135.8	135.8	67.2	0.0	0.0
2016-2017	16.3	61.5	80.1	100.2	235.1	49.8	34.0	32.2	9.1	0.0	0.0	14.3
2017-2018	10.4	71.4	16.3	110.7	99.6	67	216.4	288	68.6	276.3	0	16.5

Table 5-17: seasonal PN index results (1974/1975-2017/2018)				
Years	**Autumn**	**Winter**	**Spring**	**Summer**
1974-1975	62.1	57.2	337.6	3.9
1975-1976	126.5	110.2	169.4	418.4
1976-1977	119.3	115.5	115.8	25
1977-1978	120.8	72.6	81	0
1978-1979	101	136.8	54.9	0
1979-1980	170.8	125	118.6	0
1980-1981	60.3	58.4	125.4	**792**
1981-1982	11.6	64.8	115.1	36.8
1982-1983	104.4	55	21.3	0
1983-1984	18.7	129.5	106.5	63.2
1984-1985	127.4	51.8	99.1	0
1985-1986	61.8	122.5	131.8	0
1986-1987	193.4	119.1	13.7	140.8
1987-1988	75.1	51.2	17.4	136.8
1988-1989	34	**38.3**	136.8	22.4
1989-1990	57.1	114.5	71.5	2.6
1990-1991	54.9	70.7	117.7	0
1991-1992	89.3	46.5	257.8	284.2
1992-1993	31	87.3	111.4	0
1993-1994	123.5	131	46.1	9.2
1994-1995	61.3	98.9	80.5	26.3
1995-1996	35.9	136	70.5	11.8
1996-1997	45.1	77.5	35.9	35.5
1997-1998	104.6	59.7	82.4	113.1
1998-1999	72.3	120.3	105.4	40.8
1999-2000	103.3	48.8	63.1	0
2000-2001	149.5	112	24.7	0
2001-2002	197.6	26.1	112.7	694.7
2002-2003	131.4	152.5	49.3	48.7
2003-2004	210.3	146.8	140.2	157.9
2004-2005	80.3	128.7	71.3	0
2005-2006	70.4	113.8	132.2	21.1
2006-2007	49.4	72.4	159.3	0
2007-2008	95.9	51.7	50.9	63.2
2008-2009	249.2	240.4	88.1	18.4
2009-2010	85.1	148.6	162.9	492.1
2010-2011	145.1	70.1	69.2	31.6
2011-2012	145.1	70.1	69.2	31.6
2012-2013	297.6	130.2	93.2	148.7
2013-2014	93.5	154.7	104.3	247.3
2014-2015	92.7	192.5	49.6	126.3
2015-2016	44	75.8	108.6	27.6
2016-2017	67	124.8	27	6.7
2017/2018	30.5	89.6	200.5	121.3

Table 5-21: Monthly DI index results (1974/1975-2017/2018)												
Years	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Jl**	**A**
1974-1975	7	7	3	1	3	7	10	10	7	1	1	7
1975-1976	1	4	9	3	6	9	3	10	9	8	8	10
1976-1977	9	10	4	8	9	2	7	4	7	1	9	1
1977-1978	1	7	8	2	8	2	4	8	6	1	1	1
1978-1979	1	9	5	7	2	10	6	5	3	1	1	1
1979-1980	8	10	5	10	2	7	9	5	5	1	1	1
1980-1981	2	4	5	1	5	6	7	10	1	10	1	1
1981-1982	6	2	1	4	4	5	2	9	9	9	1	1
1982-1983	7	7	6	8	1	4	2	2	3	1	1	1
1983-1984	1	1	2	9	8	2	4	1	10	9	1	1
1984-1985	7	2	9	3	6	2	7	6	8	1	1	1
1985-1986	2	1	7	3	7	9	9	8	2	1	1	1
1986-1987	8	9	9	6	5	10	1	2	3	1	10	7
1987-1988	5	8	3	5	3	3	1	4	1	1	1	9
1988-1989	6	2	3	1	6	2	9	8	4	7	1	7
1989-1990	9	3	2	8	10	1	5	8	2	1	1	7
1990-1991	7	4	4	5	4	6	9	2	4	1	1	1
1991-1992	4	7	6	5	2	3	10	7	10	10	1	1
1992-1993	1	4	2	4	1	9	7	9	8	1	1	1
1993-1994	5	5	9	2	9	8	1	6	5	1	8	1
1994-1995	9	3	3	6	4	8	8	4	1	7	1	8
1995-1996	7	3	2	7	8	8	4	5	6	7	1	1
1996-1997	10	4	1	5	8	1	1	7	3	7	1	9
1997-1998	10	6	4	6	3	4	5	3	9	1	1	9
1998-1999	6	1	7	2	9	7	10	1	1	7	1	8
1999-2000	8	5	7	9	1	1	2	6	8	1	1	1
2000-2001	4	10	7	2	7	7	2	2	5	1	1	1
2001-2002	6	7	10	4	2	1	2	9	7	1	1	10
2002-2003	3	6	9	4	9	9	3	7	2	9	1	1
2003-2004	2	9	10	9	7	9	8	5	10	1	10	9
2004-2005	5	8	4	9	5	6	8	3	1	1	1	1
2005-2006	8	2	6	4	7	7	7	1	10	1	9	1
2006-2007	9	6	1	9	1	6	6	10	4	1	1	1
2007-2008	1	9	5	1	5	5	3	1	7	9	1	8
2008-2009	4	10	10	10	2	10	4	4	9	1	9	1
2009-2010	10	1	4	5	7	10	10	4	9	10	1	10
2010-2011	3	8	8	7	4	4	5	7	4	1	9	1
2011-2012	3	8	8	7	4	4	5	7	4	1	9	1
2012-2013	9	8	10	3	10	5	6	6	8	1	8	10
2013-2014	5	1	8	10	9	3	8	3	6	9	10	1
2014-2015	10	3	7	10	10	5	4	2	6	8	1	9
2015-2016	4	5	2	1	3	8	6	9	7	8	1	1
2016-2017	4	5	6	7	10	3	3	3	2	1	1	7
2017-2018	3	6	1	8	6	4	9	9	5	10	1	8

Table 5-23: seasonal DI index results (1974/1975-2017/2018)				
Years	**Autumn**	**Winter**	**Spring**	**Summer**
1974-1975	4.0	2.0	10.0	4.0
1975-1976	8.0	6.0	10.0	10.0
1976-1977	7.0	7.0	7.0	5.0
1977-1978	7.0	4.0	5.0	1.0
1978-1979	6.0	9.0	3.0	1.0
1979-1980	9.0	8.0	8.0	1.0
1980-1981	3.0	3.0	8.0	10.0
1981-1982	1.0	3.0	7.0	7.0
1982-1983	7.0	2.0	1.0	1.0
1983-1984	1.0	8.0	6.0	7.0
1984-1985	8.0	2.0	6.0	1.0
1985-1986	4.0	7.0	8.0	1.0
1986-1987	9.0	7.0	1.0	9.0
1987-1988	5.0	2.0	1.0	8.0
1988-1989	2.0	1.0	9.0	5.0
1989-1990	3.0	6.0	4.0	3.0
1990-1991	3.0	4.0	8.0	1.0
1991-1992	5.0	1.0	10.0	9.0
1992-1993	1.0	5.0	7.0	1.0
1993-1994	8.0	9.0	2.0	4.0
1994-1995	3.0	5.0	4.0	5.0
1995-1996	2.0	9.0	4.0	4.0
1996-1997	2.0	5.0	2.0	6.0
1997-1998	7.0	3.0	5.0	8.0
1998-1999	4.0	7.0	6.0	7.0
1999-2000	7.0	1.0	3.0	1.0
2000-2001	9.0	6.0	1.0	1.0
2001-2002	10.0	1.0	7.0	10.0
2002-2003	8.0	10.0	2.0	7.0
2003-2004	10.0	9.0	9.0	9.0
2004-2005	5.0	8.0	4.0	1.0
2005-2006	4.0	6.0	9.0	5.0
2006-2007	2.0	4.0	9.0	1.0
2007-2008	6.0	2.0	3.0	7.0
2008-2009	10.0	10.0	5.0	4.0
2009-2010	5.0	9.0	9.0	10.0
2010-2011	9.0	3.0	3.0	6.0
2011-2012	9.0	3.0	3.0	6.0
2012-2013	10.0	8.0	5.0	9.0
2013-2014	6.0	10.0	6.0	9.0
2014-2015	6.0	10.0	2.0	8.0
2015-2016	2.0	4.0	7.0	6.0
2016-2017	4.0	7.0	2.0	4.0
2017-2018	1.0	5.0	10.0	8.0

Table 5-25: Monthly MCZI index results (1974/1975-2017/2018)												
Years	S	O	N	D	J	F	M	A	M	J	Jl	A
1974-1975	0.60	0.57	-0.29	-1.09	-0.37	0.63	1.89	2.45	0.58	0.85	0.71	0.70
1975-1976	-0.52	-0.04	1.31	-0.03	0.55	1.18	-0.04	1.75	1.16	1.03	0.77	2.01
1976-1977	1.23	1.49	-0.11	0.90	1.53	-0.99	0.97	0.36	0.89	0.85	1.19	0.68
1977-1978	-0.52	0.72	0.97	-0.14	1.21	-1.10	0.14	0.78	0.37	0.85	0.71	0.68
1978-1979	-0.52	1.45	0.10	0.74	-0.40	1.95	0.31	0.42	-0.52	0.85	0.71	0.68
1979-1980	0.90	2.18	0.26	1.67	-0.47	0.55	1.32	0.43	0.15	0.85	0.71	0.68
1980-1981	-0.51	0.07	0.31	-1.09	0.20	0.21	0.39	1.61	-0.96	2.65	0.71	0.68
1981-1982	0.49	-0.57	-1.33	0.29	-0.09	0.09	-0.33	1.17	1.20	1.08	0.71	0.68
1982-1983	0.59	0.93	0.40	0.79	-0.86	-0.28	-0.27	-0.31	-0.31	0.85	0.71	0.68
1983-1984	-0.52	-0.60	-0.41	1.42	1.15	-0.60	0.08	-0.35	1.97	1.20	0.71	0.68
1984-1985	0.72	-0.43	1.23	-0.04	0.61	-1.14	0.40	0.50	1.05	0.85	0.71	0.68
1985-1986	-0.44	-0.60	0.56	0.12	0.74	1.26	1.49	0.87	-0.92	0.85	0.71	0.68
1986-1987	0.86	1.28	1.36	0.52	0.06	1.45	-0.75	-0.23	-0.18	0.85	2.21	0.71
1987-1988	0.18	1.00	-0.19	0.41	-0.19	-0.51	-0.82	0.39	-0.96	0.85	0.71	1.35
1988-1989	0.51	-0.50	-0.33	-1.09	0.25	-0.70	1.49	0.75	-0.15	0.96	0.71	0.71
1989-1990	1.41	-0.22	-0.34	0.94	1.67	-1.57	0.26	0.85	-0.56	0.85	0.71	0.69
1990-1991	0.83	-0.11	-0.10	0.36	-0.10	0.26	1.62	-0.11	-0.15	0.85	0.71	0.68
1991-1992	-0.02	0.69	0.44	0.36	-0.38	-0.48	1.96	0.63	2.31	1.86	0.71	0.68
1992-1993	-0.52	0.13	-0.47	0.16	-0.86	1.34	0.38	0.87	0.94	0.85	0.71	0.68
1993-1994	0.25	0.18	1.12	-0.29	1.38	1.00	-0.65	0.57	0.22	0.85	0.92	0.68
1994-1995	1.27	-0.18	-0.15	0.60	-0.17	0.99	1.00	0.36	-0.93	0.96	0.71	0.74
1995-1996	0.78	-0.20	-0.61	0.64	1.08	0.92	0.18	0.48	0.41	0.93	0.71	0.68
1996-1997	1.67	-0.15	-1.33	0.41	1.23	-1.57	-0.82	0.67	-0.36	0.92	0.71	0.84
1997-1998	2.22	0.33	-0.10	0.51	-0.20	-0.24	0.19	0.16	1.11	0.85	0.71	1.26
1998-1999	0.38	-0.60	0.58	-0.99	1.38	0.86	1.66	-0.35	-0.96	0.96	0.71	0.83
1999-2000	0.90	0.24	0.67	1.22	-0.86	-1.57	-0.60	0.48	0.91	0.85	0.71	0.68
2000-2001	-0.09	1.91	0.48	-0.23	1.06	0.81	-0.50	-0.23	0.11	0.85	0.71	0.68
2001-2002	0.55	0.47	1.77	0.32	-0.65	-1.25	-0.23	1.35	0.65	0.85	0.71	2.54
2002-2003	-0.37	0.38	1.23	0.24	1.55	1.12	-0.10	0.72	-0.86	1.14	0.71	0.68
2003-2004	-0.42	1.27	1.71	1.09	0.72	1.14	1.05	0.41	1.39	0.85	1.54	1.23
2004-2005	0.29	0.98	-0.07	1.50	0.13	0.55	1.00	0.04	-0.93	0.85	0.71	0.68
2005-2006	0.85	-0.31	0.32	0.19	0.91	0.80	0.93	-0.35	1.75	0.85	1.13	0.68
2006-2007	1.40	0.34	-1.33	0.96	-0.86	0.17	0.33	1.86	-0.06	0.85	0.71	0.68
2007-2008	-0.52	1.24	0.22	-1.09	0.00	0.15	-0.09	-0.35	0.76	1.11	0.71	0.81
2008-2009	-0.27	1.93	1.72	2.43	-0.50	2.13	-0.02	0.26	1.36	0.85	1.09	0.68
2009-2010	2.12	-0.60	0.00	0.37	0.93	1.60	1.67	0.26	1.07	1.70	0.71	1.76
2010-2011	-0.31	1.22	1.01	0.61	-0.01	-0.12	0.24	0.66	-0.09	0.85	1.29	0.68
2011-2012	-0.31	1.22	1.01	0.61	-0.01	-0.12	0.24	0.66	-0.09	0.85	1.29	0.68
2012-2013	1.17	0.96	2.34	0.15	1.75	0.16	0.29	0.57	0.92	0.85	0.92	1.36
2013-2014	0.14	-0.60	0.95	1.50	1.55	-0.41	1.15	0.07	0.44	1.18	2.52	0.68
2014-2015	1.45	-0.28	0.47	1.87	1.64	0.06	0.02	0.00	0.36	1.00	0.71	1.22
2015-2016	0.05	0.29	-0.35	-1.09	-0.17	1.06	0.31	0.94	0.82	1.03	0.71	0.68
2016-2017	-0.27	0.23	0.32	0.65	1.68	-0.44	-0.19	0.15	-0.74	0.85	0.71	0.72
2017-2018	-0.35	0.33	-0.74	0.74	0.55	-0.14	1.49	1.60	0.18	1.40	0.71	0.73

Table 5-27: Monthly CZI index results (1974/1975-2017/2018)												
Years	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**Jl**	**A**
1974-1975	0.25	0.18	-0.72	**NaN**	-0.94	0.39	1.90	2.49	0.29	0.32	0.18	0.16
1975-1976	-1.04	-0.55	1.15	-0.56	0.06	1.02	-0.60	1.66	0.97	0.71	0.32	1.95
1976-1977	1.03	1.34	-0.53	0.63	1.40	-1.21	0.63	-0.10	0.66	0.32	0.96	0.09
1977-1978	-1.04	0.37	0.74	-0.71	0.93	-1.30	-0.40	0.46	0.04	0.32	0.18	0.09
1978-1979	-1.04	1.30	-0.29	0.42	-0.97	1.99	-0.20	-0.02	-0.92	0.32	0.18	0.09
1979-1980	0.63	2.26	-0.11	1.57	-1.03	0.29	1.11	-0.01	-0.20	0.32	0.18	0.09
1980-1981	-1.03	-0.42	-0.05	**NaN**	-0.35	-0.08	-0.10	1.49	-1.31	2.64	0.18	0.09
1981-1982	0.12	-1.12	-1.67	-0.15	-0.66	-0.20	-0.91	0.95	1.02	0.78	0.18	0.09
1982-1983	0.24	0.63	0.05	0.49	-1.36	-0.58	-0.85	-1.59	-0.71	0.32	0.18	0.09
1983-1984	-1.04	-1.15	-0.84	1.27	0.85	-0.87	-0.47	**NaN**	1.97	0.97	0.18	0.09
1984-1985	0.41	-0.97	1.05	-0.58	0.14	-1.33	-0.09	0.09	0.84	0.32	0.18	0.09
1985-1986	-0.95	-1.15	0.24	-0.37	0.30	1.12	1.34	0.57	-1.28	0.32	0.18	0.09
1986-1987	0.57	1.08	1.21	0.14	-0.51	1.36	-1.31	-1.20	-0.57	0.32	2.17	0.18
1987-1988	-0.25	0.72	-0.61	0.00	-0.76	-0.79	-1.37	-0.06	-1.31	0.32	0.18	1.15
1988-1989	0.14	-1.05	-0.77	**NaN**	-0.29	-0.97	1.34	0.42	-0.54	0.59	0.18	0.18
1989-1990	1.25	-0.74	-0.78	0.67	1.62	-1.65	-0.26	0.56	-0.96	0.32	0.18	0.14
1990-1991	0.54	-0.62	-0.52	-0.06	-0.68	-0.03	1.52	-0.88	-0.53	0.32	0.18	0.09
1991-1992	-0.48	0.33	0.10	-0.06	-0.95	-0.76	2.00	0.26	2.40	1.78	0.18	0.09
1992-1993	-1.04	-0.35	-0.91	-0.31	-1.36	1.22	-0.11	0.57	0.71	0.32	0.18	0.09
1993-1994	-0.17	-0.29	0.92	-0.92	1.18	0.81	-1.22	0.19	-0.13	0.32	0.57	0.09
1994-1995	1.08	-0.70	-0.57	0.25	-0.74	0.80	0.68	-0.10	-1.29	0.59	0.18	0.24
1995-1996	0.48	-0.72	-1.06	0.30	0.76	0.72	-0.35	0.06	0.09	0.52	0.18	0.09
1996-1997	1.59	-0.67	-1.67	0.00	0.96	-1.65	-1.37	0.32	-0.75	0.50	0.18	0.43
1997-1998	2.29	-0.11	-0.51	0.13	-0.78	-0.53	-0.35	-0.40	0.92	0.32	0.18	1.04
1998-1999	-0.01	-1.15	0.27	-2.25	1.18	0.65	1.57	**NaN**	-1.31	0.59	0.18	0.41
1999-2000	0.63	-0.22	0.37	1.02	-1.36	-1.65	-1.17	0.07	0.67	0.32	0.18	0.09
2000-2001	-0.57	1.90	0.15	-0.82	0.72	0.58	-1.08	-1.20	-0.25	0.32	0.18	0.09
2001-2002	0.19	0.05	1.72	-0.11	-1.19	-1.41	-0.81	1.18	0.37	0.32	0.18	2.55
2002-2003	-0.88	-0.05	1.05	-0.21	1.44	0.95	-0.66	0.38	-1.23	0.87	0.18	0.09
2003-2004	-0.93	1.06	1.64	0.86	0.28	0.97	0.74	-0.03	1.25	0.32	1.40	1.00
2004-2005	-0.12	0.69	-0.48	1.36	-0.43	0.29	0.68	-0.59	-1.29	0.32	0.18	0.09
2005-2006	0.56	-0.85	-0.03	-0.27	0.53	0.58	0.58	**NaN**	1.70	0.32	0.88	0.09
2006-2007	1.25	-0.10	-1.67	0.69	-1.36	-0.12	-0.18	1.79	-0.44	0.32	0.18	0.09
2007-2008	-1.04	1.03	-0.16	**NaN**	-0.57	-0.14	-0.66	**NaN**	0.49	0.84	0.18	0.37
2008-2009	-0.76	1.92	1.66	2.50	-1.06	2.23	-0.58	-0.25	1.23	0.32	0.82	0.09
2009-2010	2.15	-1.15	-0.40	-0.04	0.55	1.55	1.59	-0.26	0.86	1.59	0.18	1.66
2010-2011	-0.81	1.00	0.78	0.26	-0.58	-0.42	-0.28	0.31	-0.47	0.32	1.08	0.09
2011-2012	-0.81	1.00	0.78	0.26	-0.58	-0.42	-0.28	0.31	-0.47	0.32	1.08	0.09
2012-2013	0.96	0.67	2.43	-0.32	1.74	-0.13	-0.22	0.18	0.69	0.32	0.57	1.16
2013-2014	-0.30	-1.15	0.71	1.36	1.43	-0.70	0.88	-0.55	0.12	0.94	2.52	0.09
2014-2015	1.30	-0.81	0.14	1.82	1.57	-0.24	-0.54	-0.67	0.03	0.65	0.18	0.99
2015-2016	-0.40	-0.15	-0.79	**NaN**	-0.75	0.88	-0.20	0.67	0.57	0.70	0.18	0.09
2016-2017	-0.76	-0.23	-0.03	0.31	1.63	-0.73	-0.77	-0.42	-1.12	0.32	0.18	0.20
2017-2018	-0.86	-0.11	-1.18	0.42	0.07	-0.44	1.34	1.48	-0.18	1.23	0.18	0.22

Table 5-31: Monthly Z-Score index results (1974/1975-2017/2018)

Years	S	O	N	D	J	F	M	A	M	J	J	A
1974-1975	0.02	-0.01	-0.76	-1.08	-0.94	0.32	2.23	4.31	0.09	-0.32	-0.34	-0.34
1975-1976	-0.94	-0.64	1.13	-0.65	-0.02	1.02	-0.67	1.99	0.90	-0.10	-0.27	2.72
1976-1977	0.96	1.42	-0.63	0.35	1.46	-1.17	0.53	-0.40	0.50	-0.32	0.37	-0.38
1977-1978	-0.94	0.18	0.58	-0.73	0.91	-1.24	-0.50	0.07	-0.15	-0.32	-0.34	-0.38
1978-1979	-0.94	1.36	-0.45	0.12	-0.96	2.21	-0.33	-0.35	-0.89	-0.32	-0.34	-0.38
1979-1980	0.43	3.02	-0.31	1.82	-1.02	0.22	1.11	-0.34	-0.37	-0.32	-0.34	-0.38
1980-1981	-0.93	-0.55	-0.25	-1.08	-0.41	-0.15	-0.23	1.64	-1.10	5.91	-0.34	-0.38
1981-1982	-0.10	-1.00	-1.21	-0.40	-0.70	-0.28	-0.90	0.69	0.96	-0.03	-0.34	-0.38
1982-1983	0.01	0.47	-0.16	0.19	-1.29	-0.62	-0.86	-0.84	-0.75	-0.32	-0.34	-0.38
1983-1984	-0.94	-1.02	-0.83	1.27	0.83	-0.88	-0.56	-0.86	2.47	0.17	-0.34	-0.38
1984-1985	0.18	-0.92	0.99	-0.66	0.07	-1.26	-0.23	-0.27	0.72	-0.32	-0.34	-0.38
1985-1986	-0.89	-1.02	0.02	-0.54	0.23	1.13	1.41	0.19	-1.09	-0.32	-0.34	-0.38
1986-1987	0.36	1.04	1.22	-0.16	-0.56	1.41	-1.17	-0.80	-0.66	-0.32	3.52	-0.33
1987-1988	-0.43	0.57	-0.69	-0.28	-0.79	-0.81	-1.21	-0.38	-1.10	-0.32	-0.34	0.72
1988-1989	-0.09	-0.96	-0.79	-1.08	-0.36	-0.96	1.41	0.03	-0.63	-0.19	-0.34	-0.33
1989-1990	1.28	-0.78	-0.80	0.40	1.73	-1.51	-0.38	0.18	-0.91	-0.32	-0.34	-0.35
1990-1991	0.33	-0.69	-0.62	-0.33	-0.71	-0.10	1.66	-0.74	-0.63	-0.32	-0.34	-0.38
1991-1992	-0.60	0.13	-0.12	-0.33	-0.95	-0.79	2.39	-0.12	3.30	1.91	-0.34	-0.38
1992-1993	-0.94	-0.49	-0.87	-0.51	-1.29	1.25	-0.24	0.19	0.56	-0.32	-0.34	-0.38
1993-1994	-0.36	-0.44	0.81	-0.82	1.19	0.78	-1.12	-0.19	-0.30	-0.32	-0.08	-0.38
1994-1995	1.03	-0.75	-0.66	-0.06	-0.77	0.77	0.58	-0.40	-1.09	-0.19	-0.34	-0.30
1995-1996	0.26	-0.76	-0.95	-0.02	0.72	0.67	-0.46	-0.29	-0.11	-0.23	-0.34	-0.38
1996-1997	1.83	-0.73	-1.21	-0.28	0.95	-1.51	-1.21	-0.07	-0.78	-0.24	-0.34	-0.18
1997-1998	3.18	-0.29	-0.62	-0.17	-0.80	-0.58	-0.45	-0.57	0.83	-0.32	-0.34	0.53
1998-1999	-0.23	-1.02	0.05	-1.06	1.20	0.60	1.74	-0.86	-1.10	-0.19	-0.34	-0.19
1999-2000	0.43	-0.39	0.16	0.88	-1.29	-1.51	-1.08	-0.29	0.52	-0.32	-0.34	-0.38
2000-2001	-0.66	2.33	-0.07	-0.78	0.68	0.53	-1.02	-0.80	-0.41	-0.32	-0.34	-0.38
2001-2002	-0.04	-0.14	2.05	-0.37	-1.15	-1.32	-0.83	1.05	0.18	-0.32	-0.34	5.19
2002-2003	-0.85	-0.24	0.99	-0.44	1.51	0.93	-0.72	-0.01	-1.06	0.06	-0.34	-0.38
2003-2004	-0.88	1.02	1.91	0.64	0.21	0.96	0.65	-0.36	1.29	-0.32	1.16	0.47
2004-2005	-0.32	0.54	-0.60	1.43	-0.48	0.21	0.57	-0.65	-1.09	-0.32	-0.34	-0.38
2005-2006	0.35	-0.84	-0.24	-0.48	0.47	0.52	0.47	-0.86	1.99	-0.32	0.26	-0.38
2006-2007	1.27	-0.28	-1.21	0.43	-1.29	-0.19	-0.31	2.30	-0.56	-0.32	-0.34	-0.38
2007-2008	-0.94	0.97	-0.35	-1.08	-0.61	-0.21	-0.71	-0.86	0.31	0.02	-0.34	-0.22
2008-2009	-0.78	2.38	1.94	4.02	-1.04	2.53	-0.65	-0.49	1.25	-0.32	0.18	-0.38
2009-2010	2.90	-1.02	-0.54	-0.31	0.50	1.65	1.77	-0.50	0.75	1.38	-0.34	1.84
2010-2011	-0.81	0.93	0.63	-0.05	-0.63	-0.48	-0.40	-0.08	-0.58	-0.32	0.56	-0.38
2011-2012	-0.81	0.93	0.63	-0.05	-0.63	-0.48	-0.40	-0.08	-0.58	-0.32	0.56	-0.38
2012-2013	0.85	0.52	3.46	-0.52	1.88	-0.20	-0.34	-0.20	0.54	-0.32	-0.08	0.74
2013-2014	-0.47	-1.02	0.54	1.43	1.49	-0.73	0.82	-0.64	-0.08	0.13	5.05	-0.38
2014-2015	1.36	-0.82	-0.08	2.32	1.67	-0.31	-0.62	-0.68	-0.16	-0.15	-0.34	0.46
2015-2016	-0.54	-0.33	-0.80	-1.08	-0.77	0.85	-0.33	0.31	0.40	-0.11	-0.34	-0.38
2016-2017	-0.78	-0.39	-0.24	0.00	1.74	-0.76	-0.80	-0.58	-1.00	-0.32	-0.34	-0.32
2017-2018	-0.84	-0.29	-1.01	0.12	0.00	-0.50	1.41	1.61	-0.35	0.57	-0.34	-0.31

Table 5-33: Monthly RAI index results (1974/1975-2017/2018)

Years	S	O	N	D	J	F	M	A	M	J	Jl	A
1974-1975	0.04	-0.04	-2.35	-3.43	-2.52	0.68	4.19	9.04	0.19	-3.00	-3.00	-2.75
1975-1976	-3.07	-1.99	2.24	-2.07	-0.04	2.19	-1.96	4.19	1.86	-0.89	-2.34	6.64
1976-1977	1.90	2.77	-1.96	0.72	2.96	-2.88	0.99	-1.53	1.04	-3.00	0.97	-3.00
1977-1978	-3.07	0.34	1.15	-2.31	1.85	-3.05	-1.47	0.14	-0.43	-3.00	-3.00	-3.00
1978-1979	-3.07	2.65	-1.40	0.24	-2.57	4.76	-0.96	-1.32	-2.54	-3.00	-3.00	-3.00
1979-1980	0.86	5.87	-0.95	3.74	-2.72	0.47	2.08	-1.28	-1.06	-3.00	-3.00	-3.00
1980-1981	-3.03	-1.70	-0.79	-3.43	-1.11	-0.38	-0.69	3.45	-3.17	17.69	-3.00	-3.00
1981-1982	-0.34	-3.12	-3.75	-1.26	-1.87	-0.68	-2.65	1.44	2.00	-0.31	-3.00	-3.00
1982-1983	0.02	0.91	-0.51	0.39	-3.44	-1.54	-2.53	-3.17	-2.16	-3.00	-3.00	-3.00
1983-1984	-3.07	-3.17	-2.58	2.60	1.67	-2.18	-1.65	-3.23	5.12	0.52	-3.00	-3.00
1984-1985	0.36	-2.87	1.97	-2.11	0.14	-3.11	-0.67	-1.01	1.50	-3.00	-3.00	-3.00
1985-1986	-2.91	-3.17	0.04	-1.73	0.47	2.44	2.65	0.40	-3.13	-3.00	-3.00	-3.00
1986-1987	0.72	2.03	2.42	-0.51	-1.49	3.03	-3.44	-3.04	-1.89	-3.00	9.17	-2.66
1987-1988	-1.41	1.12	-2.13	-0.89	-2.10	-2.01	-3.56	-1.42	-3.17	-3.00	-3.00	1.76
1988-1989	-0.28	-3.00	-2.44	-3.43	-0.96	-2.38	2.66	0.07	-1.82	-1.75	-3.00	-2.66
1989-1990	2.55	-2.41	-2.46	0.81	3.50	-3.71	-1.12	0.37	-2.61	-3.00	-3.00	-2.83
1990-1991	0.65	-2.16	-1.93	-1.05	-1.90	-0.26	3.12	-2.81	-1.80	-3.00	-3.00	-3.00
1991-1992	-1.97	0.26	-0.38	-1.05	-2.54	-1.94	4.50	-0.46	6.84	5.73	-3.00	-3.00
1992-1993	-3.07	-1.52	-2.70	-1.62	-3.44	2.69	-0.72	0.41	1.16	-3.00	-3.00	-3.00
1993-1994	-1.19	-1.37	1.60	-2.60	2.42	1.68	-3.28	-0.72	-0.87	-3.00	-0.69	-3.00
1994-1995	2.05	-2.32	-2.04	-0.20	-2.06	1.65	1.09	-1.53	-3.14	-1.75	-3.00	-2.41
1995-1996	0.51	-2.37	-2.95	-0.05	1.46	1.44	-1.36	-1.10	-0.30	-2.14	-3.00	-3.00
1996-1997	3.63	-2.26	-3.75	-0.89	1.92	-3.71	-3.56	-0.27	-2.24	-2.23	-3.00	-1.40
1997-1998	6.33	-0.89	-1.92	-0.54	-2.14	-1.44	-1.34	-2.15	1.72	-3.00	-3.00	1.29
1998-1999	-0.75	-3.17	0.10	-3.37	2.43	1.28	3.27	-3.23	-3.17	-1.75	-3.00	-1.49
1999-2000	0.86	-1.20	0.31	1.80	-3.44	-3.71	-3.19	-1.08	1.08	-3.00	-3.00	-3.00
2000-2001	-2.16	4.54	-0.22	-2.48	1.38	1.13	-3.01	-3.04	-1.19	-3.00	-3.00	-3.00
2001-2002	-0.12	-0.43	4.06	-1.16	-3.08	-3.27	-2.43	2.21	0.37	-3.00	-3.00	12.65
2002-2003	-2.78	-0.74	1.96	-1.40	3.05	2.01	-2.11	-0.04	-3.04	0.18	-3.00	-3.00
2003-2004	-2.88	1.98	3.79	1.32	0.42	2.06	1.22	-1.36	2.68	-3.00	3.02	1.14
2004-2005	-1.06	1.06	-1.85	2.93	-1.29	0.46	1.08	-2.47	-3.14	-3.00	-3.00	-3.00
2005-2006	0.70	-2.62	-0.75	-1.53	0.94	1.12	0.89	-3.23	4.12	-3.00	0.67	-3.00
2006-2007	2.53	-0.87	-3.75	0.88	-3.44	-0.47	-0.91	4.83	-1.60	-3.00	-3.00	-3.00
2007-2008	-3.07	1.89	-1.08	-3.43	-1.63	-0.53	-2.09	-3.23	0.65	0.05	-3.00	-1.74
2008-2009	-2.56	4.63	3.85	8.24	-2.79	5.44	-1.91	-1.86	2.59	-3.00	0.48	-3.00
2009-2010	5.76	-3.17	-1.68	-1.00	1.01	3.54	3.34	-1.88	1.56	4.11	-3.00	4.48
2010-2011	-2.66	1.82	1.25	-0.15	-1.68	-1.17	-1.16	-0.32	-1.67	-3.00	1.46	-3.00
2011-2012	-2.66	1.82	1.25	-0.15	-1.68	-1.17	-1.16	-0.32	-1.67	-3.00	1.46	-3.00
2012-2013	1.69	1.01	6.86	-1.64	3.81	-0.50	-1.01	-0.74	1.12	-3.00	-0.69	1.81
2013-2014	-1.53	-3.17	1.07	2.93	3.02	-1.81	1.54	-2.41	-0.22	0.40	13.18	-3.00
2014-2015	2.70	-2.55	-0.24	4.75	3.37	-0.76	-1.81	-2.56	-0.46	-1.37	-3.00	1.11
2015-2016	-1.78	-1.02	-2.49	-3.43	-2.07	1.84	-0.97	0.64	0.82	-0.98	-3.00	-3.00
2016-2017	-2.56	-1.22	-0.75	0.00	3.52	-1.87	-2.35	-2.19	-2.88	-3.00	-3.00	-2.57
2017-2018	-2.75	-0.91	-3.14	0.24	-0.01	-1.23	2.65	3.38	-1.00	1.71	-3.00	-2.50