METEOROLOGICAL AND HYDROLOGICAL DROUGHT ANALYSIS OF SINOP, KASTAMONU, BARTIN PROVINCES IN THE WESTERN BLACK SEA

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I certify that in my opinion, the thesis submitted by Amhimmid Anbeeh ALZAROUQ ALBAQOUL titled “METEOROLOGICAL AND HYDROLOGICAL DROUGHT ANALYSIS OF SINOP, KASTAMONU, BARTIN PROVINCES IN THE WESTERN BLACK SEA” is fully adequate in scope and quality as a thesis for the degree of Master of Science.

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“I declare that all the information within this thesis has been gathered and presented in accordance with academic regulations and ethical principles, and I have according to the requirements of these regulations and principles cited all those which do not originate in this work as well.”

Amhimmid Anbeeeh ALZAROUQ ALBAQOUL

ABSTRACT

M. Sc. Thesis

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In recent years, a significant change has been observed in the climate characteristics of Turkey. These changes, which are compatible with the general trend of global climate change, are also felt in the Western Black Sea Basin. One of the biggest effects of global climate change is occurring on precipitation; While this situation causes drought in some regions due to the lack of precipitation; In some regions, it manifests itself in the form of floods and overflows as a result of extreme precipitation. Drought is a natural hazard characterized mainly by three dimensions: severity, duration, and areal extent. Although several simplifications were proposed to analyze droughts to assist water managers and policymakers in addressing this complex phenomenon, drought severity remains the key factor for the characterization of drought. Drought severity is conventionally assessed by drought indices, which are simple or composite indicators useful for identifying and monitoring drought events in a meaningful way.

The thesis reports on the calculation of drought indices, with emphasis on two recently developed indices, the Reconnaissance Drought Index (RDI) and the Streamflow Drought Index (SDI) using specialized software package, named DrinC (Drought Indices Calculator). Additionally, DrinC includes a module for the estimation of potential evapotranspiration (PET) through temperature-based methods (Hargreaves, Blaney - Criddle, and Thornthwaite) that can be used for the calculation of RDI.

In this study carried out in the Western Black Sea region, meteorological/agricultural drought analyses using monthly total precipitation and monthly average temperature data for 1-, 3-, 6- ve 12 months were made for 8 precipitation monitoring stations in the provinces of Sinop, Kastamonu, Bartın, and monthly average temperature data of 3 flow monitoring station in the region were used to determine the hydrological drought analyses.

Key Words : Drought analysis, Standard Precipitation Index (SPI), Reconnaissance Drought Index (RDI), Streamflow Drought Index (SDI), Sinop, Kastamonu , Bartın , West Black Sea Region.
Bilim Kodu : 91106

ÖZET

Yüksek Lisans Tezi

BATI KARADENİZ BÖLGESİNDE BULUNAN SİNOP, KASTAMONU, BARTIN İLLERİNİN METEOROLOJİK VE HİDROLOJİK KURAKLIK ANALİZİ

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Son yıllarda, Türkiye'nin iklim özelliklerinde belirgin bir değişim izlenmektedir. Küresel iklim değişikliği genel trendi ile uyumluluk gösteren bu değişiklikler Batı Karadeniz Havzası'nda da kendini hissettirmektedir. Küresel iklim değişikliğinin en büyük etkilerinden biri yağışlar üzerinde meydana gelip; bu durum bazı bölgelerde yağış azlığı nedeniyle kuraklığa neden olurken; bazı bölgelerde ise ekstrem yağışlar sonucu sel ve taşkınlar şeklinde kendini göstermektedir. Kuraklık, başlıca şiddet, süre ve alansal boyutla karakterize edilen doğal bir tehlikedir. Buna rağmen su yöneticilerine ve politika yapıcılara yardımcı olmak için kuraklık analizleri için çeşitli basitleştirmeler önerilmiştir. Bu karmaşık fenomeni ele almak ve kuraklık olaylarının anlamlı bir şekilde tanımlanması ve izlenmesi için kuraklık şiddeti oldukça önemlidir.

Bu tezde, basit bir arayüz sağlamayı amaçlayan ve son zamanlarda geliştirilen iki endekse (Keşif Kuraklık Endeksi (RDI) ve Akarsu Kuraklık Endeksi (SDI)) vurgu yapan, DrinC (Drought Indices Calculator) adlı yazılım paketi kullanılmıştır. RDI hesaplamaları, sıcaklığa dayalı Hargreaves, Blaney-Criddle ve Thornthwaite yöntemleriyle yapılabilmektedir.

Batı Karadeniz bölgesnde gerçekleştirilen bu çalışmada, Sinop, Kastamonu, Bartın illerindeki 8 yağış gözlem istasyonu için aylık toplam yağış ve aylık ortalama sıcaklık verileri kullanılarak 1-, 3-, 6- ve 12 aylık meteorolojik/tarımsal kuraklık analizleri yapılmış, ayrıca aynı bölgedeki hidrolojik kuraklığın belirlenmesi için, 3 akım gözlem istasyonunun aylık ortalama akım verileri kullanılmıştır.

Anahtar Kelimeler : Kuraklık analizleri, Standart Yağış İndeksi (SPI), Keşif Kuraklık Endeksi (RDI), Akım Kuraklık İndeksi (SDI), Sinop, Kastamonu , Bartin , Bozkurt , Ulus , Devrekani , Amasra Batı Karedeniz Bölgesi

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SYMBOLS AND ABBREVIATIONS

SYMBOLS

Pij : Precipitation

Qij : Monthly flow volume

Vi : Cumulative flow volume

I : Observation order of data

K : First hydrological year

Σ : Standard deviation

J : Month in the hydrological year

R_{xi} : i observation sequence number

S : Mann-Kendall test coefficient

SYİ : Standardized Rainfall Index

Vk : Average of cumulative flow volumes of reference period k

Sk : Standard deviation

X : Observation series vector

x_{ij} : i at the precipitation station j. monthly rainfall at observation

x_{im} : Long term precipitation averages

Z : Significance standard normal variable

A : Level of importance

Q : Probability of zero precipitation

Xi : Amount of precipitation

P : Speed deviation

Pi : The axis quantity

N : Total number of years of the available data.

$\bar{y}$: Arithmetic mean

αk : Values follow the lognormal distribution

$\Gamma(\gamma)$: Gamma function

γ,β : Shape and scale parameters

G(x) : Cumulative probability

ABBREVIATIONS

ANN : Artificial Neural Networks
PNI : Percentage Normal Index
SPI : Standardized Precipitation Index
RDI : Reconnaissance Drought Index
EDI : Effective Drought Index
SDI : Streamflow Drought Index
PD : Precipitation Deciles
PET : Potential Evapotranspiration

PART 1

INTRODUCTION

Although drought is one of the natural disasters that has a significant negative impact not only on human life but also on all living things, it is different from other natural disasters in terms of its structure. Drought is not experienced suddenly like other natural disasters, and it is very difficult to compensate for the consequences that will occur after it occurs [1]. Although the definition of drought is made differently by different disciplines, in the United Nations Convention to Combat Desertification, drought is "a natural event that causes significant hydrological imbalances, negatively affecting land use and resource production systems, as a result of a significant decrease in precipitation below the normal measured levels." It is defined as [2]. In another definition, drought is briefly defined as "periods in which serious decreases in precipitation, which is a very important parameter in the nutrition of water resources, are experienced" [3]. On the other hand, it is seen that the frequently used expressions when defining drought are "water need", "temporary decrease in humidity", "long term" and "large areas" [4]. From this point of view, it is possible to express drought as “water scarcity experienced in a certain time interval, in a certain area or time and both areas” [5].

Drought is the most important natural disaster today, which occurs as a result of people's negative effects on the ecosystem, and it is one of the problems that will increase in importance [1]. Drought is not only caused by the direct activities of people, but the increasing temperature values and decreases in precipitation in many parts of the world due to global climate change have led to an increase in the frequency of drought events [6]. Drought can directly affect the life of living things, as well as cause serious sociological, socioeconomic, agricultural and environmental problems[4;7]. Although its effect cannot be measured in a short time such as floods and landslides, it is one of the most destructive natural disasters [7]. Also, when the droughtNot knowing when it will start and end, its cumulative increase, and its negative impact on more than one source at the same time if it occurs are the most important features that distinguish it from other natural disasters [8]. For this reason, it is very important to detect long-term droughts in advance, and to determine the measures to be taken so that living things are less affected by this destructive natural disaster [5].

1.1. AIM OF THE STUDY

The main purpose of this study is to determine the sensitivity of drought by conducting analyzes of meteorological and hydrological drought in the western Black Sea region. Moreover, this study aims to determine the most extended dry period in the study area. For the purpose of this study, a meteorological, agricultural and hydrological analysis of drought in the region will be conducted for eight monitoring stations and the three flow monitoring stations in the western Black Sea.

1.2. THE AIMS AND OBJECTIVES

The main concern is to find one of the driest years of all the stations and to find the years with the highest drought rates.

For the purpose of this study, the meteorological, agricultural, hydrological drought analysis of the study area were performed for eleven monitoring stations in the Western Black Sea Region.

- To analyze the drought index by SPI method, in the Western Black Sea regions.
- To examine the sensitivity of drought in the Western Regions of the Black Sea.
- To calculate and clarify the most extreme years in the Western Regions of the Black Sea.
- To check the temporal changes of the drought index.

1.3. PROBLEM STATEMENT

Drought is a pernicious natural hazard that involves a wide range of climatic processes and has far-reaching effects on both the environment and society. Due to the present harsh climatic occurrences, there has been an interest in drought consequences and monitoring in recent years. This phenomenon set up an interconnection between various fields, such as agriculture sustainability, food security, ecosystem functions, and services, biodiversity and carbon stocks, water resources, and wildfires. According to the newly released IPCC (Intergovernmental Panel on Climate Change) 5th Assessment Report [9], a drop in precipitation paired with rising temperatures associated with drought occurrences is predicted, particularly in the Mediterranean Basin, which would reduce water availability for natural and agricultural. The main and important topic in this situation is to find one of the driest years of all the stations and to find the years with high drought rates.

Drought is the consequence of a natural reduction in the amount of precipitation over extended period of time, usually a season or more in length, often associated with other climatic factors (such as high temperatures, high winds and low relative humidity) that can aggravate the severity of the event [10].

Drought is a natural disaster with multiple varieties. According to the purpose of the study and the data used, many methods assessed drought and its development in various factors. Therefore, according to methods, developed by Palmer (1965) [11] to translate drought into the language of mathematics and Palmer Drought Severity Index (PDSI) based on precipitation and temperature data [12], and had analyzed solely of precipitation data Standardized Precipitation Index (SPI) which had explored meteorological drought [13]. Also, the Reconnaissance Drought Index (RDI) had analyzed during the compare and completion of the results.

1.4. THE GEOGRAPHY OF THE AREA

The Black Sea region has a steep, rocky coast with rivers that cascade through the gorges of the coastal ranges. Some larger rivers, those cutting back through the Pontic Mountains (Doğu Karadeniz Dağları), have tributaries that flow in broad, elevated basins. Access inland from the coast is limited to a few narrow valleys because mountain ridges, with elevations of 1,525 to 1,800 meters in the west and 3,000 to 4,000 meters in the east in Kaçkar Mountains, form an almost unbroken wall separating the coast from the interior. The higher slopes facing northwest tend to be densely forested. Because of these natural conditions, the Black Sea coast historically has been isolated from Anatolia. The region, which has 18% of Turkey's surface area, ranks third in the region in terms of surface area with this ratio. It is the longest in the east-west direction. The region has a length of approximately 1400 km from west to east and a width ranging from 100 to 200 km in the north-south direction [14]. The mild, damp oceanic climate of the Black Sea coast makes commercial farming profitable. Running from Zonguldak in the west to Rize in the east, the narrow coastal strip widens at several places into fertile, intensely cultivated deltas. [15].

The North Anatolian Mountains in the north are an interrupted chain of folded highlands that generally parallel the Black Sea coast. In the west, the mountains tend to be low, with elevations rarely exceeding 1,500 meters, but they rise in an easterly direction to heights greater than 3,000 meters south of Rize. Lengthy, trough-like valleys and basins characterize the mountains. Rivers flow from the mountains toward the Black Sea. [16] .

1.5. DEFINITION OF DROUGHT INTRODUCTION

Drought is defined as a phenomenon that may be related to the area under investigation and should be addressed using a specific application. The region can faces environmental, economic, and social challenges and so, many definitions of the dangerous drought have been developed [17]. During a drought, a lack of moisture usually results in a severe hydrological imbalance. The areas can had also experienced dry weather and long-term water scarcity due to water scarcity. According to Hagman (1984), drought is the most common natural disaster [18]. The event are the most complex of all-natural disasters that have affected man, but the nature of drought has been described as the event observed in a specific period and circumstances. Every year, various regions of the world are affected by the drought [19, 20].

1.6. THE EFFECTS OF DROUGHT

Drought is a natural occurrence with numerous consequences. Economic, environmental, and social effects are all common. With the emergence of drought due to a lack of rainfall, the region's water and water resources, which were the source of life, decreased. It is also possible that agricultural productivity will suffer as a result. For example at some countries as Libya, where the effects of drought and semi-arid climate characteristics, some issues may arise due to the agricultural and hydrological drought, which occurred due to the country's meteorological drought. Specific agricultural sectors, which are among Libya's most important essential sectors, have suffered due to the agricultural drought. Similarly, the products cultivated by farmers, which are considered the essential elements of this sector, are generally climate dependent. As a result, a decrease in rainfall usually results in problems such as decreased product yield and an inability to meet the country's food needs [21].

1.7. TYPES OF DROUGHTS

Considering the severity, duration, and effects of the drought, there are certain drought types; meteorological drought, agricultural drought, hydrological drought, andsocioeconomic drought [22].

1.7.1. Meteorological Drought

Meteorological drought is defined by the severity and duration of the drought. Depending on rainfall data, it is the first type of drought we encounter. Because its effect is dependent on rainfall, the period of rainfall corresponds to an average level in that drought type. Because the climate regime of the regions is an important factor, meteorological droughts vary in different locations. Taking two regions with different precipitation amounts as an example, the average annual rainfall in the first region is estimated to be 500 mm/year for longer years. In contrast, the annual rainfall in the second region is estimated to be around 1500 mm/year. If the amount of rainfall in the region in the same year is 750 mm/year, then the first region is experiencing a humid year, while the second region is experiencing a dry year. The main reason for this is due to atmospheric conditions that caused a lack of precipitation based on the climatic regime. Furthermore, meteorological drought had recorded monthly rainfall data. It is assessed on a seasonal, water-year, and annual time scale [23]. As a result, the researcher observed the significant socioeconomic impact of such frequent changes.

1.7.2. Agricultural Drought

Agricultural drought is investigated due to a lack of rainfall due to meteorological drought and soil water deterioration. The water demand of a plant is determined by its biological properties, as well as the growth or stages of the soil's physical and biological properties [24]. During the agricultural drought, even plants that were thought to be able to meet their nutritional needs in the developmental stage suffered from flaws caused by insufficient subsoil moisture. The moisture in the soil has the potential to change the final product. Furthermore, if the lack of subsoil moisture persisted, a significant yield loss would occur. As a result, an important feature in agricultural drought triggered is the subsoil that plants require the most. The presence of moisture in the soil had played an essential role during the plant's growth and development phase. As a result, in agricultural drought, monthly assessments are regarded as more important than annual assessments. Furthermore, agricultural drought is the most severe and widespread type of drought after meteorological drought. As a result, agriculture is the first sector to be affected by meteorological drought.

1.7.3. Hydrological Drought

A lack of water in the hydrological system was referred to as a hydrological drought. It was a type of drought in which water levels in rivers, lakes, reservoirs, and groundwater were unusually low [25]. The hydrological drought indicated that the total flow of the dry year was lower than the previous year's average flow. Furthermore, the frequency and severity of hydrological drought are typically defined at the river basin scale. Hydrological drought is considered to be ongoing if the actual flow in a river during a specified time period falls below a certain threshold. As a result, the effects of hydrological drought upstream of a river basin may reduce downstream flow and vice versa [25]. Although the meteorological drought was not studied in this part of the basin, it would eventually result in lower reservoir and groundwater levels at downstream locations, particularly at the basin's bottom. As a result, decreases in reservoir and groundwater levels in certain parts of the city may have serious consequences for public water resources, hydroelectric power generation, recreation, transportation, agriculture, and other sectors. Furthermore, because it was thought to be a time-consuming process to fill reservoirs and groundwater, hydrological drought could last for months or years [25]. For example, after years of severe drought in a river basin, many years of normal rainfall were required to replenish the reservoirs.

1.7.4. Socioeconomic Drought

The socioeconomic drought occurred due to meteorological, hydrological, and agricultural drought factors being linked to the supply and demand for certain economic goods or services. Water, food, and hydroelectric energy supply, for example, are all affected by weather conditions. In most cases, demand for these goods is increasing due to rising per capita consumption. As a result, droughts are typically caused by an increase in demand for supply goods and a decrease in climate factors [25].

PART 2

LITERATURE REVIEW

2.1. INTRODUCTION

If we look at the studies on the Standard Precipitation Index in our country and in the world in general, it is seen that the scientists doing research on the subject are especially in arid, semi-arid or slightly arid regions or where the population is high, directly affected by precipitation, agriculturally developed or drought progression.

It is seen that in the case of precipitation, the probability of deterioration of the agricultural balance necessary for the continuation of life in that region is high, and that they go on this issue in the precipitation basins and plains where the precipitation gauge stations that provide data that can be used in the research are located.

it is seen that the standard precipitation index method is used more than other more complex methods such as the Erinç index and the Palmer drought index, which are used for drought monitoring, as they only use the precipitation values obtained from the stations, which gives practical, useful and quick results. Standard indicator of precipitation for different periods, eg 3 monsoon months and 12 months It is also important for researchers to analyze drought annually or in longer periods such as 24, 48, to show the severity of drought that occurred in any month or year, indicate drought in which category, and give percentages of drought.

Analyzing the history of the drought is just as important as predicting future floods in a region or watershed. The traces of drought in the past should be read well in order to predict the destruction caused by the drought, which can be described as catastrophic, or to avoid repeating the deep wounds caused by the negative results of the past droughts. A good analysis is required for these situations, which are well known by academicians who are experts in the literature. Researchers have always emphasized the importance of drought, its effects on water resources and, of course, its effects on agricultural activity. This chapter will present a few previous studies related to the thesis subject and thesis area and its vicinity.

2.2. PREVIOUS STUDIES

Tigkas et al. (2012) presented a comprehensive and simply thought out methodology for estimating annual hydrological drought based on current meteorological drought indications early in the hydrological year. The area of N. Peloponnese (Greece), which includes several small river basins, was chosen as the study area. A meteorological drought of 3, 6, and 9 months is estimated using the Reconnaissance Drought Index (RDI) method; Annual hydrological drought was represented by the Streamflow Drought Index (SDI) method. Regression equations are derived between RDI and SDI by estimating the hydrological drought level for the whole year in real-time. In addition, nomographs have been designed to estimate annual runoff flow change using various scenarios representing possible climate changes and drought events of varying severity. It was concluded that the Medbasin precipitation-runoff model could be used to connect meteorological data to flow and could be useful in developing preparedness plans to combat the consequences of drought and climate change.[26].

The study aimed to investigate the meteorological and hydrological drought, Standardized Precipitation Index (SPI) and Streamflow Drought Index (SDI) method conducted by Gümüş et al., (2019) in the Ceyhan region of Turkey and it is determined that methods gave similar results and also it is stated that they help to understand the drought better [27].

Bacanlı and Pilgir (2011) studied reservoir management under drought and the results obtained from Palmer Drought Severity Index, Erinç Index, De Martonne's Climate Classification, and Standard Precipitation Index (SPI) methods were evaluated in the study. It has been suggested by researchers to carry out studies such as developing a climate monitoring system and estimating future droughts in order to minimize the effects of drought. According to the SPI drought index, the Euphrates-Tigris basin in the Middle East underwent a recent drought study [28].

Tabari et al. (2013) conducted a hydrological drought analysis using the Streamflow Drought Index (SDI) method for 3, 6, 9, and 12-month periods, using the data of 14 flow observation stations located in the northwest of Iran between 1975 and 2009. The analysis revealed that all stations experienced extreme drought during the study period. [29].

Arslan et al. (2016) investigated the droughts that occurred in the Gediz Basin between these years by using the Standard Precipitation Index (SPI) for 1,3,6,9,12 and 60-month periods, using the monthly precipitation data of 8 meteorological precipitation stations between 1973 and 2013. As a result of the study, it was determined that the droughts experienced in recent years lasted longer for periods of 12 and 60 months. It has been stated that the drought period has increased by 3-7 times in recent years compared to the past [30].

Gümüş (2017) used the Stream Arid Index approach to conduct drought studies in the Asi Basin. Data from four flow monitoring sitations between 1954 and 2005 were analyzed in the research. In the basin, the flow drought index calculations for the 3, 6, and 12-month time series indicated the dry, humid, and wet times of year. There were many more dry years between 1980 and 2005 than in prior years, according to the statistics. In addition, 2000 and 2001 were shown to be very dry years [31].

Atmaca (2011) analyzed the drought of Konya's region with the L-moments approach and utilized the methods of Standardized Precipitation Index method. In his study, he created 3, 6, 9, and 12-month cumulative rainfall series using the monthly precipitation. As a result, he observed that mild drought was common in the regions according to SPI values [32].

A meteorological drought study in Northern Iraq was undertaken by Awchi and Kalyana (2017) utilizing the Standardized Precipitation Index (SPI) and Geographic Information Systems (GIS) techniques. Meteorological drought was studied using the standardized precipitation index (SPI) at various time intervals (3, 6, 12, and 24 months). A total of nine meteorological stations in the research region were utilized to gather monthly precipitation data from 1937 to 2010. A geographic information system (GIS) was used to map the spread of drought in the research region at various time intervals. Since 1997–2001 and 2006–2010, the research region has seen the most severe drought periods in terms of frequency and severity [33].

Bakanoğulları (2020) to analyze the Istanbul-Damlca Stream Basin droughts used SPEI (Standardized Precipitation Evapotranspiration Index) and SPI indices. The Thornthwaite evapotranspiration technique was used to determine the SPEI drought index in the basin between 1982 and 2006. The 0.977 regression coefficient (r2) between the yearly SPEI and SPI indices is statistically noteworthy. Drought patterns differed across the 1, 3, and 6- month time frames, however. it is specified that SPEI Drought Index more accurate regarding agricultural productivity and its usage is healthier [34].

Balcı (1992) examined the drought situation of Salihli, Akhisar, Manisa, and Menemen in the Gediz Basin using the Thornthwaite method within the scope of researcher’s master's thesis. In the study, it is used monthly and annual data between 1931-1989. As a result, it was revealed the years in which drought problems were encountered in various places. Therefore, it was examined and found that the dry period lasted at least four months and at most six months for the Gediz Basin [35].

Çaldağ et al. (2004) made a drought analysis for the Thrace Region using the SPI method. As a result, extreme drought conditions were detected in most of the studied stations, and the most extreme drought years were found in 2000 and 2001 [36].

In research by Coşkun (2020), a long-term precipitation trend analysis in the Van Lake basin was performed. The long-term recorded precipitation data from Van, Muradiye, Erçiş, Gevaş, Zalp, Tatvan, and Ahlat meteorological stations were used to evaluate both yearly and seasonal patterns in precipitation. Gevaş and Ahlat stations have declined yearly precipitation. The MannKendall Test, Spearman's Rho, and en Tests were used to analyze the data. Van station had an increase in annual precipitation. However, this increase was negligible. Erciş and Ahlat stations have had a considerable fall in precipitation, whereas Van-Region has seen a slight rise [37].

Dai (2011) claimed that the atmospheric demand for moisture has grown due to the present warming and that this has likely altered the atmospheric circulation patterns, which has contributed to dryness [38].

Doğan (2013) had compared “Konya Closed Basin drought characterization six different drought indices that were widely used in the world within the scope of in the doctoral dissertation named "Temporal-Spatial Analysis of Konya Closed Basin." These are Normal Precipitation Percentage (PNI), Precipitation Tails (YK), Z-Score, Chinese Z Index (ÇZI), Standardized Precipitation Index (SPI), and Effective Drought Index (EKI) methods. It was made the drought analysis of Konya Closed Basin for the years 1972-2009, and was successfully determined the variabilities. It was determined that the extreme drought event, was between the years 1973-1974, and the longest drought events were between 1996-2000 periods [39].

Dupigny-Giroux (2001), küçük ila orta zaman aralıklarında çalışan SPI kuraklık profilinin nem indekslerinden ve Modifiye Palmer'dan daha iyi olduğunu düşünmektedir. [40].

Numerous studies have examined the effects of meteorological drought on a global, regional, and local level. This approach was developed by Dutra et al. (2014) and is based on probabilistic predictions from the European Centre for Medium-Range Weather Forecasts (ECMWF) [41].

Edossa et al. (2010) conducted a drought analysis for the Awash River Basin in Ethiopia. With the Standard Precipitation Index method, 30 precipitation stations between 1987 and 2000 were used to determine the 3, 6, and 12-month SPI timelines. İt was determined that the most extreme drought periods in the basin were between May 1988-June 1988 and April 1998-May 1998 [42].

Efe and Özgür, (2015) have conducted a drought analysis of Konya and its vicinity. In the study, drought analysis was made using the monthly total precipitation data of 20 stations between 1972-2013. According to the SPI method, it was observed that 2013 was dry at all stations except only one station [43].

Eklund and Seaquist (2015) used the improved vegetation index (EVI) to study agricultural drought in Iraqi Kurdistan. Over the region, it is founded that precipitation decreased by around 50%, resulting in a 62% reduction in vegetative cover in 2008 [44].

According to Gleick (2014) drought frequency and severity in the eastern Mediterranean have shifted since 2008 [45].

Gümüş and Algin (2017) conducted a drought analysis using SPI and SDI in their study for the Seyhan-Ceyhan River Basins. Meteorological and hydrological drought analyzes were carried out in 3, 6, and 12 month time periods from the data obtained from 12 meteorology stations and 12 flow monitoring stations, and drought periods and drought severity were determined at different time periods in all stations [46].

Hayes et al. (1999) studied the advantages and disadvantages of using SPI for drought severity traits. Due to the simplicity of the calculations, SPI can calculate for any desired period as the most suitable indicator for monitoring meteorological drought. Positive values of the SPI index indicate that precipitation is more than the average precipitation amount, and negative values have the opposite meaning. When the SPI is persistently negative and drops to -1 or below, it is considered drought. A drought's length and severity may be gauged using SPI values, which are calculated by subtracting positive numbers from negative ones [47].

Droughts in the Mediterranean area were examined using global climate models in research by Hoerling et al. (2012). While, 1902–1970 was a time of widespread wet, 1971–2010 was marked by widespread dry conditions. Researchers discovered that the frequency of droughts has risen since 1970 [48].

Ilgar (2010) made a 12-month (annual) and 3-month (seasonal) drought analysis by using the monthly precipitation totals observed at Çanakkale Central Meteorology Station between 1929 and 2007 using the SPI method. According to the study results, in Çanakkale, an increase was observed in annual drought conditions. According to the results of seasonal drought analysis, an increase in drought was observed in winter, whereas a decreasing trend in drought in spring was also examined. In the summer and autumn seasons, a not obvious increase trend was observed in drought [49].

Karabulut (2015) tried to determine the drought in Antakya - Kahramanmaraş. Long-term precipitation data of 4 meteorological stations in the Mediterranean were used to determine the Standard Precipitation Statistics (SPI) values. The time sets used selected from 1975-2010. As a result, the four stations heavily depend on precipitation for their water supply [50].

Analysis of Upper Gediz Basin precipitation by Kumanlioglu and Fistikoglu (2019) was conducted. The Standardized Precipitation Index (SPI) drought index research was carried out using six meteorological stations data between 1960 and 2017 periods. It is determined that droughts experienced in the winter months have been shown to have a significant impact on the yearly droughts and this area has been experiencing more extreme and long-lasting droughts recently [51].

Lana et al (2001) used SPI to investigate deposition patterns in the Catalonia region of Spain. Consequently, some considerations must be made about the true meaning of lack and excess for the four seasons [52].

İt is determined that climate change is expected to cause increasingly extreme and frequent droughts in the Middle East, according to research in the Eastern Mediterranean and the Middle East (EMME) by Lelieveld et al. [53].

Lloyd-Hughes and Saundersa (2002) calculated SPI on a different time scale (between 1 and n months) and observed that SPI values (2-3 months time scale) could be used for agricultural drought. Furthermore, it is determined that the trend in

SPI values represented a significant shift in severe or moderate drought rates in Europe during the twentieth century [54].

Loukas et al. (2003) used Z number, precipitation anomaly, and three indicators of standard sediments to investigate meteorological droughts at different time scales in Greece. it is concluded that the three indicators for the 21-month time frame had the same trend and had good agreement with Palmer's index (PDMS) [55].

Masarie and Tans (1995) discussed the drought analysis of Karaman province using SPI (Standartized Pricipitation Index), RDI (Reconnaissance Drought Index), and EDI (Effective Drought Index). For this purpose, the monthly total precipitation and monthly average temperature were used between 1975 and 2009 at the Karaman meteorological station. It had been used the ETo (Reference plant water consumption) values determined according to the FAO56 Penman-Monteith relationship. Cumulative monthly precipitaion for four different reference periods (k1, January-March; k2, January-June; k3, January-September; k4, January-December) were determined and had been expressed that a dry period was started in Karaman in recent years [56].

McKee et al. (1993) applied the SPI index for the first time in Colorado and found that the gamma distribution was the most suitable distribution for matching the sedimentation data, defined drought, and divided it into four different classes. In this study, it was developed the Standard Precipitation Index (SPI), and it was used as input into 3, 6, 9, 12, and 48-month periods, and compared them among themselves [57].

Merkoci et al. (2013) tried to find the 1, 3, and 6 month SPI values using the Standard Precipitation Index (SPI) in the Albanian region and used the data between 1951-2000. it was determined that during the 1961-1970 and 1971-1980 periods, moderate, severe, and extreme drought conditions occurred ten times (over a 10-year period) and 2003 was the most notable year for drought [58].

Özgürel and Kılıç (2003) classified the annual precipitation in İzmir province in the period 1960-2001 according to the Standardized Precipitation Index (SPI) system. At the end of the study, it was stated that the most near-normal humid year occurred during specific time frame [59].

Shafer and Dezman (1982) used the Water Level Indexs, which are primarily used in mountainous regions, for surface water assessment. It is expressed that the (SWSI) Index was designed for Colorado in 1982, (PDSI) index is a hydrological indicator designed to describe snow, water resources, river flow, and rain fall, Palmer Drought Index is a soil moisture algorithm, and the SWSI indicator is designed to describe surface water conditions [60].

Soliman (2020) caried out the meteoroogical analysis in the Libya meteorolgical stations, which are eight coastal stations, five desert stations, and three moutain stations. The author expressed that the highest temperatures during the winter season exhibited discernible patterns, in general, all stations except those around Green Mountain and Zwara stations in the west have exhibited warming in the average maximum temperatures, temperatures are warming at all locations except Shahat in the summer, according to the data, and temperatures rose at all sites throughout the spring, except those at high elevations like Nalut and Ghadames [61].

Stagge et al. (2015) used meteorological drought indexes to estimate the drought impact across Europe. Precipitation Evapotranspiration Index (SPEI) and Precipitation Index (SPI) were employed in the research. Five European nations' freshwater ecosystems and agriculture are both included in this study's four distinct effect categories. it was expressed that it is possible that agricultural impacts may be explained by anomalies of 2 to 12 months in length, which is most likely a consequence of agricultural management techniques, it takes longer for hydropower and energy cooling water to influence the energy and industrial sectors (6–12 months), and a more complicated mix of short (1-3 months) and mean-long (6-12 months) aberrations is responsible for public water supply and freshwater ecological consequences [62].

Drought predictions for Konya province were created using artificial neural networks by Terzi and Ersoy (2018). For the province of Konya, long-term monthly average precipitation data from several meteorological stations were used using the Standardized Precipitation Index (SPI) approach to analyze drought conditions. Drought categories for 3, 6, 9, and 12 months were identified. It was utilized to simulate the predicted drought using an artificial neural network. For a 12-month period, the modeling analysis of several time series yielded the most significant coefficient of determination and the lowest mean square error value. The scientists expressed that drought forecasts may benefit from artificial neural network technology [63].

Tonkaz and Çetin (2005) carried out drought analysis in Şanlıurfa with SPI method using monthly total precipitation data collected from meteorological precipitation stations. In addition, flow analysis was performed using the Mann-Kendall method. As a result, February, March, April was reported as severe short-term drought periods, and it has been revealed that drought is frequently seen in January [64].

The Mediterranean and Central Anatolian regions would be the most hit by climate change, according to a report by Turan (2018). As indicated in the report, the drought dangers in our semi-arid nation have not yet been completely recognized, and the most pressing issue will be a lack of water. Our country's drought is deemed a natural catastrophe, which necessitates the development of natural disaster legislation in order to safeguard the drought from its long-term impacts, according to reports [65].

From Wu and Hayes (2001), SPI, CZI, Z-Score drought analysis were evaluated on 1, 3, 6, and 9 month time scales for wet and arid climates of China. The researchers concluded that all three indicators gave the same results at all time intervals, but the calculations of the CZI and Z-Score numbers were more comfortable than the SPI index [66].

Yenigun and İbrahim (2019), were able to analyze drought analysis (the length and intensity of drought) in the North Iraq area during various time periods by employing the Standardized Precipitation Index (SPI). In this study, m onthly precipitation data from 15 meteorological stations in Northern Iraq provinces were utilized from 1979 to 2013 to record dry and wet seasons, as well as the severity and duration of droughts. MATLAB software was used to do calculations on the SPI using the SPI code. As a result of, ıt was determined that dry periods in the 6, 9, and 12 month time intervals were seen more than the 1 and 3 month intervals. According to the calculations, 2008 was the driest year [67].

Yıldız Bozkurt (2021), meteorological drought analysis was carried out using data from 33 meteorological observation stations in the Black Sea Region. Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI) methods were used to determine the meteorological drought of the region at 3, 6, 9, and, 12-month time scales. The drought indices of the two methods obtained at different time scales were compared. The drought occurrence percentages were determined at different time scales at each station and the occurrence percentages of different drought classes were evaluated. From the findings obtained by using two different methods, the longest dry periods, the most severe drought value, and the times when it occurred were determined for each station [68]. While this study not fully overlaps with our thesis due to study area, study method and/or study duration, the results generally overlap with general meteorological results. The percentages of dry and rainy months in the region are generally similar in both studies, and As stated in both studies, an increase in meteorological, agricultural and hydrological droughts has been observed in recent years.

PART 3

MATERIAL AND METHOD

3.1. INTRODUCTION

At this chapter will present the study methodology used to collect and analyze the data of the study. The scope of the study is to determine drought sensitivity and calculate drought years to show the driest year in the western Black Sea region with the help of data from 8 precipitation and 3 flow observation stations data. In order to track changes in drought index values through time, drought analysis was used. The Standard Precipitation Index (SPI), the Reconnaissance Drought Index (RDI) and the Streamflow Drought Index (SDI) used for this aim. Sinop, Kastamonu and Bartın provinces in the Western Black Sea region was selected for research due to sometimes the scarcity of precipitation. Analyzes for meteorological, agricultural and hyrological drought analysis were performed with the help of data between 1969-2019, and 1965-2915, respectively. Missing precipitation, temperature and flow data were completed with regression analysis.

3.2. METHODOLOGY

Different indicators of drought have been proposed by different researchers in the analysis of atmospheric drought. Various meteorological data are used as input parameters in these drought indicators. Standard Precipitation Index (SPI), Survey and Drought Index - RDI, Flow Index (SDI) which uses mean, minimum, and maximum temperature data as well as rainfall and flow data, because it uses only rainfall data to determine atmospheric drought in the world and in our country. It was used to assess the atmospheric aridity of the Black Sea Basin.

A meteorological and hydrological drought analysis will be conducted for 8 precipitation and 3 flow observation stations data in the study area. Missing data were completed with regression analysis. The Standard Precipitation Index (SPI) method is used to determine meteorological drought using monthly total rainfall data. The Reconnaissance Drought Index (RDI) method is used to determine meteorological drought using average monthly temperature data and total monthly precipitation data. Also The Streamflow Drought Index (SDI) method is used to determine hydrological drought using monthly mean flow data A drought analysis were performed using DrinC software at the study areas for 1, 3, 6, and 12 months .

3.3. STUDY AREA

The Black Sea Region is located in Turkey between 40° - 42° North parallels and 30°-42.5° East meridians and takes its name from the Black Sea to its north. It starts from the Georgian border in the east and extends to the east of Bilecik with the Sakarya Plain in the west. In the Black Sea Region, which consists of three parts as the west, middle, and east, the altitude of the mountains extending along the Black Sea is around 2000 m in the west, it goes down to 1000 m in the Central Black Sea region and rises to 4000 m in the east. Black Sea climate conditions are generally effective in the study area. It is rainy in all seasons. However, the annual temperature difference is slight. Summer seasons are cool, and winter seasons are warm [69].

The Black Sea Region is the region that receives the most precipitation in Turkey. In the Black Sea Region, there are significant differences between the coastal part and the interior part, as the humid air in the coastal part of the mountains prevents the passage of the interior parts. Due to the continentality in the interior, summer seasons are hot, and winter seasons are cold and snowy[69].

3.4. DATA

Monthly total precipitation and mean temperature data for 8 stations in the Sinop, Kastamonu and Bartın provinces were obtained from the General Directorate of Meteorology and monthly mean flow data for 3 stations in the stıdy area were obtained from the General Directorate of State Hydraulic Works. The average annual temperatures, the total annual averages of precipitation, and the average flow data obtained from these stations are shown in Table 3.1. Missing precipitation, temperature and flow data were completed with regression analysis. In the completion of missing data, it care was taken not to exceed 10% of the existing data. While Bartın precipitation and temperature monitoring station data has full data, Kastomunu, İnebolu, Sinop precipitation and temperature monitoring station have a litlle month missing data, and Devrekani, Ulus, Amasra have some years missing data.

Table 3.1. Precipitation and flow monitoring stations and its geographic locations.

Station Number	**Station Name**	**Connected Province**	**Heigh t (m)**	**Coordinate**	Observed Period	Using Period
17602	Amasra	Bartın	73	41°45'09.4"N 32°22'57.7"E	1970-2019	1965-2019
17020	Bartın	Bartın	33	41°37'29.3"N 32°21'24.8"E	1961-2019	1965-2019
17618	Devrekani	Kastamonu	1050	41°35'58.6"N 33°50'04.2"E	1965-2019	1965-2019
17024	İnebolu	Kastamonu	64	41°58'44.0"N 33°45'49.0"E	1951-2019	1965-2019
17074	Kastamonu	Kastamonu	800	41°22'15.6"N 33°46'32.2"E	1930-2019	1965-2019
17026	Sinop	Sinop	32	42°01'47.6"N 35°09'16.2"E	1936-2019	1965-2019
17606	Bozkurt	Kastamonu	167	41°57'34.9"N 34°00'13.3"E	1960-2019	1965-2019
17615	Ulus	Bartin	50	41°34'54.8"N 32°38'13.2"E	1965-2019	1965-2019
E13A007	Devrekani River	Kastamonu	815	41° 38' 39" N 33° 18' 03" E	1953-2015	1965-2015
D13A031	Kocaırmak River	Bartın	15	41° 38' 33" N 32° 16' 55" E	1968-2015	1965-2015
D13A032	Karasu River	Sinop	20	41° 59' 57" N 35° 01' 57" E	1968-2015	1965-2015

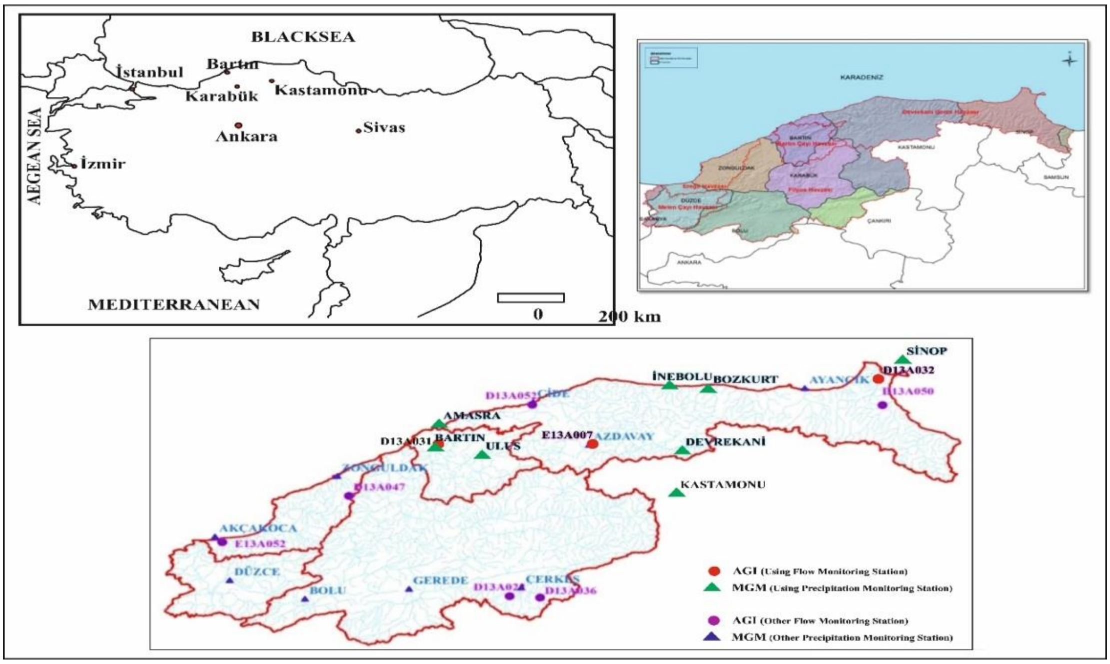


Figure 3.1. The locations maps of the study area [70].

3.5. REGRESSION ANALYSIS

After the lost data occurs, there are multiple approaches to problem solving. Approaches can be adopted to ignore missing data in statistical analysis and to use data deletion methods or to replace missing data in accordance with missing data sets with one of the value assignment methods.

When assigning instead of missing data, this value can be the average value or data can be created close to the data set previously defined by the variable or based on some estimations. In the estimation method, on the other hand, missing data analysis can be performed by creating substitute data for missing values or using a regression model. Intended; It is to act as if the data are complete and to use the most appropriate one of the missing data evaluation methods. Determining the method to be followed to determine this correct method;

- Adding a new observation value for the missing value to the existing data set.
- Creating a complete sample by deleting data or data groups from the data set.

- Determining a value close to or approximate to the missing data as missing data by estimation.
- Using existing observation values.
- The displacement of the observation values.

Although it is not always possible to add new observation values to the data sets, it can cause both labor and time loss. In addition to the missing data, removing the observation values from the existing sample will reduce the power of the statistical methods to be applied, as it will cause a large loss of both data and data [71,72]. In the predictive value assignment method, if you are not careful while assigning estimated values to the data sets, it may lead to the emergence of new problems by moving away from the solution [71,73].

Working with the right method while evaluating data groups is important in obtaining meaningful results for the data. For this reason, while deciding for the right analysis, determining the appropriate method by answering questions such as the structure of the methods, the data groups that are used extensively, which methods are preferred more in the analysis and the cost of the methods are among the priority criteria in dealing with missing data.

In the regression assignment method, the regression value can be calculated by creating a regression model over the existing data. This value can show the analysis results that we need to use to estimate missing data or data sets as the average value. A data assignment can be made by establishing the regression equation for missing data over variables and all variables that are related to each other [74]. Since this method does not contain restrictive analysis results, it can provide a significant advantage in creating more objective results. As long as the independent variable-dependent variable explanation rate is high in the data, the regression data assignment method can come to the fore as a usable technique. In the regression method, the relationship between missing data can be estimated and statistical analyzes can be performed according to these estimation values. For a lossless data set, it is possible to assign data to unobservable parts by creating an equation for the variables of the estimated missing data [75].

The aim of this method is to calculate the missing data with the existing data, by establishing a regression equation. Instead of values with missing data, a regression model is developed from data sets that do not contain missing data in the sample, and a data set is obtained. As the sample size grows, the results will be close to neutral. Missing data or variable estimates of data can be obtained. These estimated values are used instead of missing data. Thus, sample groups that are complete and do not contain missing data are created. If the disadvantages of the regression assignment method are listed; In cases where the error term is not included in the model, it can make the variance small [76]. If the correlation between observed and unobserved values is weak, this method may not be considered as a usable method.

Regression; It is an analysis that reveals the relationship and level between two or more variables. Generally; In statistics, mathematics and engineering, it is used to determine whether there is a relationship between the data, its level and direction (+,-) [77]. Unlike ANN models, that is one of the new generation incomplete data completion methods, as long as the input and output values do not change, a single output set will be obtained in the regression analysis. The values calculated as output reach the desired error values; It determines the level of functional and mathematical relationship between inputs and outputs [77]. Regression is not always used to get a definitive result, but sometimes it is used to give a preliminary idea. For all data estimation calculations, regression analysis can be performed first. In this way, a preliminary knowledge of the level and severity of the relationship between the data used as the training set is obtained. The choice of ANN and different artificial intelligence estimation methods and the arrangement of the training set can be decided according to these regression analysis data. In short, regression analysis results are used in the selection of the prediction model type, shape, structure and training set [77].

While performing regression analysis, not only the relationship between two data sets is considered, sometimes two or more data sets can affect a data together. Before performing regression analysis, dependent and independent variables need to be defined [78].

Independent Variable: It is a variable that is not affected by the increase or decrease of other variables used in the analysis. They are the variables that are thought to affect the cause of the dependent variable or the value of the dependent variable together with other variables. It is sometimes encountered in the literature as an explanatory variable.

Dependent variable : It is the variable that is affected by the values of the independent variables and increases or decreases with their values. It is the variable that is explained and resolved through independent variables. Regression Analysis requires only one set of dependent variables. The opposite situation cannot be explained by regression analysis, in such cases solutions are tried to be found with multicollinearity and correlation analysis.

After determining the dependent and independent variables, it is necessary to decide on the regression analysis and the type of equation that will explain the relationship between these variables. When choosing the regression analysis type, preference is made by looking at the number of data, the structure of the independent variables, the number and possible relationship level. Commonly used regression analysis types are as follows;

Simple linear regression: it is the most common and used regression type. It is used to express the linear relationship between 2 variables as a first-order equation.

Independent variable : x
Dependent variable: y
Intersection point: a (fixed value, y value when $x=0$)
Regression Coefficient: b
$y= a+bx$
the regression analysis equation is obtained.

Multiple linear regression: It is used to explain the linear relationship between more than one independent variable and one dependent variable. Regression is made with the assumption that the independent variables affect the independent variable. There are varieties such as standard multiple regression, hierarchical multiple regression and statistical multiple regression. Nonlinear regression analysis: It is used in the analysis of data whose relationship level and form between dependent and independent variables cannot be expressed with linear equations.

Interpretation of regression analysis outputs;

Constant value: It is the value of the dependent variable when it is assumed that the independent variables have no effect.

Independent variable coefficients; They are numerical values that can be positive or negative that affect the independent variables as factors used to explain the dependent variable.

Correlation Coefficient (R): It is a coefficient that expresses the relationship and direction between the independent variables and the dependent variable. The correlation coefficient (R) takes values between -1 and +1. R value of -1 indicates that there is a negative, inverse relationship between the variables. R value of +1 indicates that there is a positive (direct-sided) relationship between the variables [78].

In this study, the years 1965-2019, which is the most suitable common year interval of meteorology stations, were evaluated in the analysis. However, while the precipitation and temperature data of Bartın, Kastamonu, İnebolu, Sinop and Bozkurt stations are complete, the data of Amasra, Devrekani and Ulus stations are missing with 5, 6, and 4-year, respectively. Regression analysis, which is the most preferred in the literature for hydrological data, was preferred to complete the missing data. In addition, in completing the missing data, care was taken not to exceed 10% of the existing data. Similarly, the years 1965-2015, which is the most suitable common year interval of the flow observation stations, were taken into consideration in the analysis. E13A007 Devrekani/Kastamonu River flow observation station is missing with 2 years, while D13A031 Kocaırmak/Bartın River and D13A032 Karasu/Sinop River stations are missing with 10 and 4 years, respectively. Although the missing data of D13A032 Karasu (Sinop) station exceeds 10% of the existing values, the missing data were completed with regression analyzes in order to compare only roughly with other drought analysis methods.

The determination value was appropriate for all stations when analyzing the data. The values of determining precipitaion data from 1965 to 2019 ranged from 0.5693 to 0.7749 as shown in Figure 3.2. The values for determining the temperatures from 1965 to 2019 ranged from 0.9683 to 0.924 as shown in Figure 3.3, and the values for determining the flow data from 1965 to 2015 ranged from 0.5092 to 0.5886 as shown in Figure 3.4.

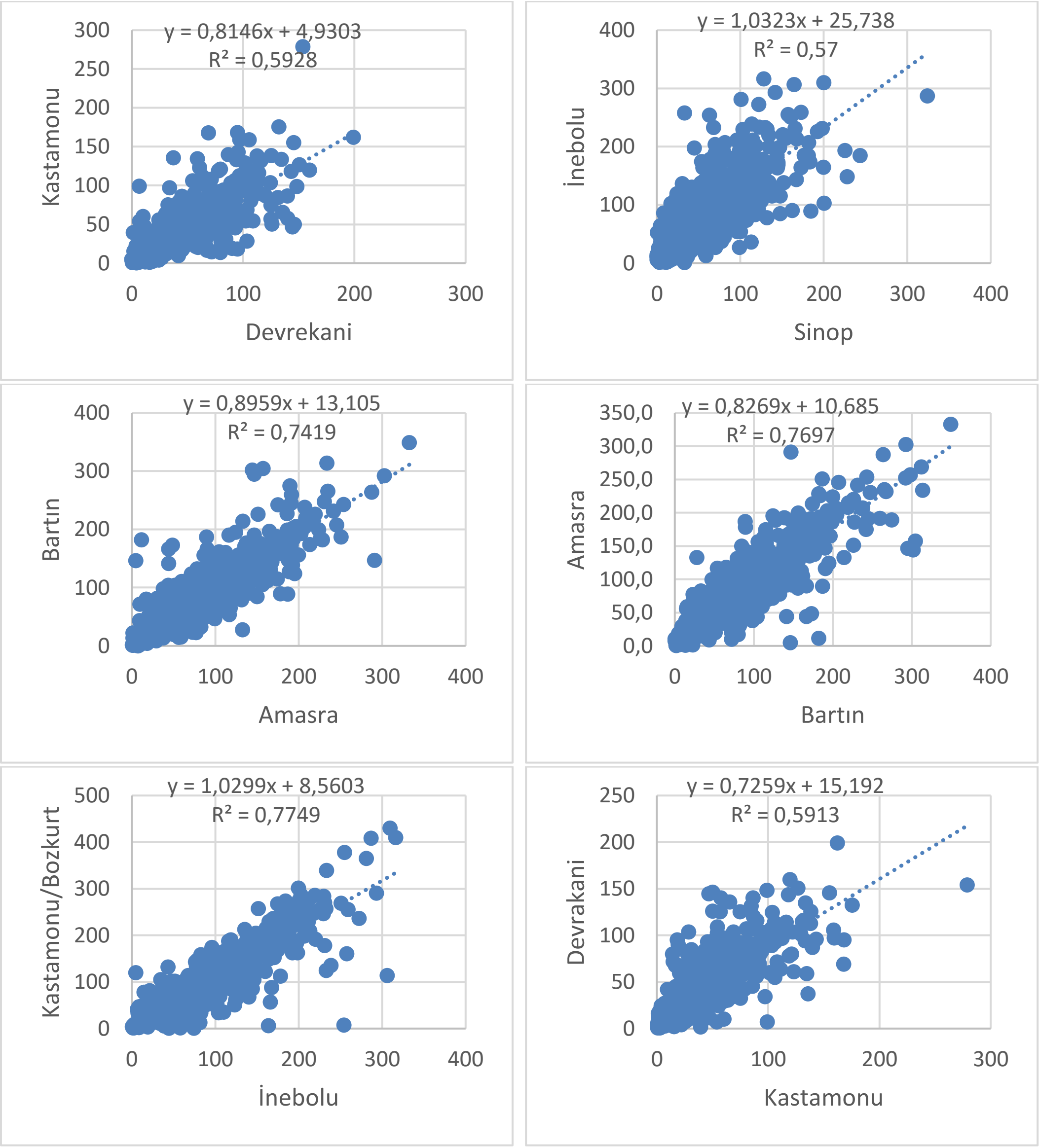


Figure 3.2. The results of the regression analysis of precipitation data.

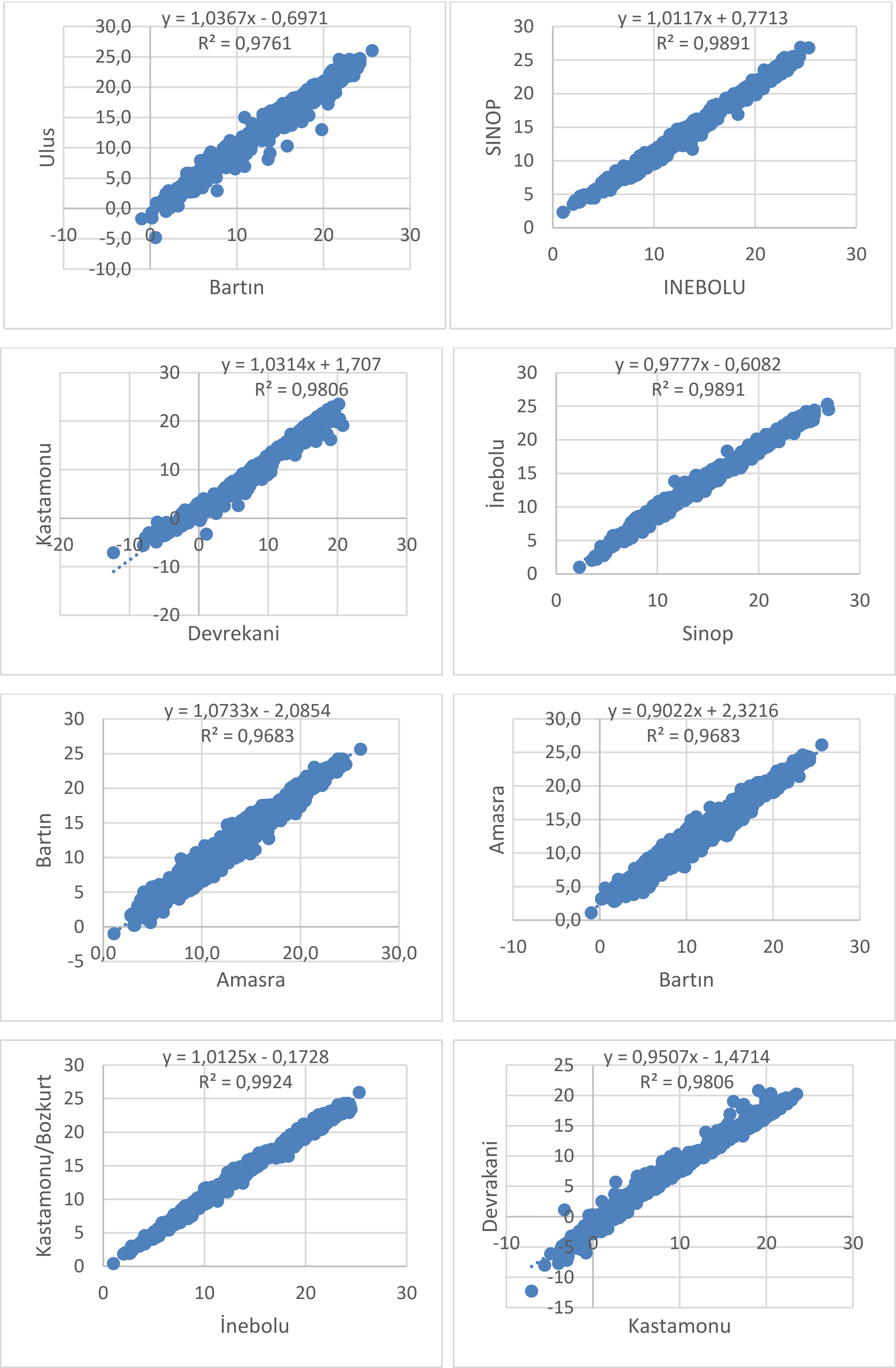
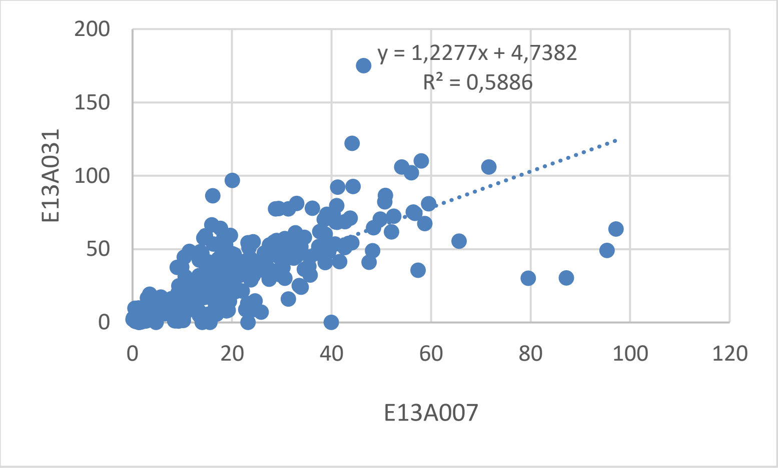


Figure 3.3. The results of the regression analysis of temperature data.



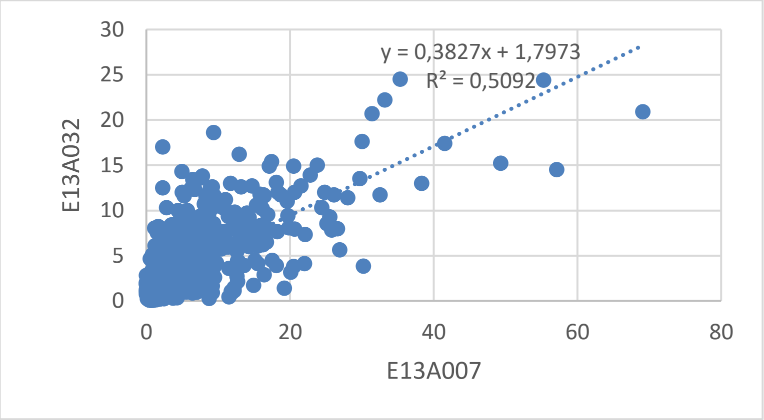


Figure 3.4. The results of the regression analysis of flow data.

3.6. DROUGHT INDICES OVERVIEW

The DrinC (Drought Indices Calculator) aimed at providing a user-friendly tool for the calculation of several drought indices. The key objective in its design is the widest possible applicability for several types of droughts (meteorological, hydrological, agricultural) and different locations. It is also considered that drought studies were particularly essential in arid and semi-arid regions, where data availability is usually limited. Therefore, the main criteria for the selection of indices are [79]:

- To have relatively low data requirements, allowing the software application in many regions.

- Their results are to be clearly interpreted for direct and efficient operational use.
- The process is based on these criteria, two recently developed and two more widelyknown indices are included in DrinC:

1. The Reconnaissance Drought Index (RDI)
2. Th Streamflow Drought Index (SDI)
3. Standardized Precipitation Index (SPI)
4. Precipitation Deciles (PD).

They could be easily understood; RDI, SPI, and PD referred to the meteorological drought and used as the primary determinant of the precipitation (and additionally the potential evapotranspiration for RDI only). Further, RDI could also be used for the agricultural drought analysis, as it could adequately describe the water balance. In addition, it is beneficial when reference periods related to the development stages of the crop are selected [11]. On the other hand, SDI applied to hydrological drought and had used streamflow as the critical determinant [79].

Apart from the proposed initial methods of calculation for each index, DrinC incorporated alternative methods that allowed the comparison of the results among the indices. Further, this has given three key advantages to the user since it has provided the flexibility to select among various options for adjusting the outputs to his particular needs. Following, there is a short presentation and the key characteristics of the drought indices calculated by DrinC [79].

3.6.1. Standardized Precipitation Index (SPI)

The Standard Precipitation Index (SPI) was developed by (McKee et al. 1993). to determine the effects of the reduction in precipitation on groundwater, reservoir storage, soil moisture, snow drifts, and streams. It is obtained by dividing the precipitation difference from the mean, which is converted to normal distribution within the specified time period by the standard deviation. In fact, SPI provides a standardized conversion of the observed precipitation probability and could be calculated for desired time periods such as 1, 3, 6, 9, 12, 24, and 48 months.

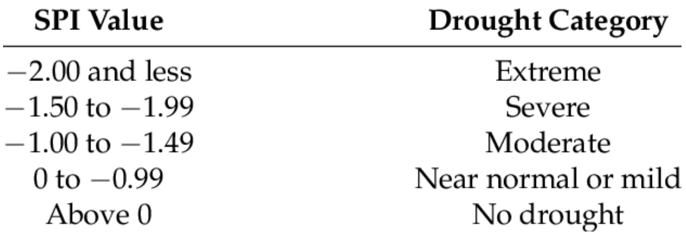
The formula and classification of the method are given below [80]:

$$SPI = (X_i - X_i) / \sigma \tag{3.1}$$

Where:

- SPI: Standard Precipitation Index
- Xi: amount of precipitation
- Xi: average of precipitation
- σ: standard deviation

Table 3.2. Index values and classification of SPI method [80].



SPI Value	Drought Category
−2.00 and less	Extreme
−1.50 to −1.99	Severe
−1.00 to −1.49	Moderate
0 to −0.99	Near normal or mild
Above 0	No drought

In a drought assessment made by taking SPI values into consideration, the time period in which the index is constantly negative, defined as the "dry period." The first month in which the index is fallen below zero is considered the beginning of the drought, while the month in which the index raised to a positive value is considered the end of the drought [81].

3.6.2. Reconnaissance Drought Index (RDI)

The Reconnaissance Drought Index (RDI) is developed to approach the water deficit in a more accurate way, as a sort of balance between input and output in a water system [82,83]. It is based on both cumulative precipitation (P) and potential evapotranspiration (PET), which is one measured (P) and later calculated (PET) determinant. The initial value (α k) of RDI was calculated for the ith year on a time basis of k (months) as follows:

$$\alpha_k^{(i)} = \frac{\sum_{j=1}^{k} P_{ij}}{\sum_{j=1}^{k} PET_{ij}}, \mathrm{i} = 1(1)\mathrm{N} \text{ and } \mathrm{j} = 1(1)\mathrm{k} \tag{3.2}$$

Where:

- P_{ij} and PET_{ij} are the precipitation and potential evapotranspiration of the j- th month of the i-th year
- N is the total number of years of the available data
- The values of α_k satisfactorily follow both the lognormal and the gamma distributions in a wide range of locations and different time scales, in which they were tested.

By assuming that the lognormal distribution was applied, the following equation could be used for the calculation of RDI_{st} [83,84]:

$$RDI_{st}^{(i)} = \frac{Y^{(i)} - \overline{Y}}{\hat{\sigma}_y} \tag{3.3}$$

Where:

- $y^{(i)}$ is the $\ln(a_k)^{(i)}$
- y is its arithmetic mean
- σy is the standard deviation of y

From comprehensive research on various data from several locations and different time scales (3, 6, 9, and 12 months), it is concluded that the α_k values follow satisfactorily both the lognormal and the gamma distributions in almost all locations and time scales. However, in most cases, the gamma distribution is more successful. Therefore, the calculation of the RDI_{st} could be performed better by fitting the gamma probability density function (pdf) to the given frequency distribution of the αk, following the procedure described below [83,84]. This approach also solved the problem of calculating the RDIst for small time steps, such as monthly, which might include zero- precipitation values (αk = 0), for which Eq. (3.3) could not be applied. The gamma distribution was defined by its frequency or probability density function:

$$g(x) = \frac{1}{\beta^{y}\, I\,(\gamma)}\, x^{y-1}\, e^{-x/\beta} \;, \quad for\; x > 0 \tag{3.4}$$

Where:

- γ and β are the shape and scale parameters, respectively,
- x is the precipitation amount
- Γ(γ) is the gamma function.

Parameters γ and β of the gamma pdf are estimated for each station and for each time scale of interest (1, 3, 6, 9, 12 months, etc.). Maximum likelihood estimations of γ and β are, and n is the number of observations [83,84].

$$Y\frac{1}{4A}\left(1+\sqrt{1+\frac{4A}{3}}\right), \beta\frac{\bar{x}}{y}\;, Where\; A = In\,(\bar{x}) - \frac{\sum In\,(x)}{n} \tag{3.5}$$

The resulting parameters are then used to find the cumulative probability of α_k for a given year for the location in question. Since the gamma function is undefined for x= 0 and a precipitation distribution might contain zeros, the cumulative probability became [83,84]:

$$H(x) = q + (1-q)G(x) \tag{3.6}$$

Where [85]:

- q is the probability of zero precipitation

- G(x) is the cumulative probability of the incomplete gamma function
- If m is the number of zeros in a αk time series, then q could be estimated by m/n. The cumulative probability H(x) is then transformed to the standard normal random variable z with mean zero and variance of one, which is the value of the RDI$_{st}$.

Positive values of RDIst indicated wet periods, while negative values indicated dry periods compared with the normal conditions of the area. Drought severity could be categorized into mild, moderate, severe, and extreme classes, with corresponding boundary values of RDIst as shown in Table 3.3 [86].

Table 3.3. Corresponding boundary values of RDIst [86].

Mild	Moderate	Severe	Extreme classes
-0.5 to -1.0	- 1.0 to -1.5	-1.5 to -2.0	< -2.0

3.6.3. The Streamflow Drought Index (SDI)

The index is a hyrological drought analysis. According to Nalbantis and Tsakiris (2009), if a time series of monthly streamflow volumes Qi,j is available, in which i denotes the hydrological year and j the month within that hydrological year (j = 1 for October and j = 12 for September), Vi,k can be obtained based on the equation [87]:

$$V_{i,k} = \sum_{j=1}^{3k} Q_{i,j} \quad i = 1, 2, \ldots \quad j = 1, 2, \ldots, 12 \quad k = 1, 2, 3, 4 \tag{3.7}$$

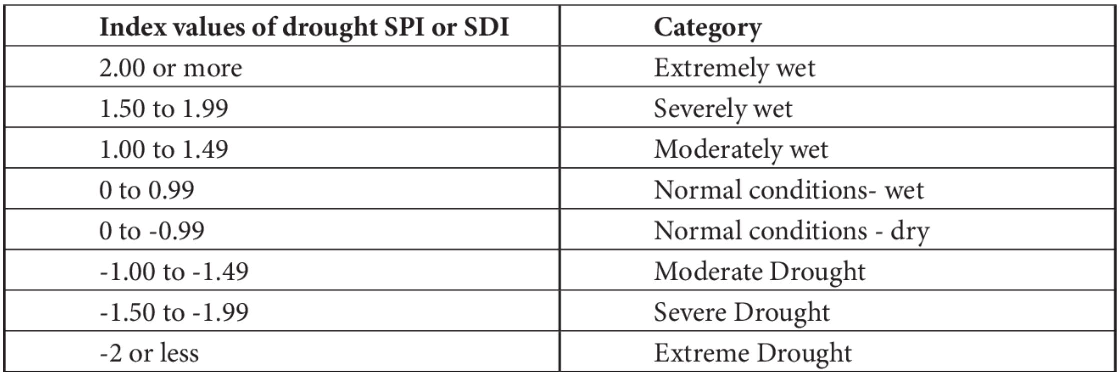
in which Vi,k is the cumulative streamflow volume for the i-th hydrological year and the k-th reference period, k = 1 for October-December, k = 2 for October-March, k = 3 for October-June, and k = 4 for October-September. Based on the cumulative streamflow volumes Vi,k , the Streamflow Drought Index (SDI) is defined for each reference period k of the i-th hydrological year as follows[87]:

$$\mathrm{SDI}_{i,k} = \frac{y_{i,k} - \bar{y}_k}{s_{y,k}} \quad i = 1, 2, \ldots, \quad k = 1, 2, 3, 4 \tag{3.8}$$

in where “V_k’’ and “s_k ’’ are respectively the mean and the standard deviation of cumulative streamflow volumes of the reference period *k* as these are estimated over a long period of time. In this definition, the truncation level is set to V_k, although other values based on rational criteria could also be used[87].

According to Nalbantis and Tsakiris (2009), states (classes) of hydrological drought are identically defined for SDI to those used in the meteorological drought indices SPI and RDI. Five states are considered, which are denoted by an integer number ranging from 0 (non-drought) to 4 (extreme drought) and are defined through the criteria of Table 3.4.

Table 3.4. Definition of states of hydrological drought with the aid of SDI [87].



Index values of drought SPI or SDI	Category
2.00 or more	Extremely wet
1.50 to 1.99	Severely wet
1.00 to 1.49	Moderately wet
0 to 0.99	Normal conditions- wet
0 to -0.99	Normal conditions - dry
-1.00 to -1.49	Moderate Drought
-1.50 to -1.99	Severe Drought
-2 or less	Extreme Drought

3.6.4. The Drought Indices Calculator (DrinC) Software

There has been a lot of work put into developing DrinC (Drought Indices Calculator), a piece of software designed to make it easy to calculate drought indices. Reconnaissance Drought Index (RDI) and Streamflow Drought Index (SDI) may both be calculated using DrinC, as well as the Standardized Precipitation Index (SPI) and the Precipitation Deciles (PD) indices. RDI may also be calculated using a module that uses temperature-based techniques to estimate potential evapotranspiration (PET). Drought monitoring, the evaluation of drought's geographical distribution, the analysis of climate and drought scenarios, and so on, may all benefit from the software DrinC is gaining popularity as a research and operational tool for drought analysis in arid and semi-arid countries, where it has been tested extensively [88].

PART 4

RESEARCH FINDINGS AND DISCUSSION

4.1. INTRODUCTION

This chapter presents the research results and discussion of the data collected from 8 precipitation monitoring stations and 7 flow monitoring stations of the Western Black Sea region, which is the following stations.

- Amasra Station (17602)
- Bartın Station (17020)
- Devrekani Station (17618)
- İnebolu Station (17024)
- Kastamonu Station (17074)
- Sinop Station (17026)
- Bozkurt Station (17606)
- Ulus Station (17615)
- Devrekani River Station (E13A007)
- Kocaırmak River Station (D13A031)
- Karasu River Station (D12A032)

4.2. RESEARCH FINDINGS AND DISCUSSION

Within the scope of this research, SPI, RDI and SDI values for 1, 3, 6, and 12 months were calculated and evaluated using the Precipitation, Reconnaissance and Streamflow Drought Index method respectively. The process used the values of the total monthly precipitation, the average monthly temperature and mean mounthly discharge for total 12 monitoring stations of the Sinop, Kastamonu and Bartın provinces.

4.2.1. Amasra Precipitation Monitoring Station (17602) Meteorological Drought Analysis (SPI)

SPI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation data measured between 1965-2019 of the Amasra station. The rate of drought and wet of monthly is shown in the Figure 4.1 and Table 4.1. The figure hereby shows that the monthly drought ranged between 43% and 57% according to SPI values. The highest drought ratio was 57% Jun, and the lowest drought period was 43% in Dec. The period of drought and wet for each of 3, 6, and 12 months for the SPI values are shown in Figure 4.2. The Driest periods with the highest SPI-3 values are SPI-3 in April period of 61% and the lowest dry period is SPI-3 in January period with 44%. The driest periods with the highest SPI-6 values are SPI-6 in April period at 54%. SPI-12 calculated according to 12-month values dryness is 54% and moisture is 46%.

According to Figure 4.3 and Table 4.2, when examining 1-month SPI values from 54-year monthly rainfall data at Amasra Station.the highest dry month was in Feb (2012-2013); the highest moist month was May 1998-1999. Figure 4.4 shows the time distribution of the SPI values for 3, 6 and 12 months to examine the SPI values, the highest dry period was at SPI-3 in April period in the year 2011-2012, the highest wet period was at SPI-3 in October period in the year 1973-1974. The highest dry period at SPI-6 was in October period in the year 1976-1977, the highest moist period was SPI-6 in October period in the year 1967-1968, and the highest dry period was at SPI-12 in the year 1993-1994, the highest moist period was in the year 1967-1968.

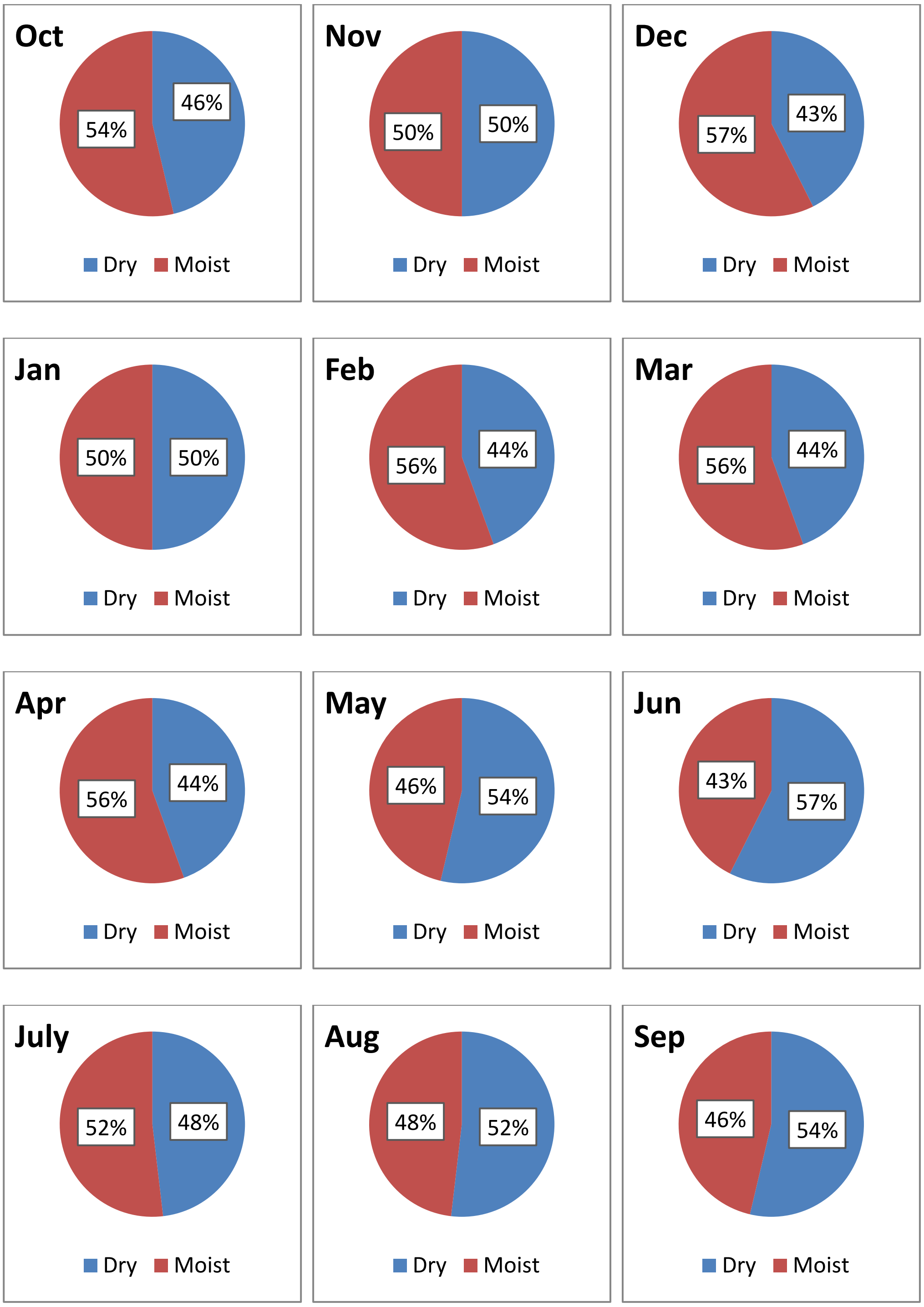


Figure 4.1. Dry - moist period distributions according to the monthly SPI values for the Amasra station (No. 17602) from 1965 to 2019.

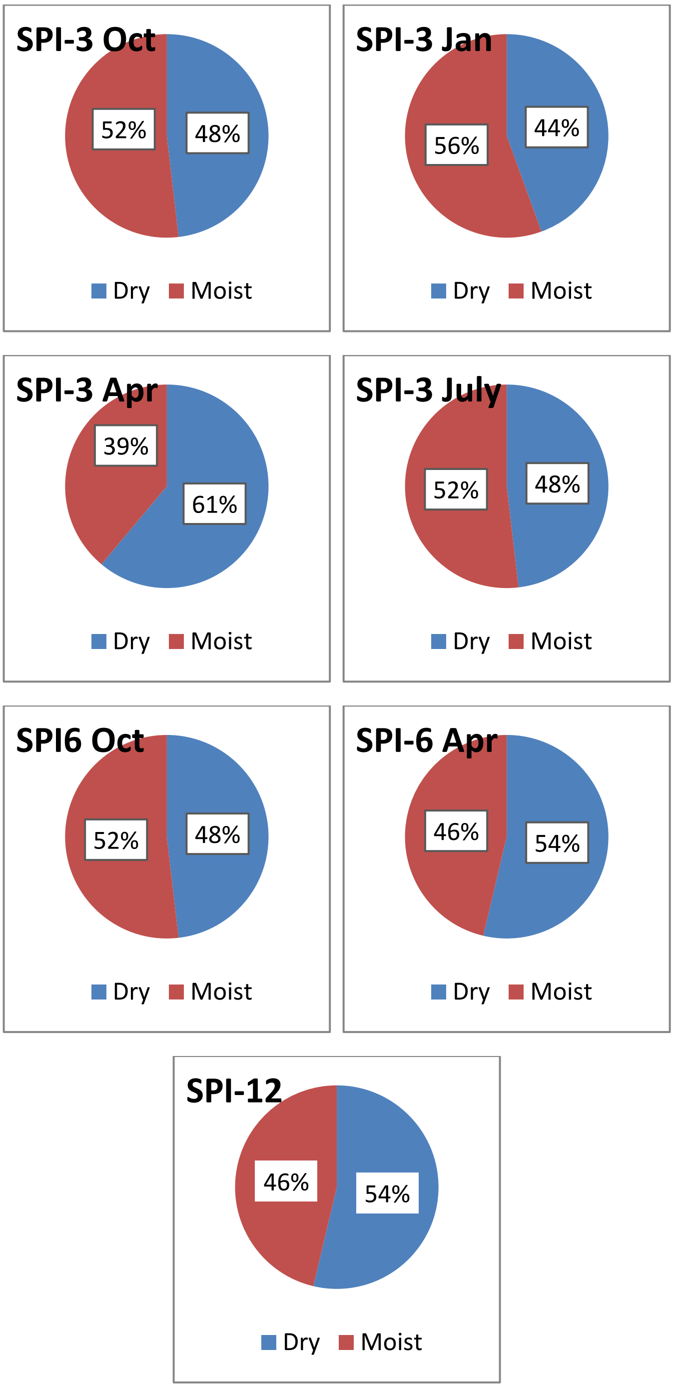


Figure 4.2. Dry - moist period distributions according to the 3,6,12 month SPI values for the Amasra station (No. 17602) from 1965 to 2019.

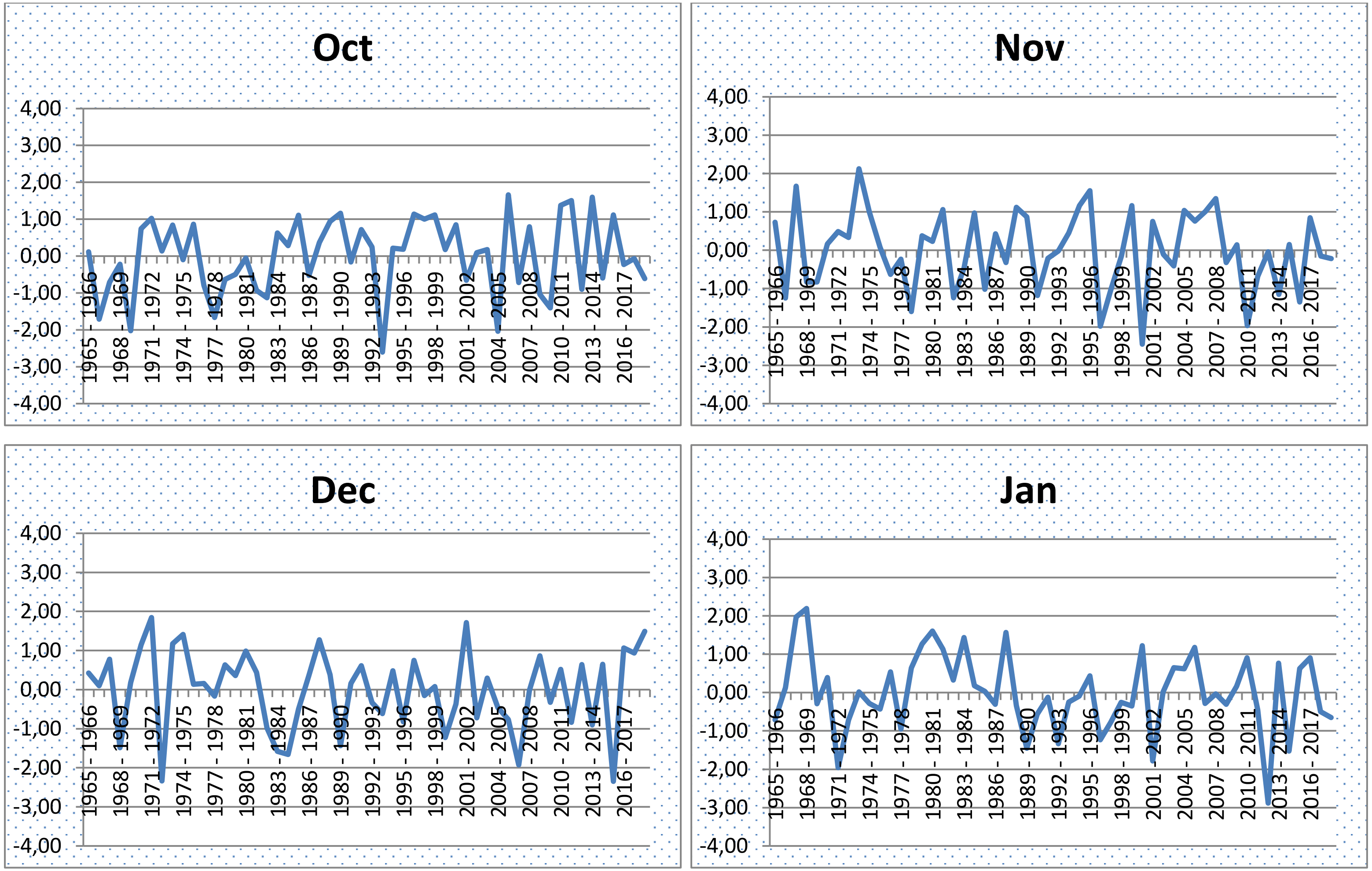


Figure 4.3. Temporal distribution of monthly SPI values of the Amasra Station (No.17602) from 1965 to 2019.

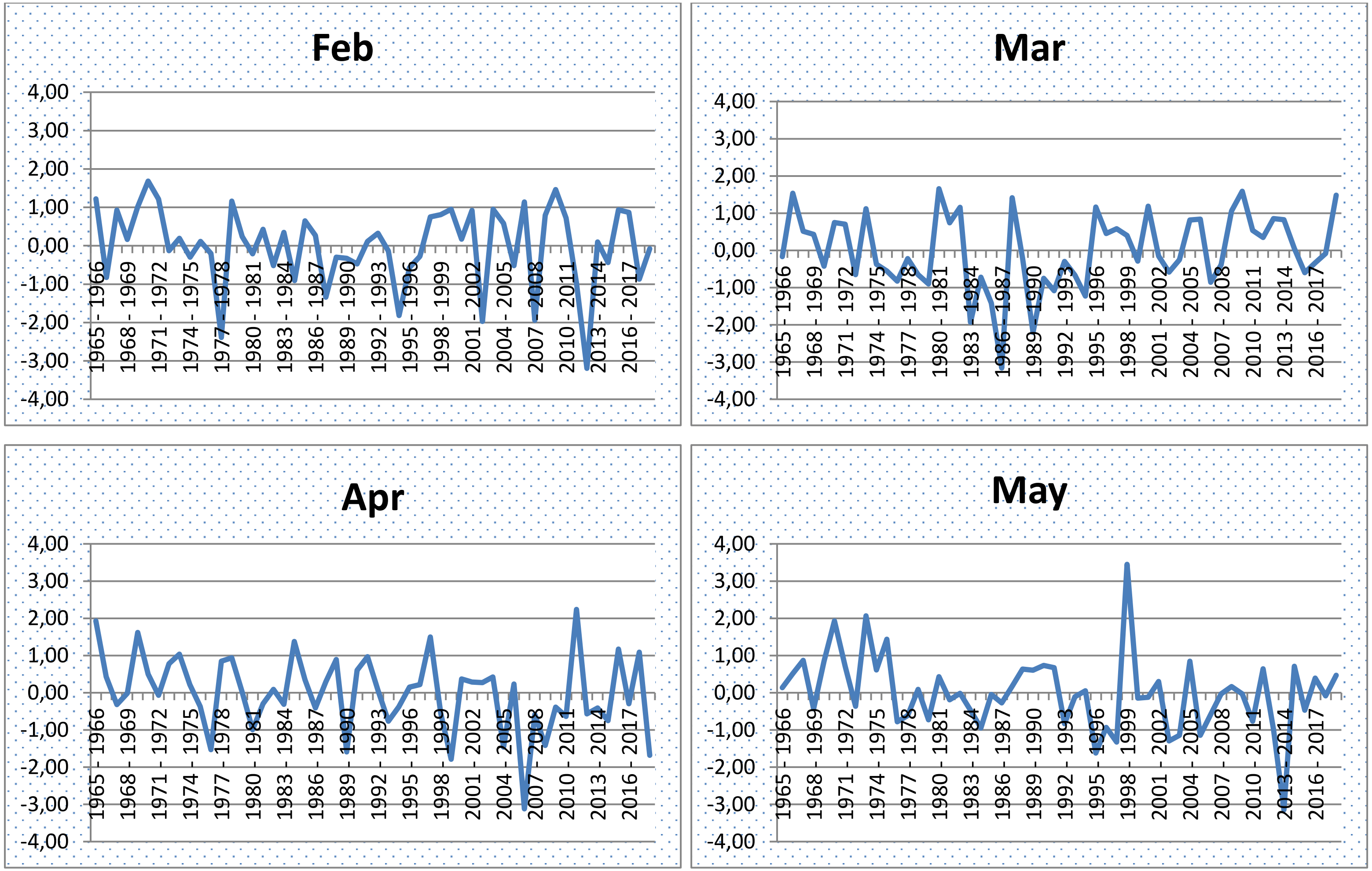


Figure 4.4. (Continued).

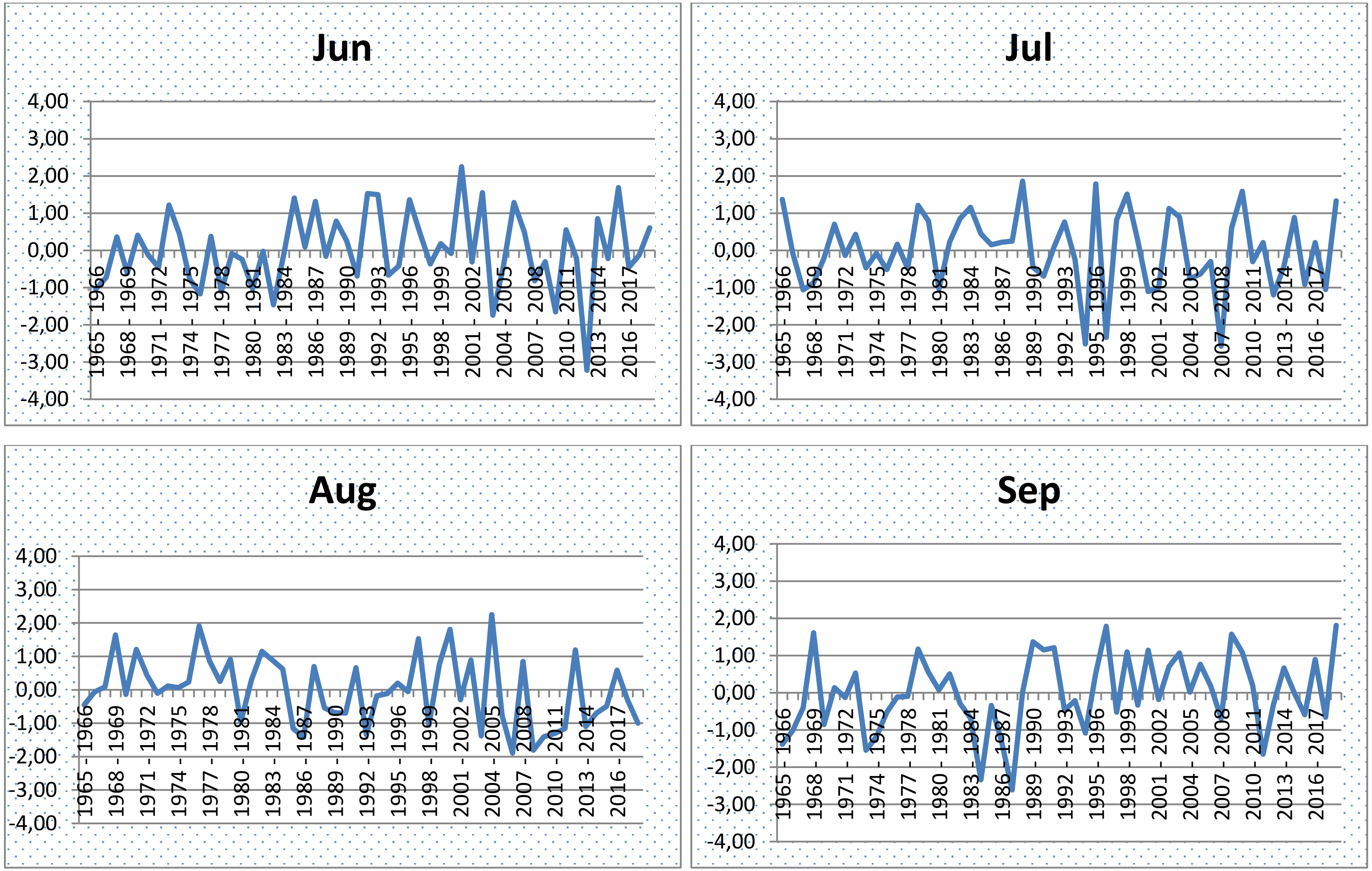


Figure 4.5. (Continued).

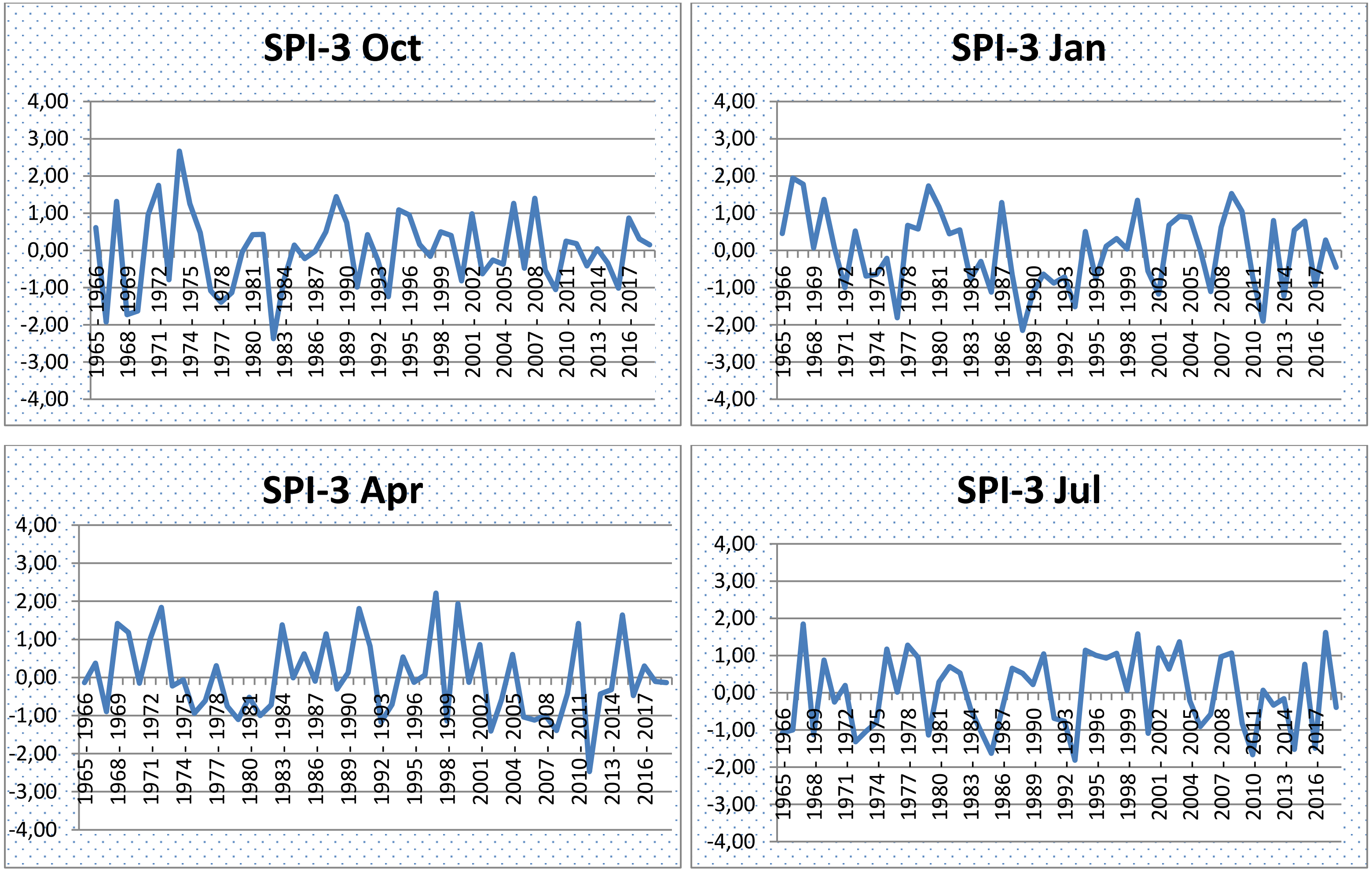


Figure 4.6. Temporal distribution of 3, 6, and 12 month SPI values of the Amasra Station (No.17602) from 1965 to 2019.

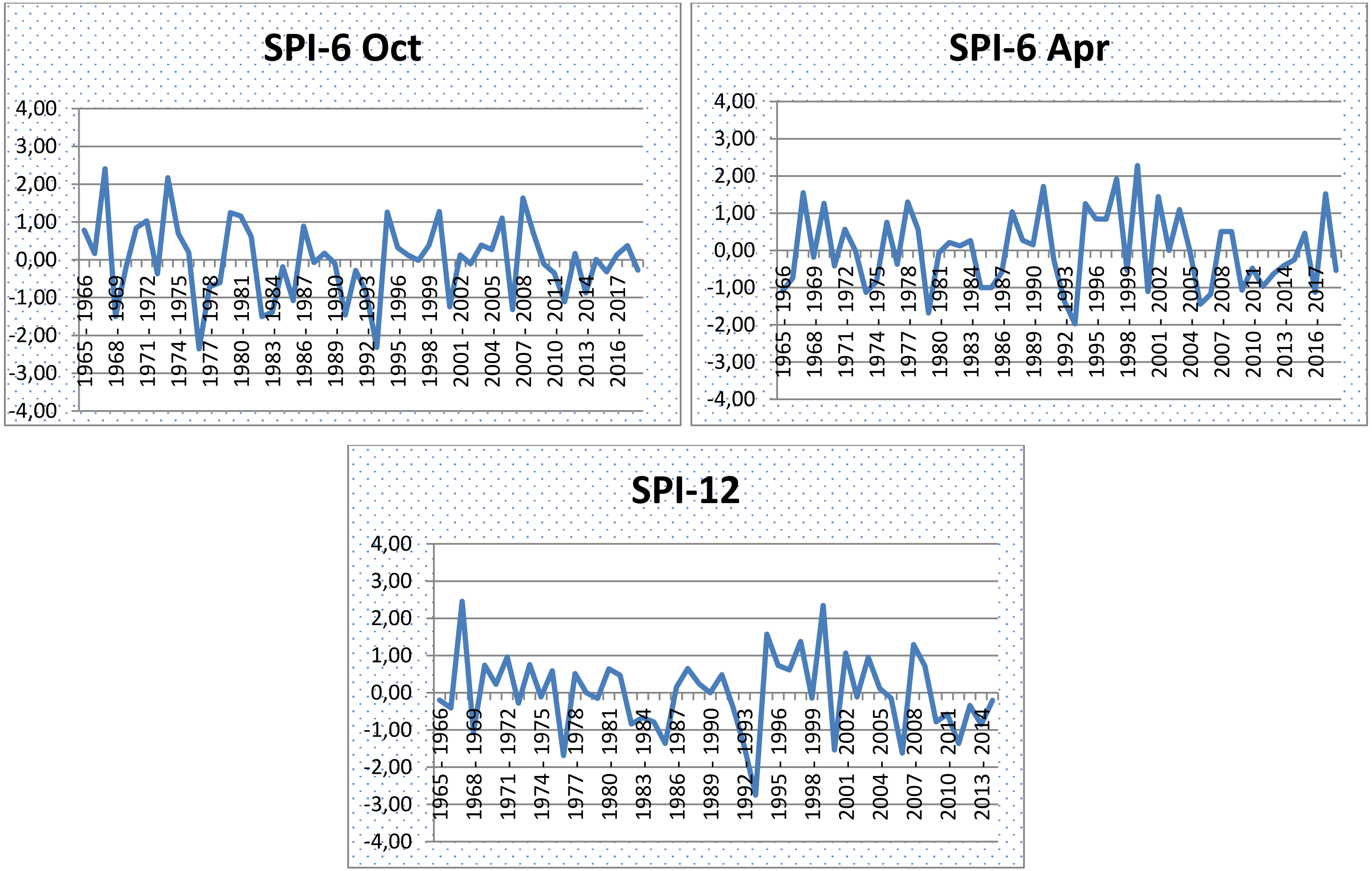


Figure 4.7. (Continued).

4.2.2. Bartın Precipitation Monitoring Station (17020) Meteorological Drought Analysis (SPI)

SPI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation data measured between 1965-2019 of the Bartın Station. The rate of dryness and wet of monthly is shown in the Figure 4.5 and Table 4.1. The figure hereby shows that the monthly dryness ranged between 41% and 54% according to SPI values. The highest drought ratio was 54% July, and the lowest drought ratio was 41% in April. The period of drought and moisture for each of 3, 6, and 12 months for the SPI values are shown in Figure 4.6. The driest periods with the highest SPI-3 values are in July period with 54% and the lowest SPI-3 dry period is in October and in January periods with 50%. The driest periods with the highest SPI-6 values are in April period at 57%. SPI-12 calculated according to 12-month values dryness is 56% and moisture is 44%.

According to Figure 4.7 and Table 4.2, when examining 1-month SPI values from 54-year monthly rainfall data at Bartın Station. The highest dry month was in April 2005-2006; the highest moist month was May 1997-1998. Figure 4.8 shows the time distribution of the SPI values for 3, 6 and 12 months to examine the SPI values, the highest dry period was at SPI-3 in April period in the year 2005-2006, the highest moist period was at SPI-3 in April period in the year 1990-1991, The highest dry period at SPI-6 was in October period in the year 1993-1994, the highest moist period was at SPI-6 in October period in the year 1967-1968, and the highest dry period was at SPI-12 in the year 1993-1994, the highest moist period was in the year 1967-1968.

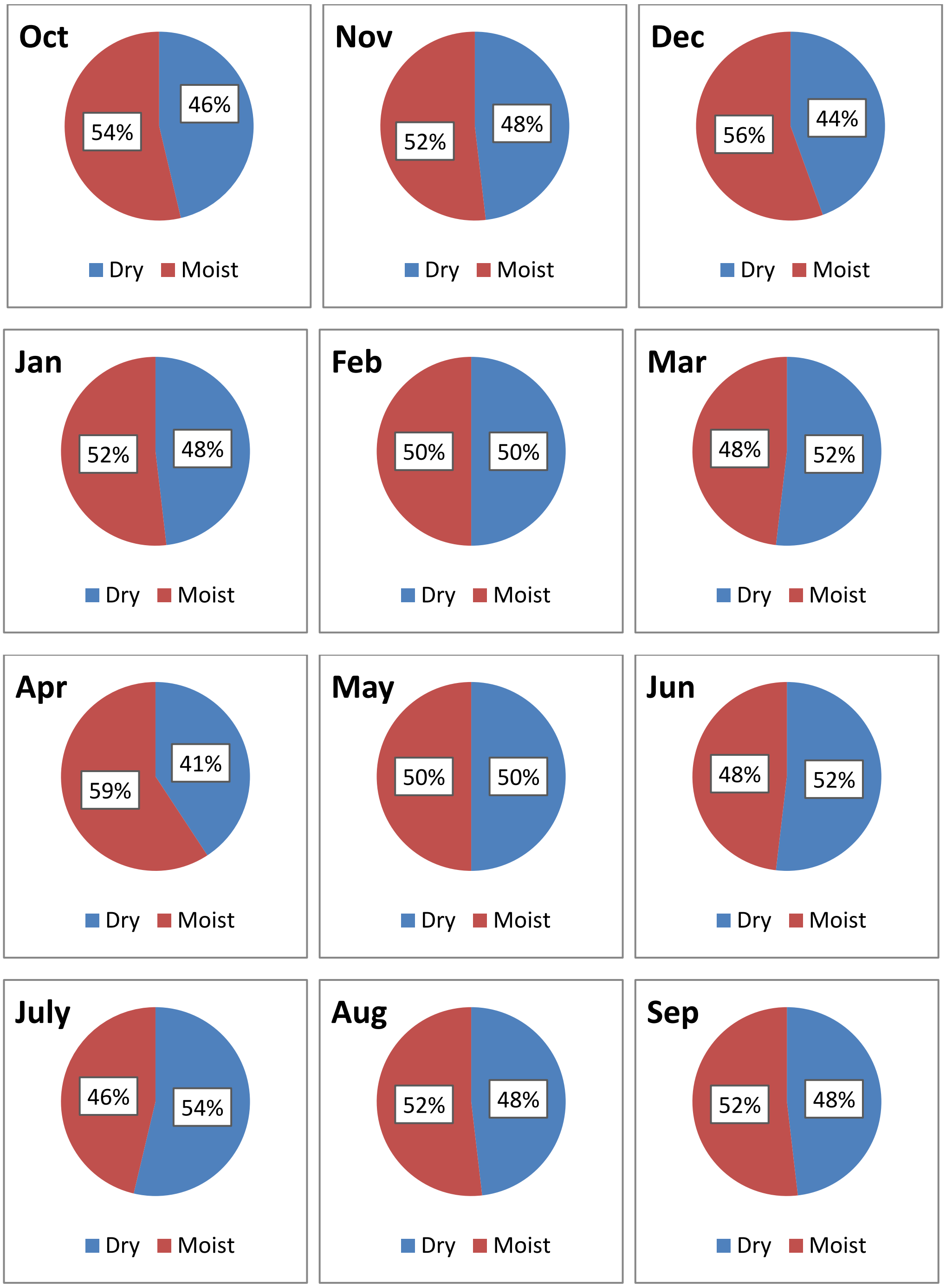


Figure 4.8. Dry - moist period distributions according to the monthly SPI values for the Bartın Station (No. 17020) from 1965 to 2019.

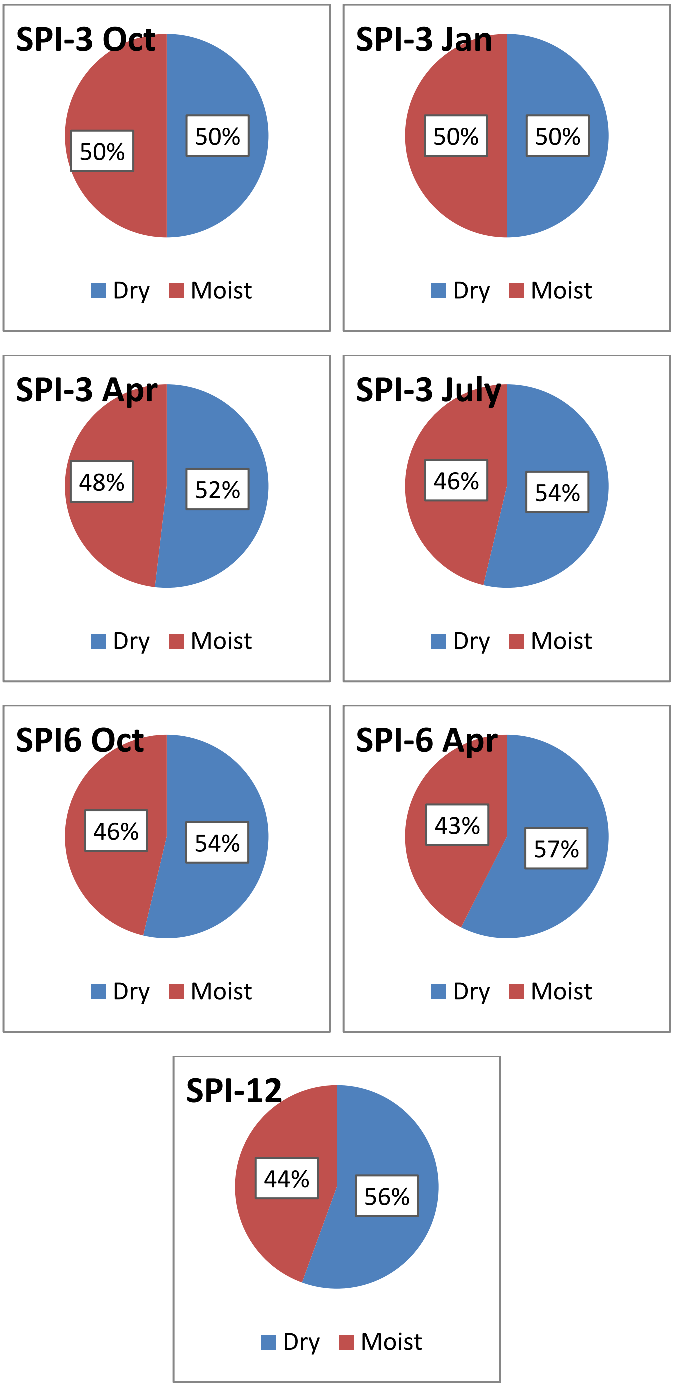


Figure 4.9. Dry - moist period distributions according to the 3,6,12 month SPI values for the Bartın Station (No. 17020) from 1965 to 2019.

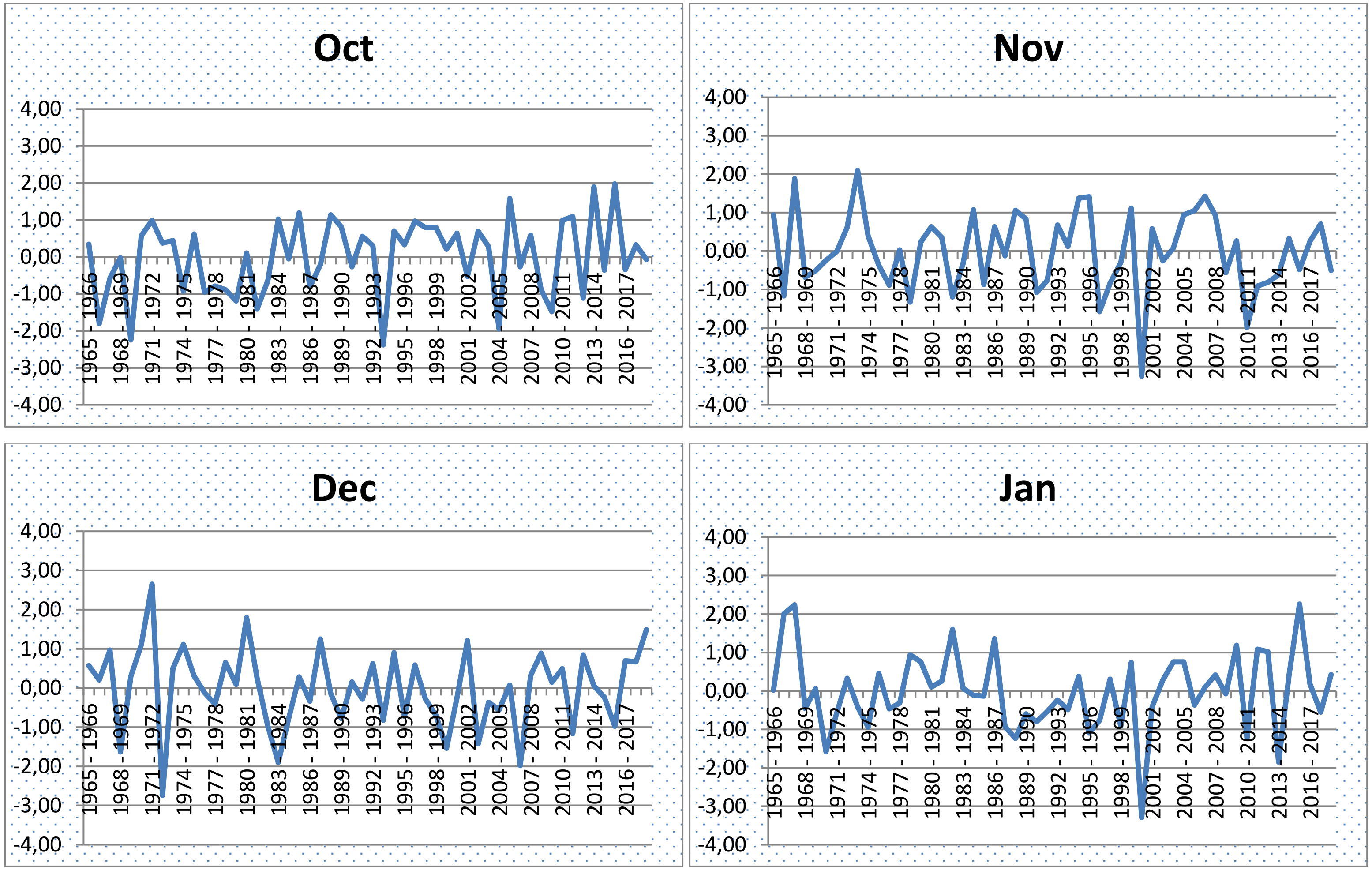


Figure 4.10. Temporal distribution of monthly SPI values of the Bartın (No.62010) from 1965 to 2019.

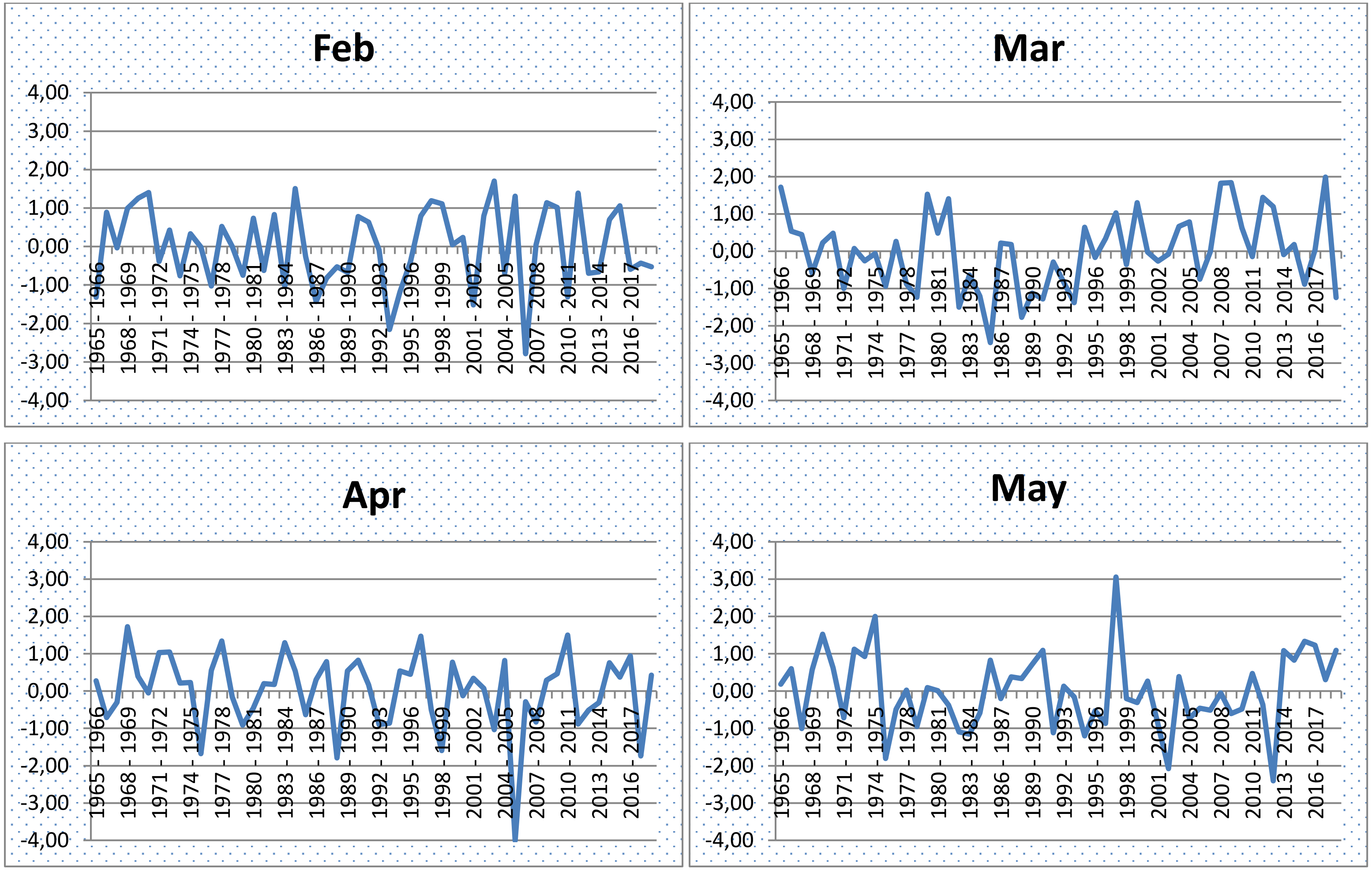


Figure 4.11. (Continued).

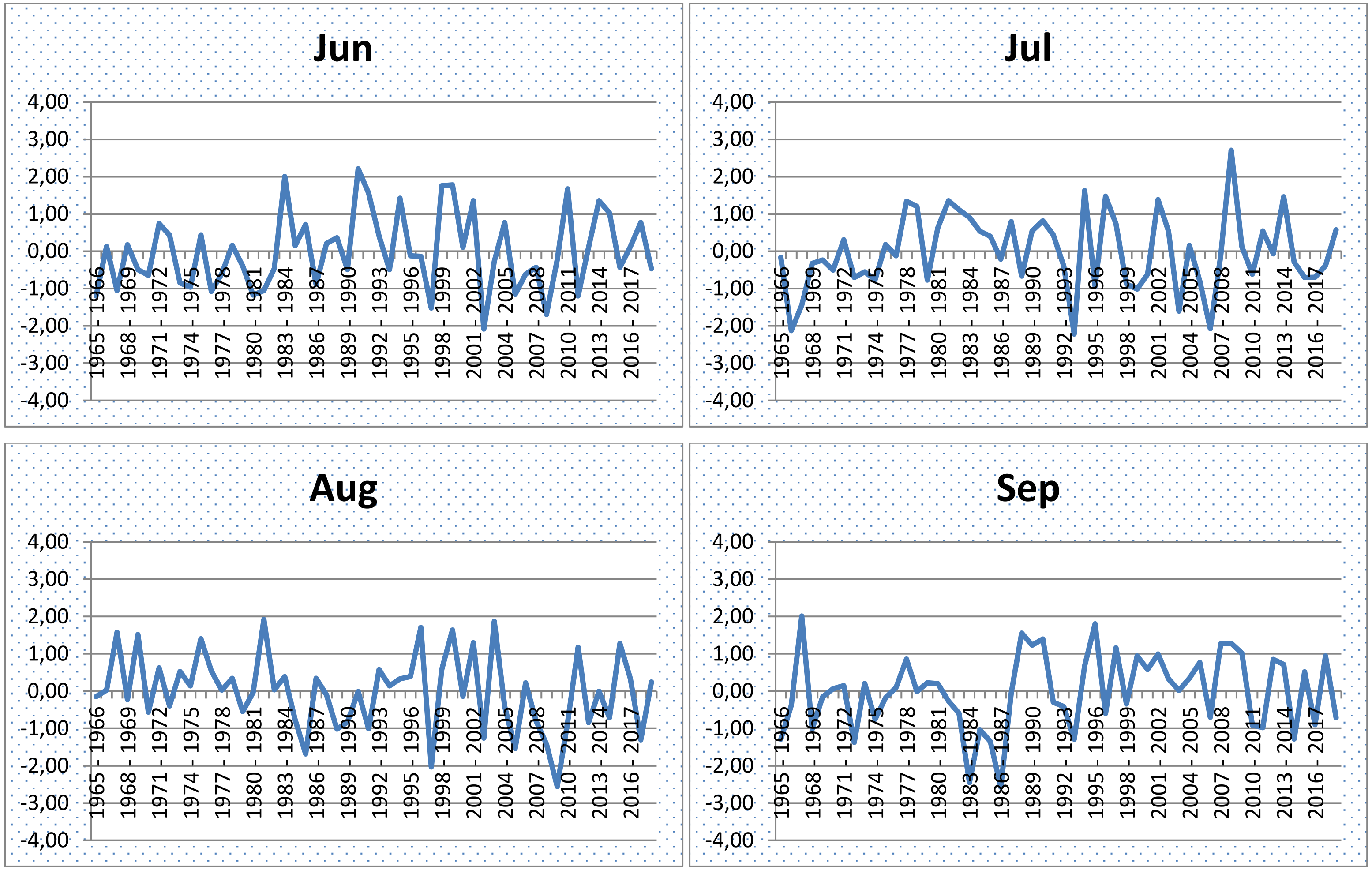


Figure 4.12. (Continued).

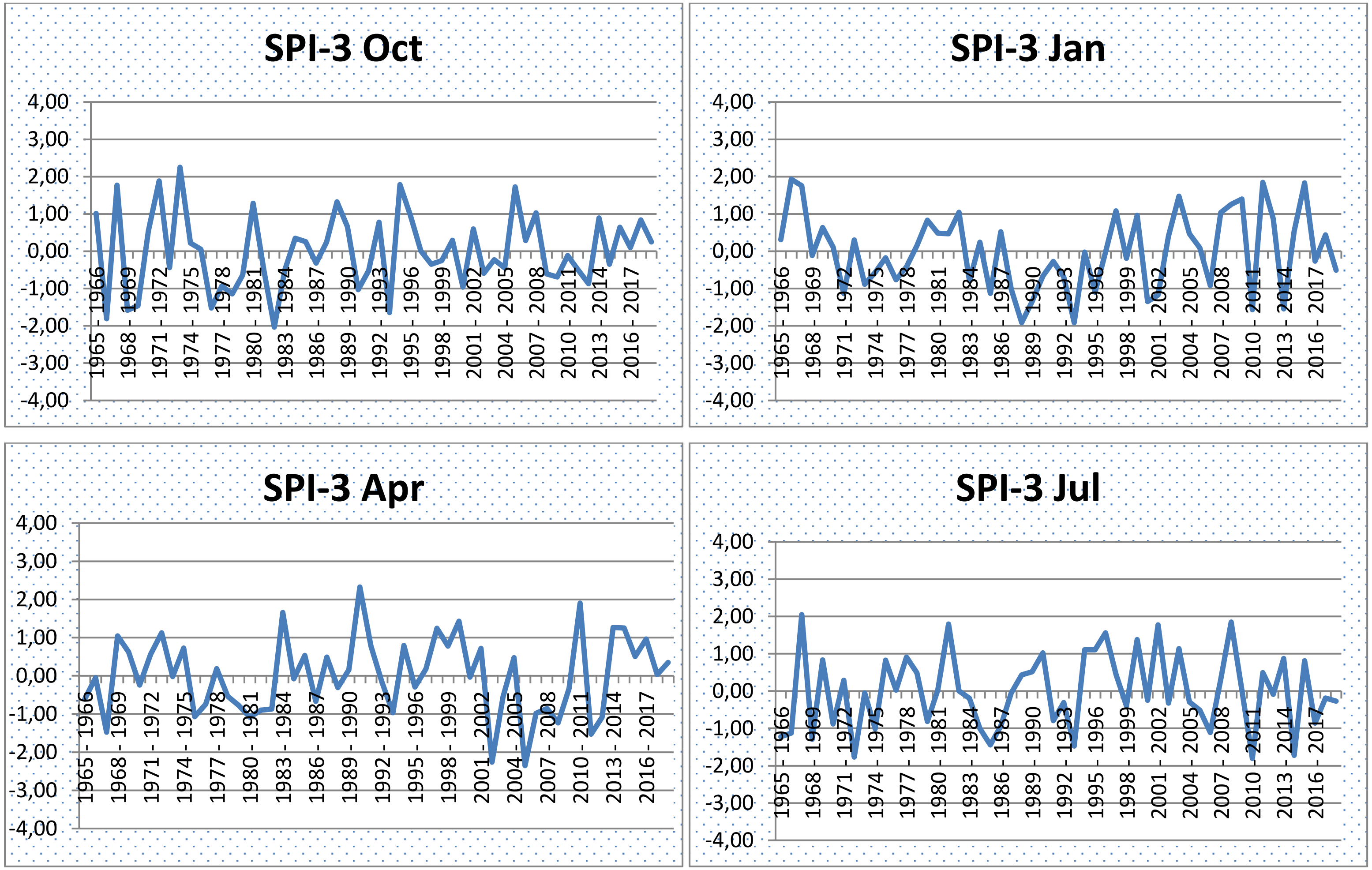


Figure 4.13. Temporal distribution of 3, 6, and 12 month SPI values of the Bartın (No.1702) from 1965 to 2019.

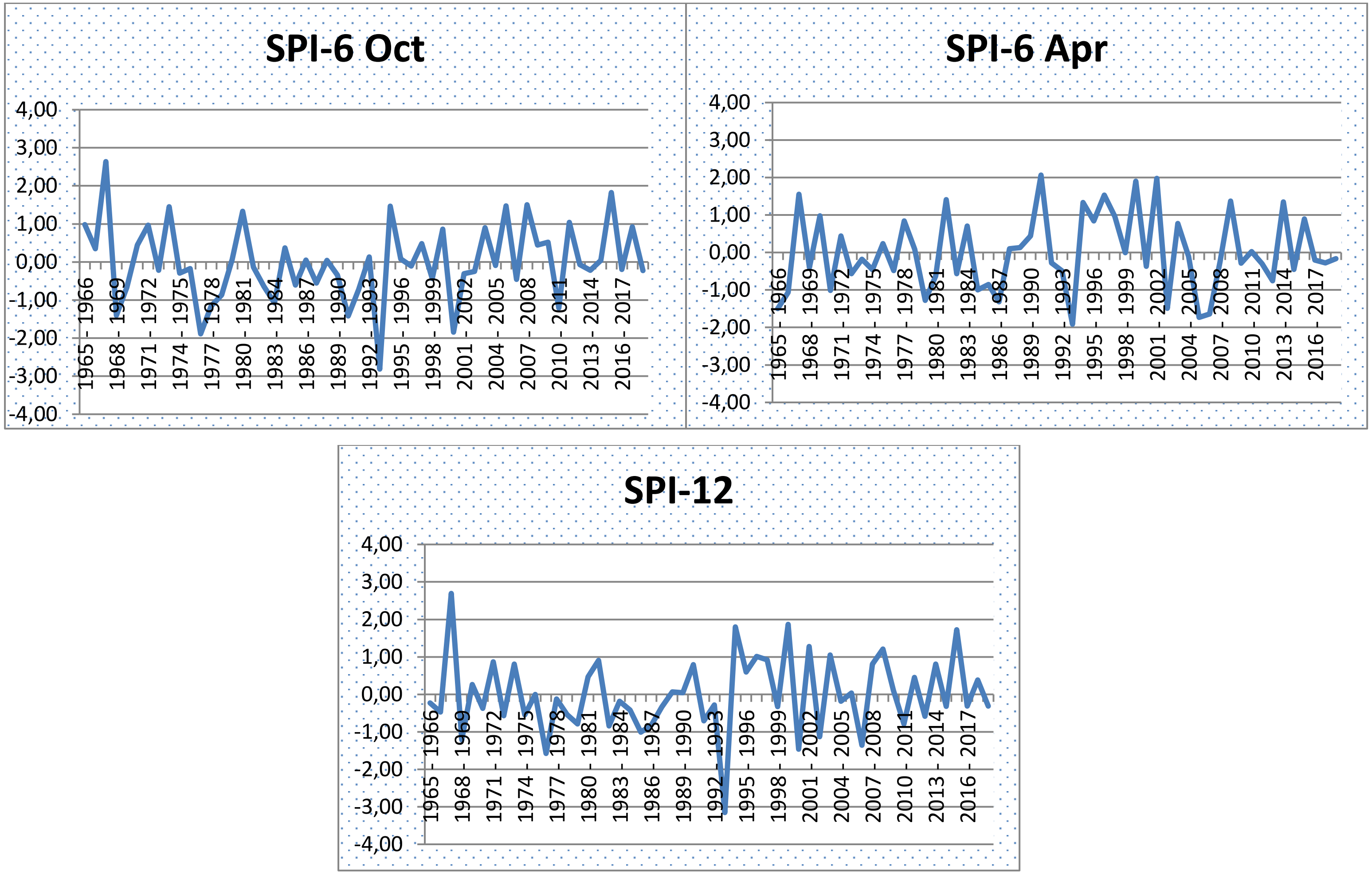


Figure 4.14. (Continued).

4.2.3 Devrakani Precipitation Monitoring Station (17618) Meteorological Drought Analysis (SPI)

SPI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation data measured between 1965-2019 of the Devrekani Station. The rate of dryness and humidity of monthly is shown in the Figure 4.9 and Table 4.1. The figure hereby shows that the monthly dryness ranged between 41% and 52% according to SPI values. The highest drought ratio were 52% September and August, the lowest drought ratio was 41% in January and April. The period of drought and moisture for each of 3, 6, and 12 months for the SPI values are shown in Figure 4.10. The driest periods with the highest SPI-3 values are in July period of 54% and the lowest dry period is October period at 44%. The driest periods with the highest SPI-6 values are October period at 56%. SPI-12 calculated according to 12-month values dryness is 50% and moisture is 50%.

According to Figure 4.11 and Table 4.2, when examining 1-month SPI values from 54-year monthly precipitation data at Devrekani monitoring station. The highest dry month was in November 2000-2001; the highest moist month was January 1967-1968. Figure 4.12 shows the time distribution of the SPI values for 3, 6 and 12 months to examine the SPI values, the highest dry period was at SPI-3 in October in the year 2001-2002 and April 2002-2003, the highest moist period was at SPI-3 in July in the year 2001-2002. The highest dry period at SPI-6 was in April in the year 1993-1994, the highest moist period was SPI-6 in October in the year 1967-1968. The highest dry period was at SPI-12 in the year 2005-2006 and 1993-1994, the highest moist period was in the year 1981-1982.

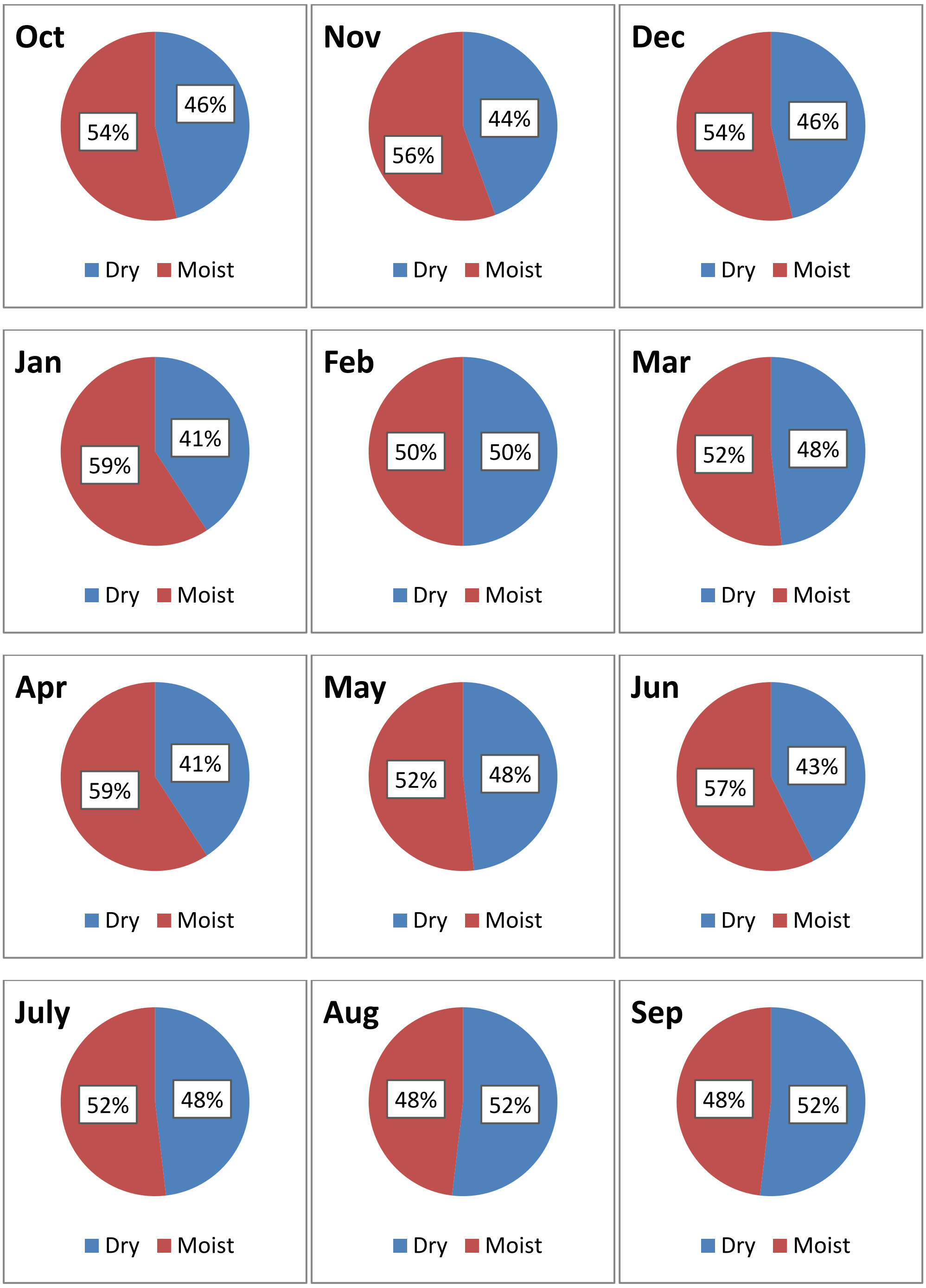


Figure 4.15. Dry - moist period distributions according to the monthly SPI values for the Devrekani Sation (No. 17618) from 1965 to 2019.

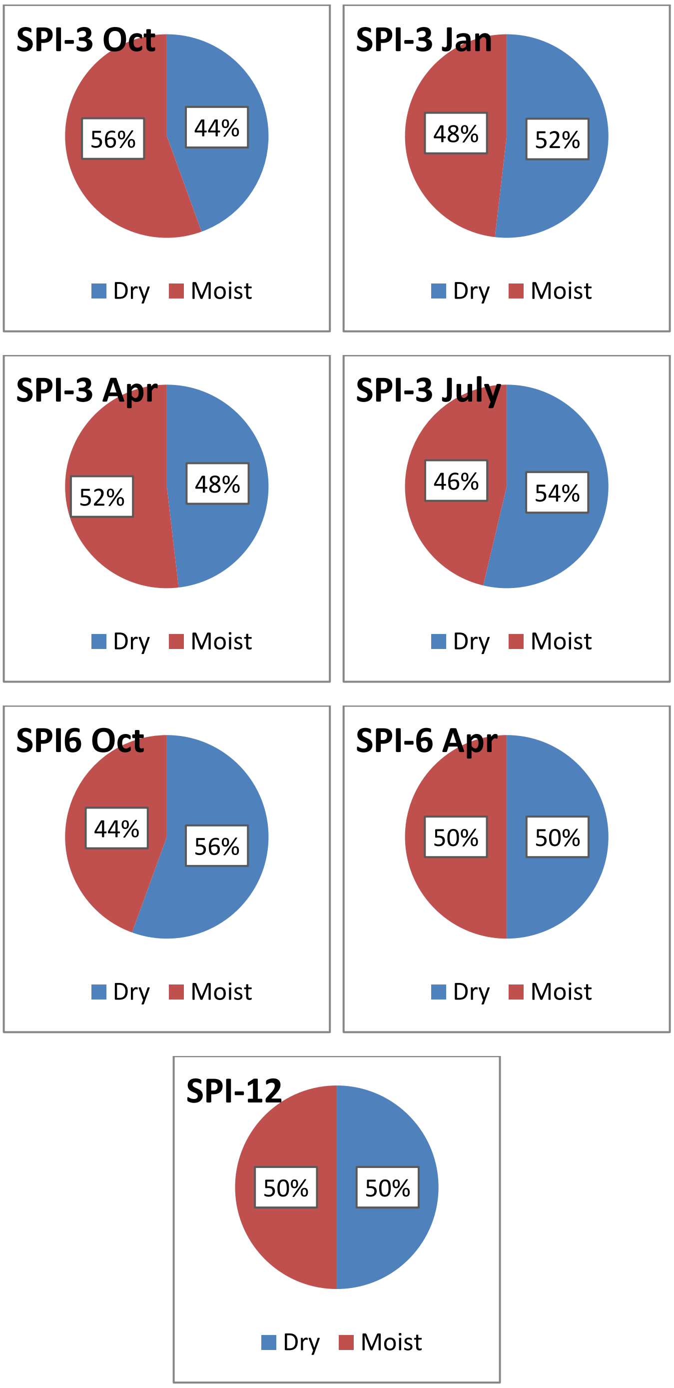


Figure 4.16. Dry - moist period distributions according to the 3,6,12 month SPI values for the Devrekani Station (No. 17618) from 1965 to 2019.

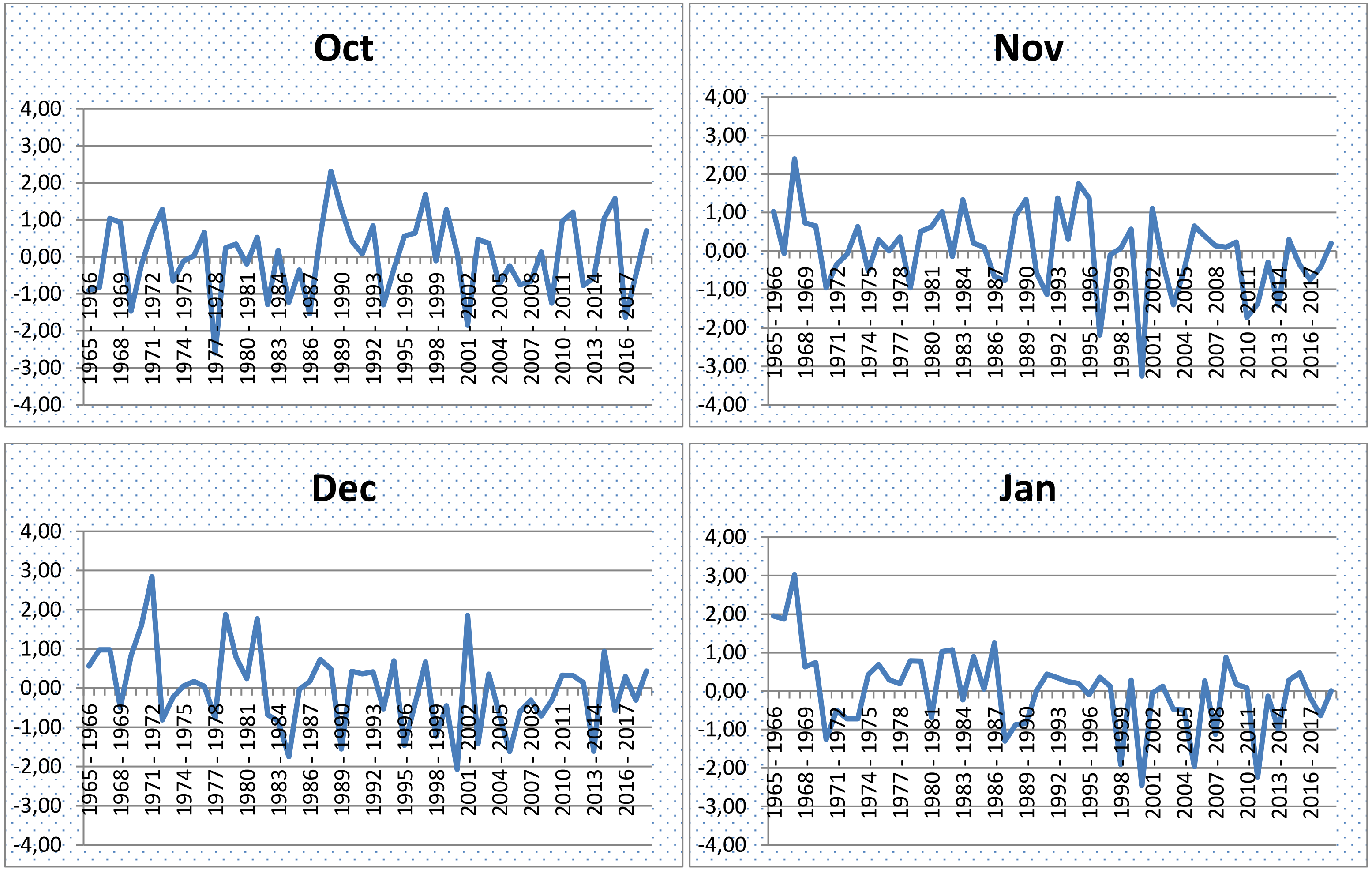


Figure 4.17. Temporal distribution of monthly SPI values of the Devrekani Station (No.17618) from 1965 to 2019.

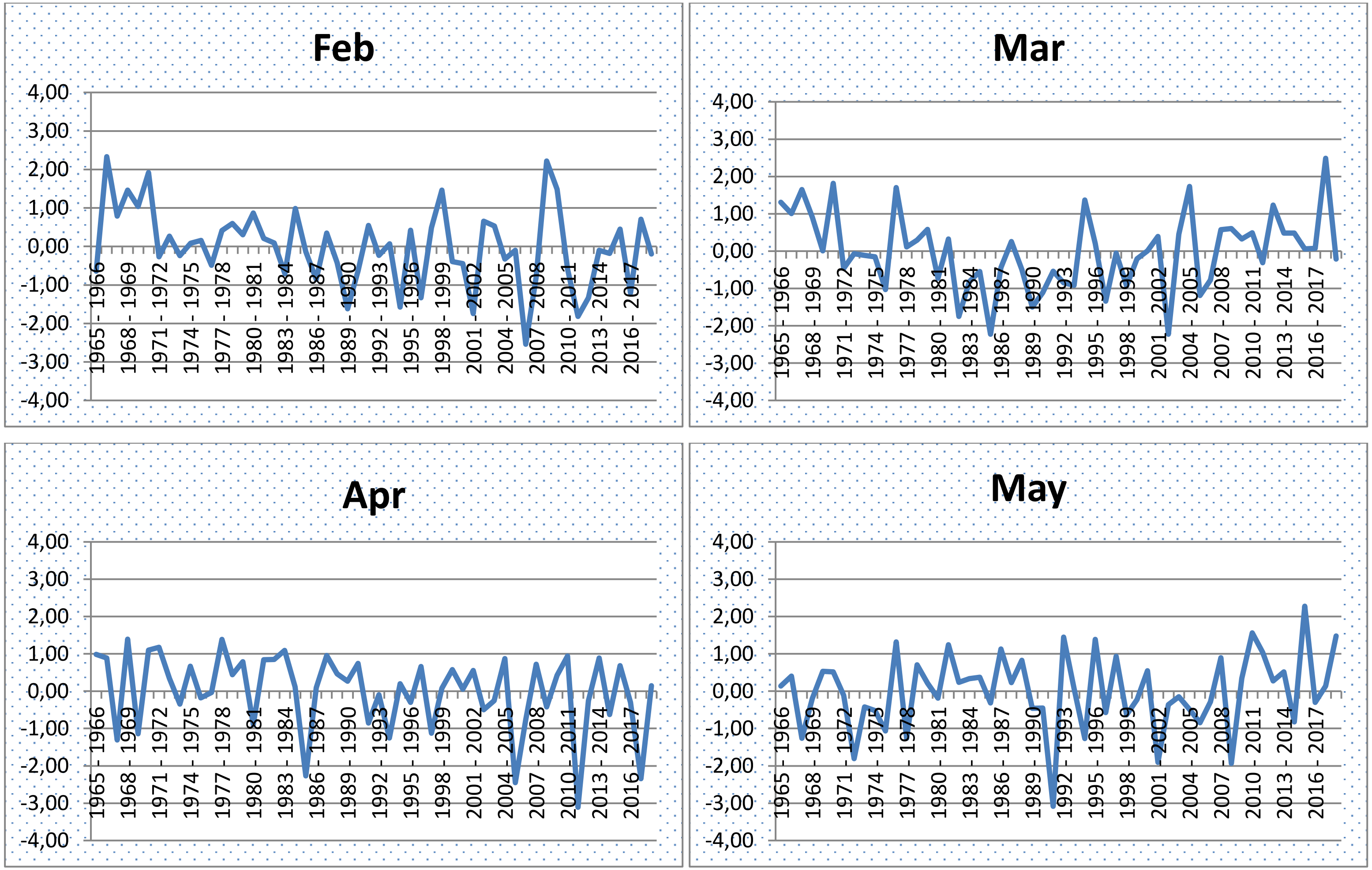


Figure 4.18. (Continued).

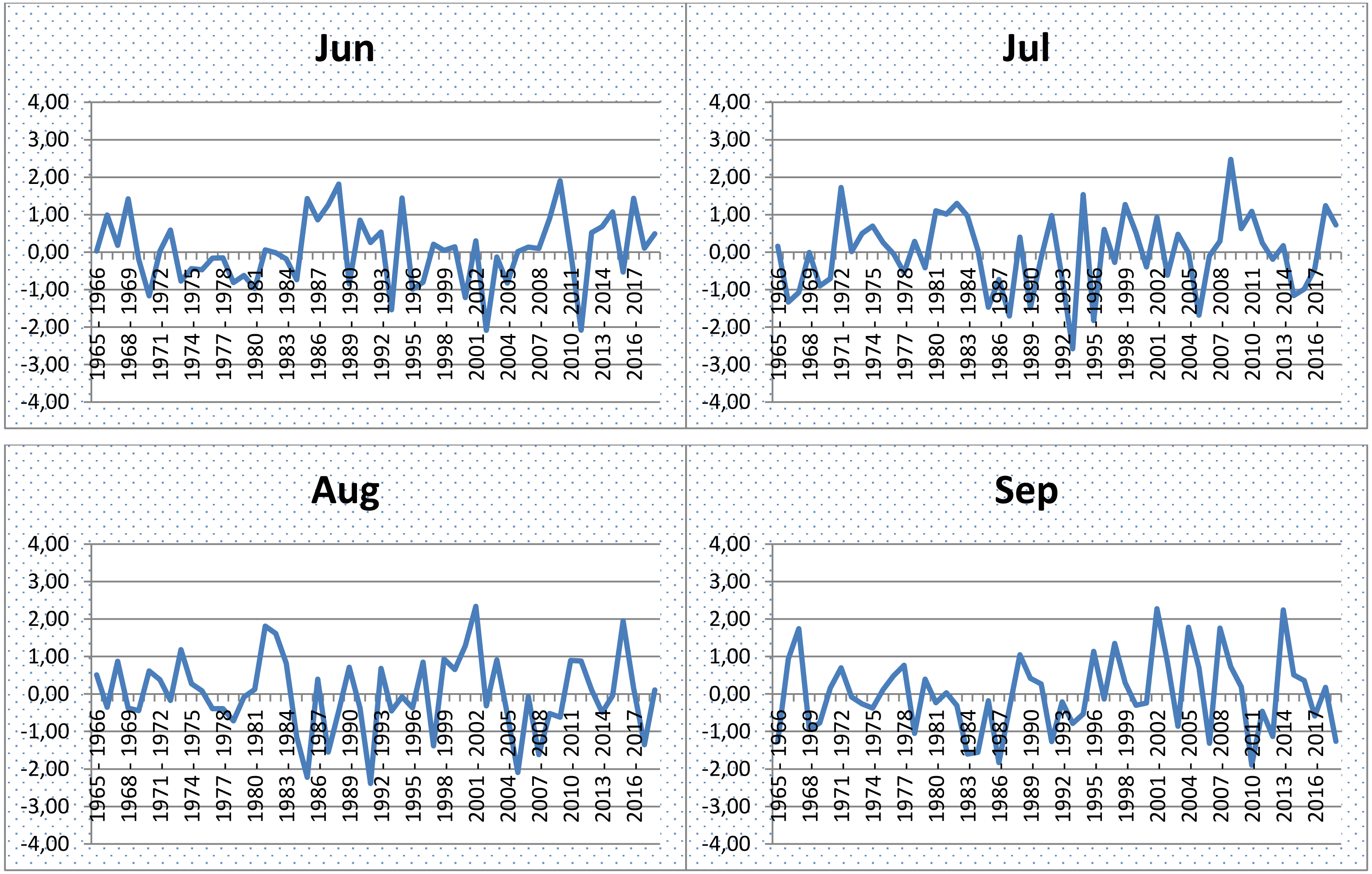


Figure 4.19. (Continued).

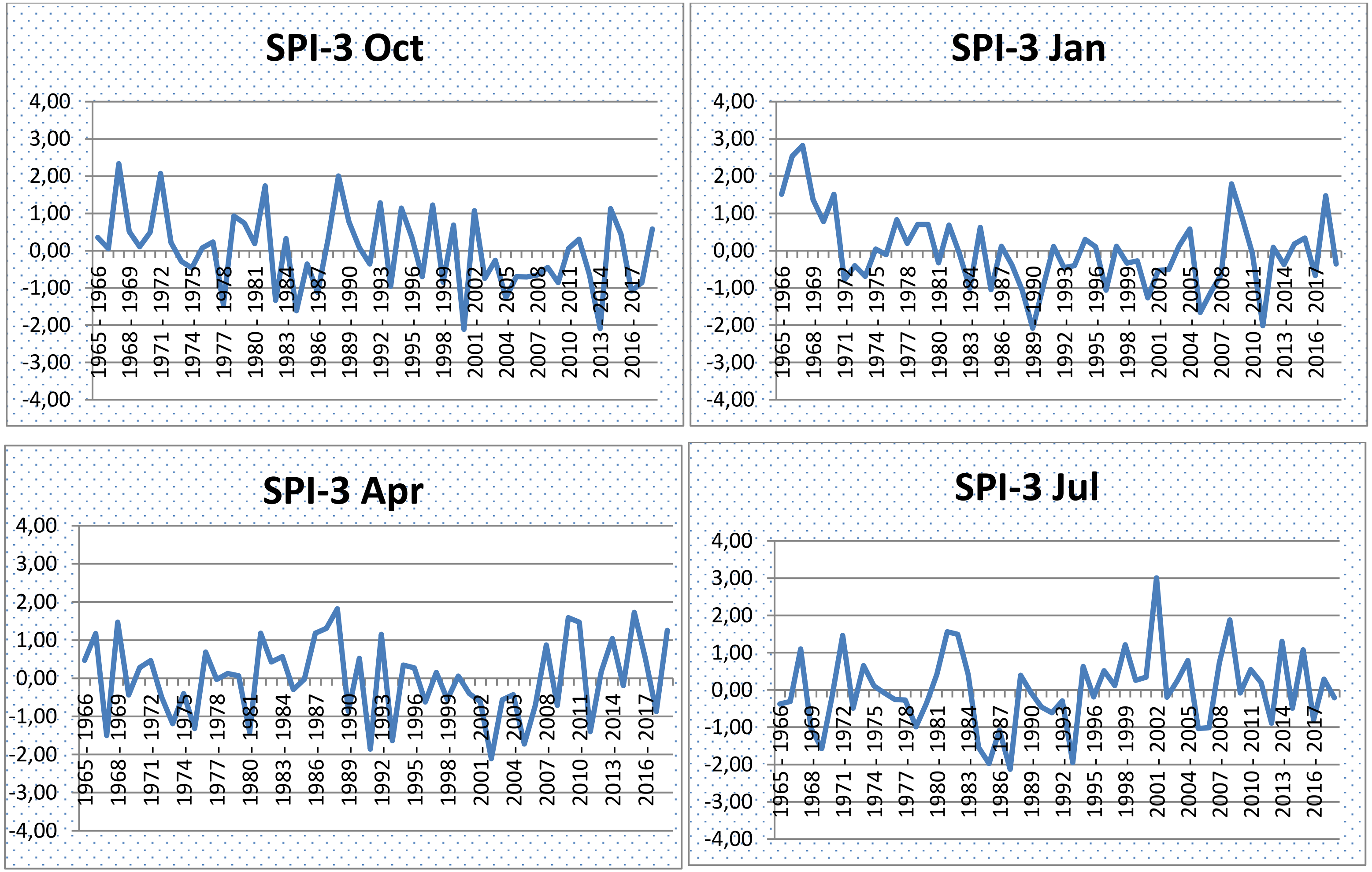


Figure 4.20. Temporal distribution of 3-, 6-, and 12 month SPI values of the Devrekani Station (No.17618) from 1965 to 2019.

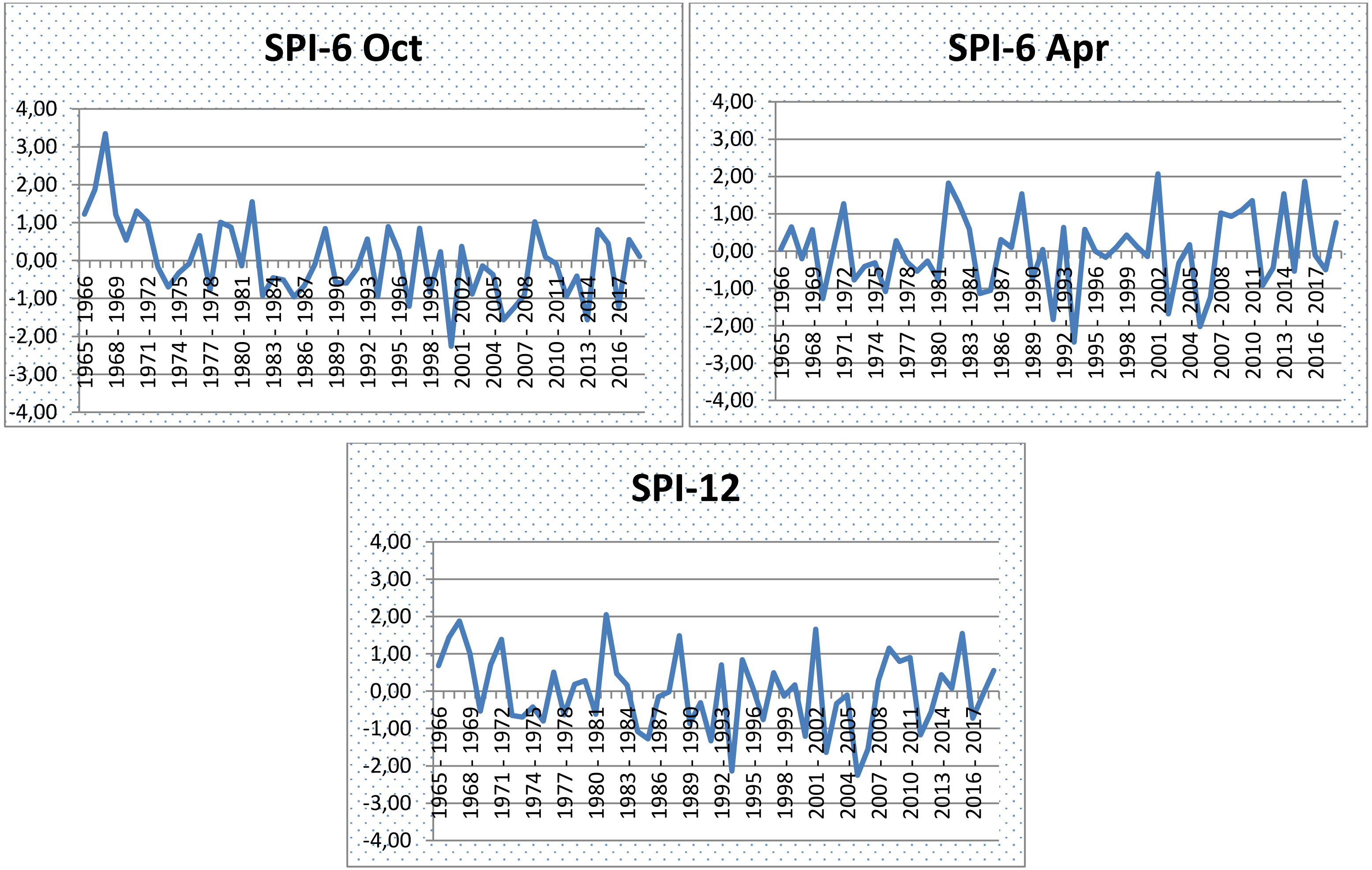


Figure 4.21. (Continued).

4.2.4. İnebolu Precipitation Monitoring Station (17024) Meteorological Drought Analysis (SPI)

SPI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation data measured between 1965-2019 of the İnebolu Station. The rate of dryness and humidity of monthly is shown in the Figure 4.13 and Table 4.1. The figure hereby shows that the monthly dryness ranged between 35% and 56% according to SPI values. The highest drought ratio were 56% October and July and the lowest drought ratio was 35% in September. The period of drought and moisture for each of 3, 6 and 12- months for the SPI values are shown in Figure 4.14. The driest periods with the highest SPI-3 values are in July of 50% and the lowest dry period is in April of 41%. The driest periods with the highest SPI-6 values are in April with 50%. SPI-12 calculated according to 12-month values dryness is 48% and moisture is 52%.

According to Figure 4.15 and Table 4.2, when examining 1-month SPI values from 54-year monthly precipitation data at İnebolu monitoring station. The highest dry month was in November 2000-2001; the highest moist month was February 1984-1985. Figure 4.16 shows the time distribution of the SPI values for 3, 6 and 12 months to examine the SPI values, the highest dry period was at SPI-3 in October in the year 1966-1967, the highest moist period was at SPI-3 in January in the year 2011-2012. The highest dry period at SPI-6 was in April in the year 1973-1974, the highest moist period was SPI-6 in October in the year 2011-2012. The highest dry period was at SPI-12 in the year 1974-1975, 2005-2006 and 1993-1994, the highest moist period was in the year 2015-2016 .

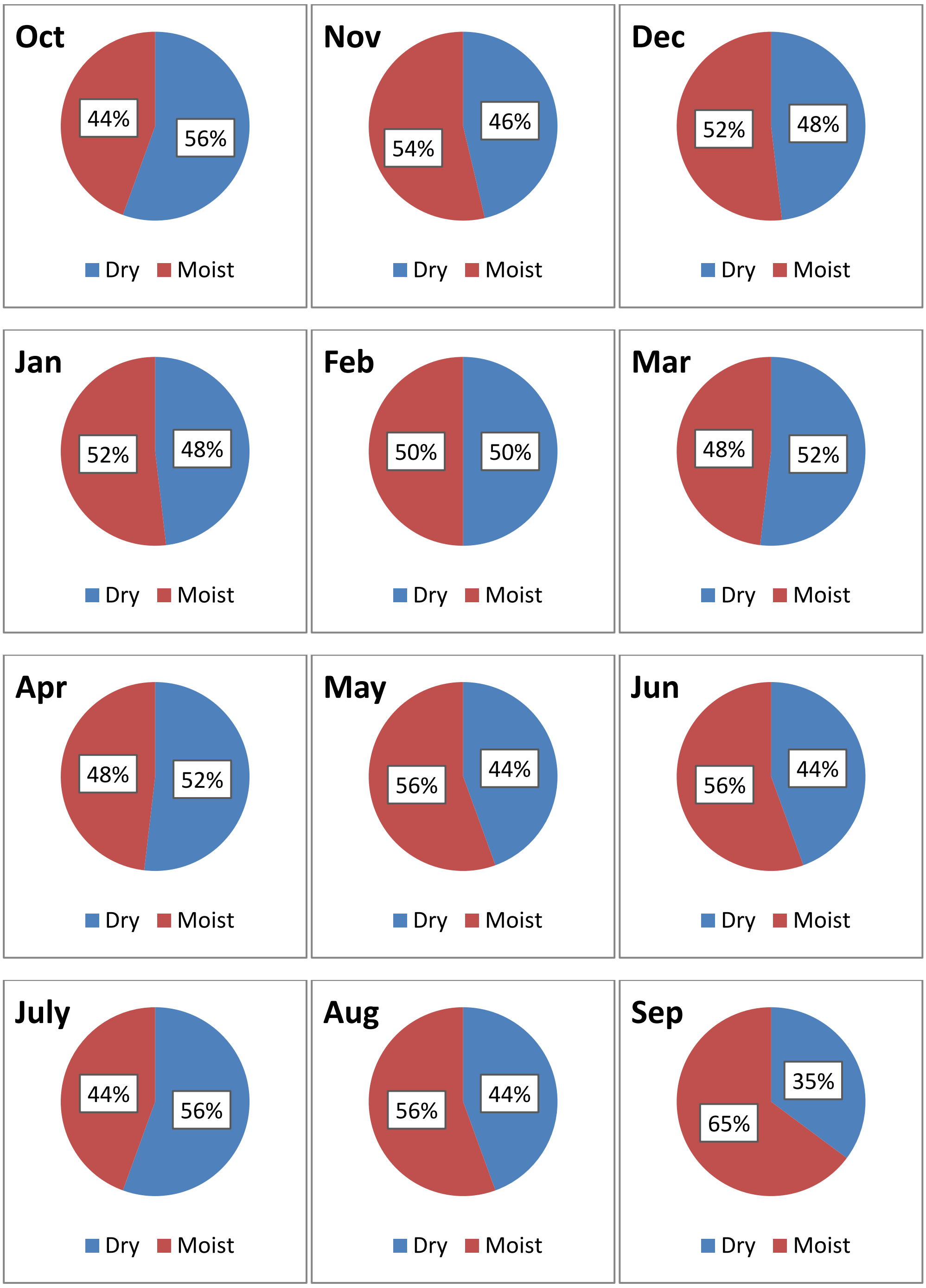


Figure 4.22. Dry - moist period distributions according to the monthly SPI values for the İnebolu Station (No. 17024) from 1965 to 2019.

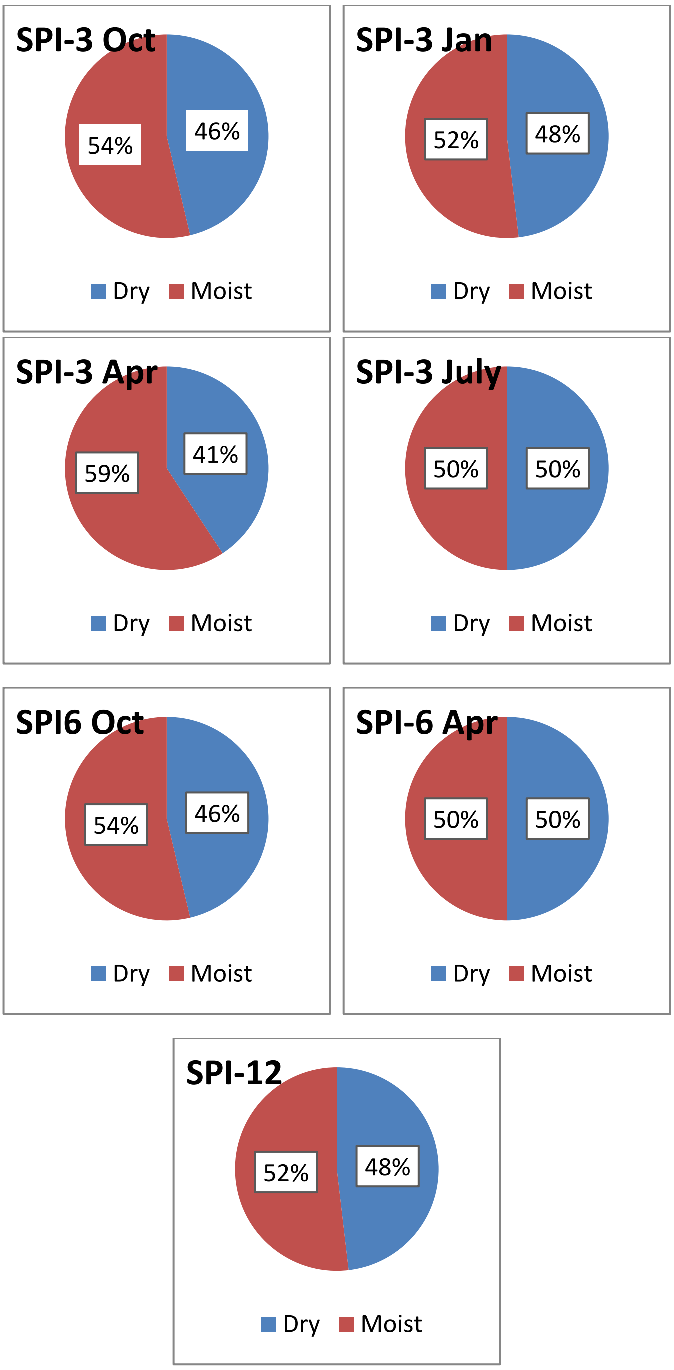


Figure 4.23. Dry - moist period distributions according to the 3,6,12 month SPI values for the İnebolu Station (No. 17024) from 1965 to 2019.

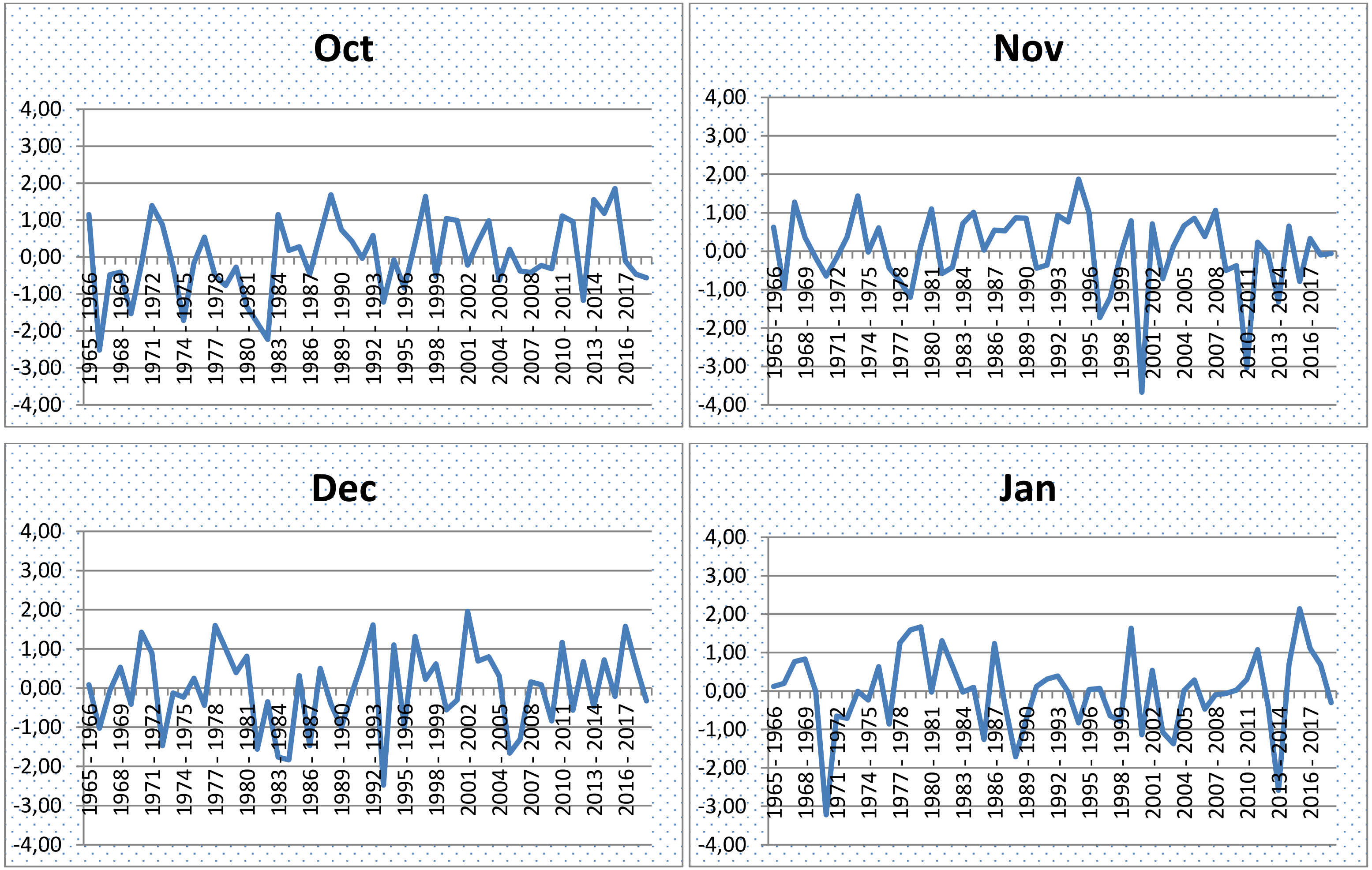


Figure 4.24. Temporal distribution of monthly SPI values of the İnebolu Station (No.17024) from 1965 to 2019.

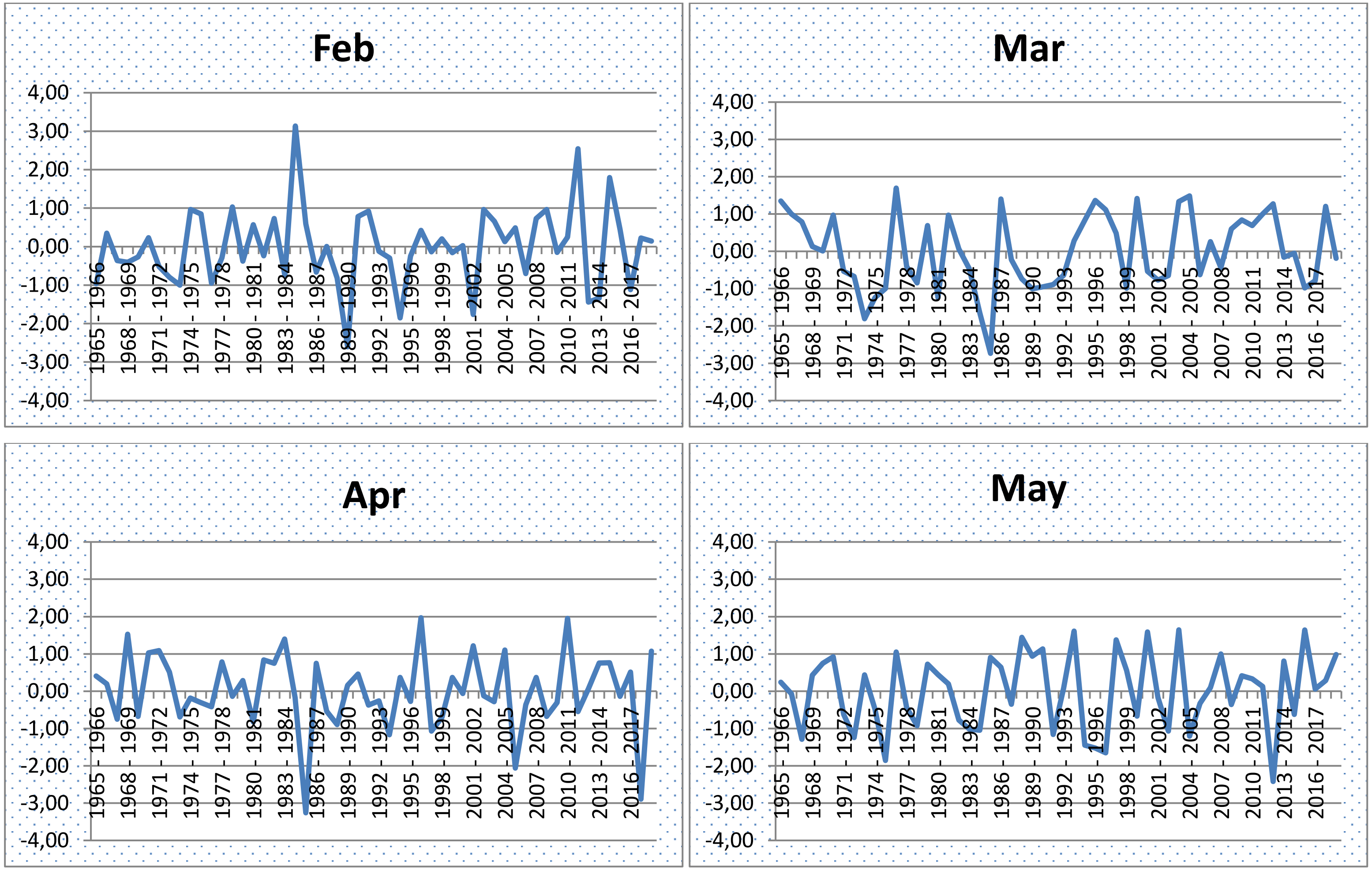


Figure 4.25. (Continued).

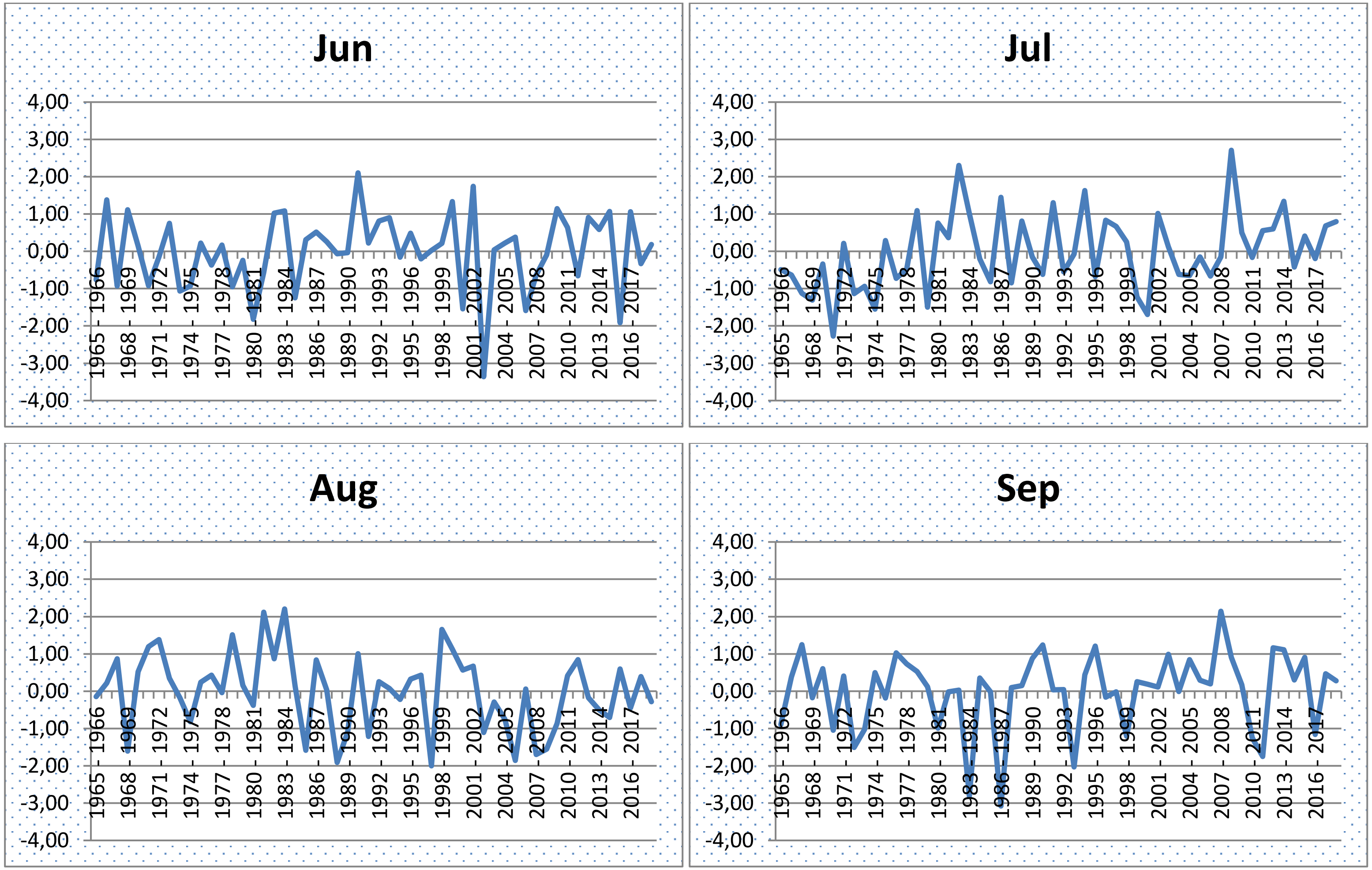


Figure 4.26. (Continued).

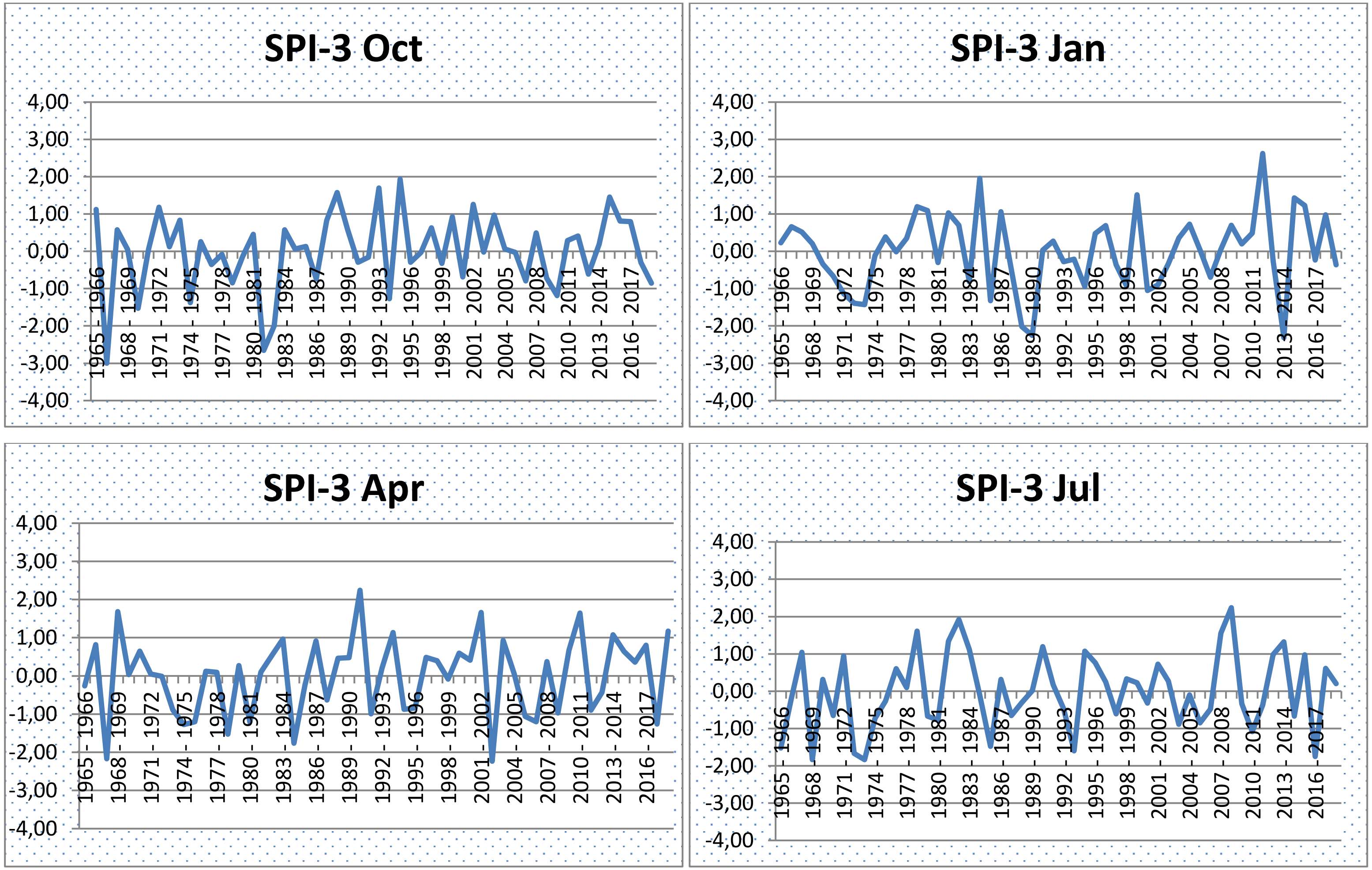


Figure 4.27. Temporal distribution of 3-, 6- and 12-month SPI values of the İnebolu Station (No.17024) from 1965 to 2019.

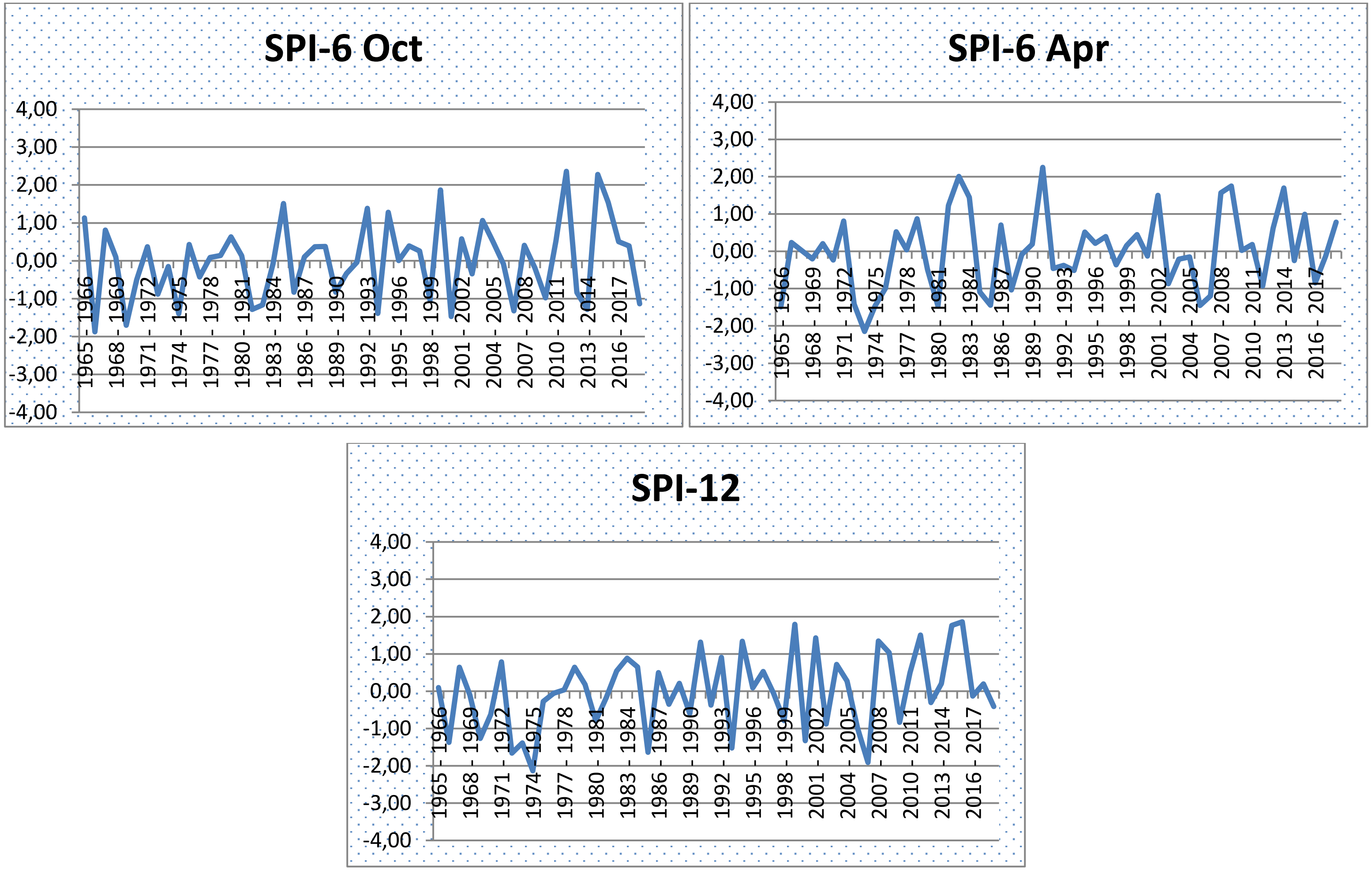


Figure 4.28. (Continued).

4.2.5. Kastamonu Precipitation Monitoring (17074) Meteorological Drought Analysis (SPI)

SPI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation data measured between 1965-2019 of the Kastamonu Station. The rate of dryness and humidity of monthly is shown in the Figure 4.17 and Table 4.1. The figure hereby shows that the monthly dryness ranged between 37% and 54% according to SPI values. The highest drought ratio was 54% October and July, and the lowest drought ratio was 37% in August. The period of drought and moisture for each of 3, 6 and 12 months for the SPI values are shown in Figure 4.18. The driest periods with the highest SPI-3 values are in October of 54% and the lowest dry period is April at 43%. The driest periods with the highest SPI-6 values are in April with 50%. SPI-12 calculated according to 12-month values dryness is 50% and moisture is 50%.

According to Figure 4.19 and Table 4.2, when examining 1-month SPI values from 54-year monthly precipitation data at Kastamonu Station. The highest dry month was in December and April 1984-1985; the highest moist period month were January 2009-2010 and September 2013-2014. Figure 4.20 shows the time distribution of the SPI values for 3, 6 and 12 months to examine the SPI values, the highest dry period was at SPI-3 in October in the year 2013-2014, the highest moist period was at SPI-3 in October in the year 1988-1989. The highest dry period at SPI-6 was in April in the year 1993-1994, and the highest dry period was at SPI-12 in the year 1993-1994, the highest moist period was in the year 2009-2010.

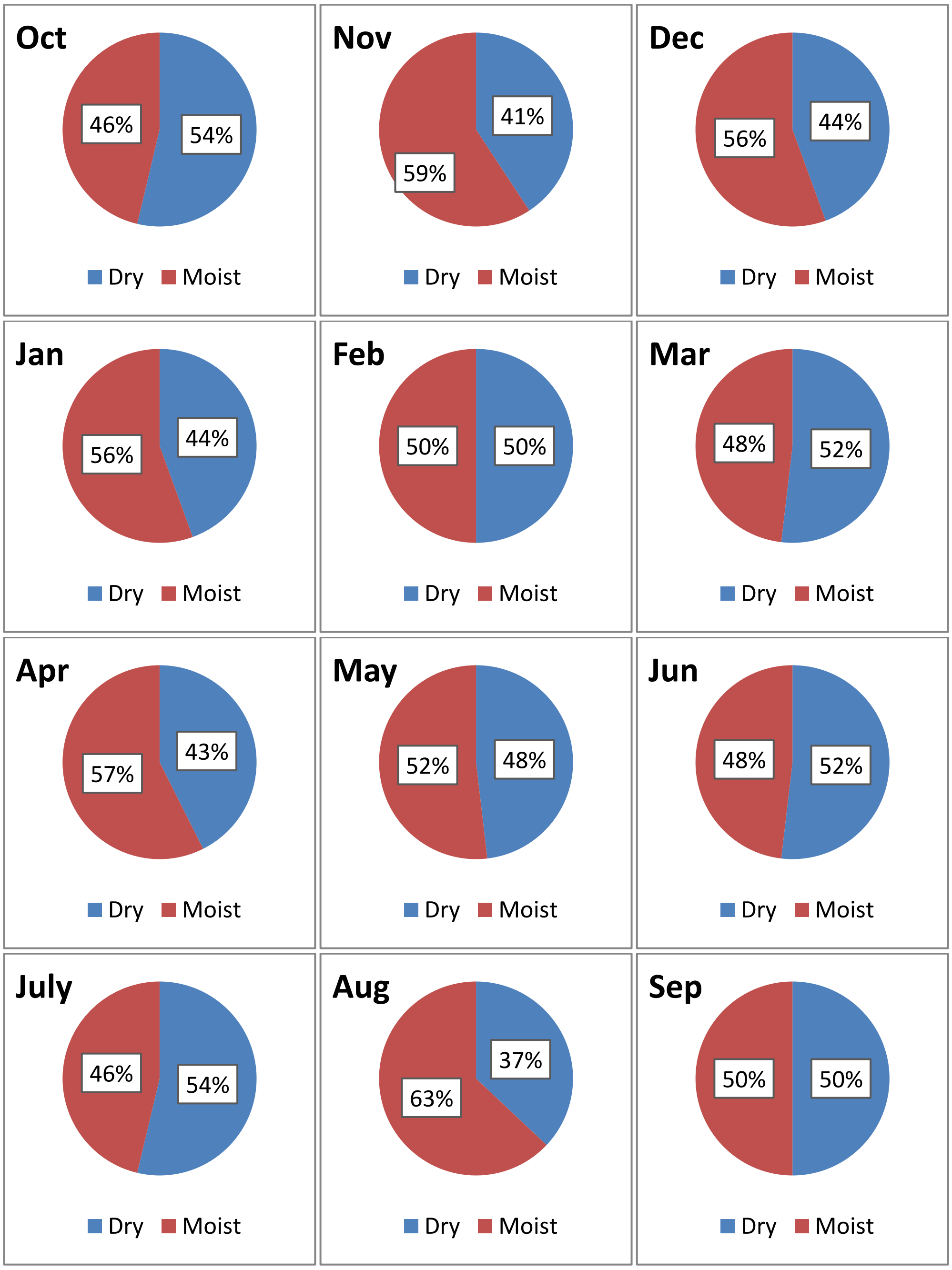


Figure 4.29. Dry - moist period distributions according to the monthly SPI values for the Kastamonu Station (No. 17074) from 1965 to 2019.

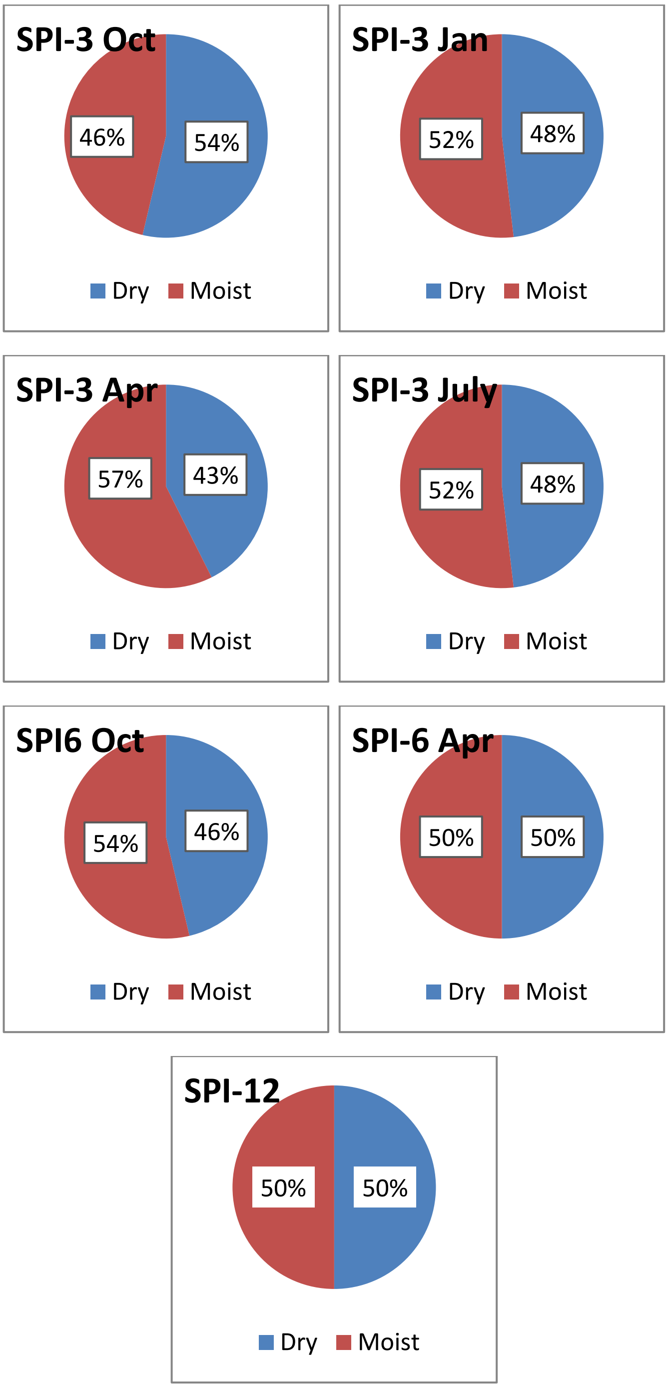


Figure 4.30. Dry - moist period distributions according to the 3,6,12month SPI values for the Kastamonu Station (No. 17074) from 1965 to 2019.

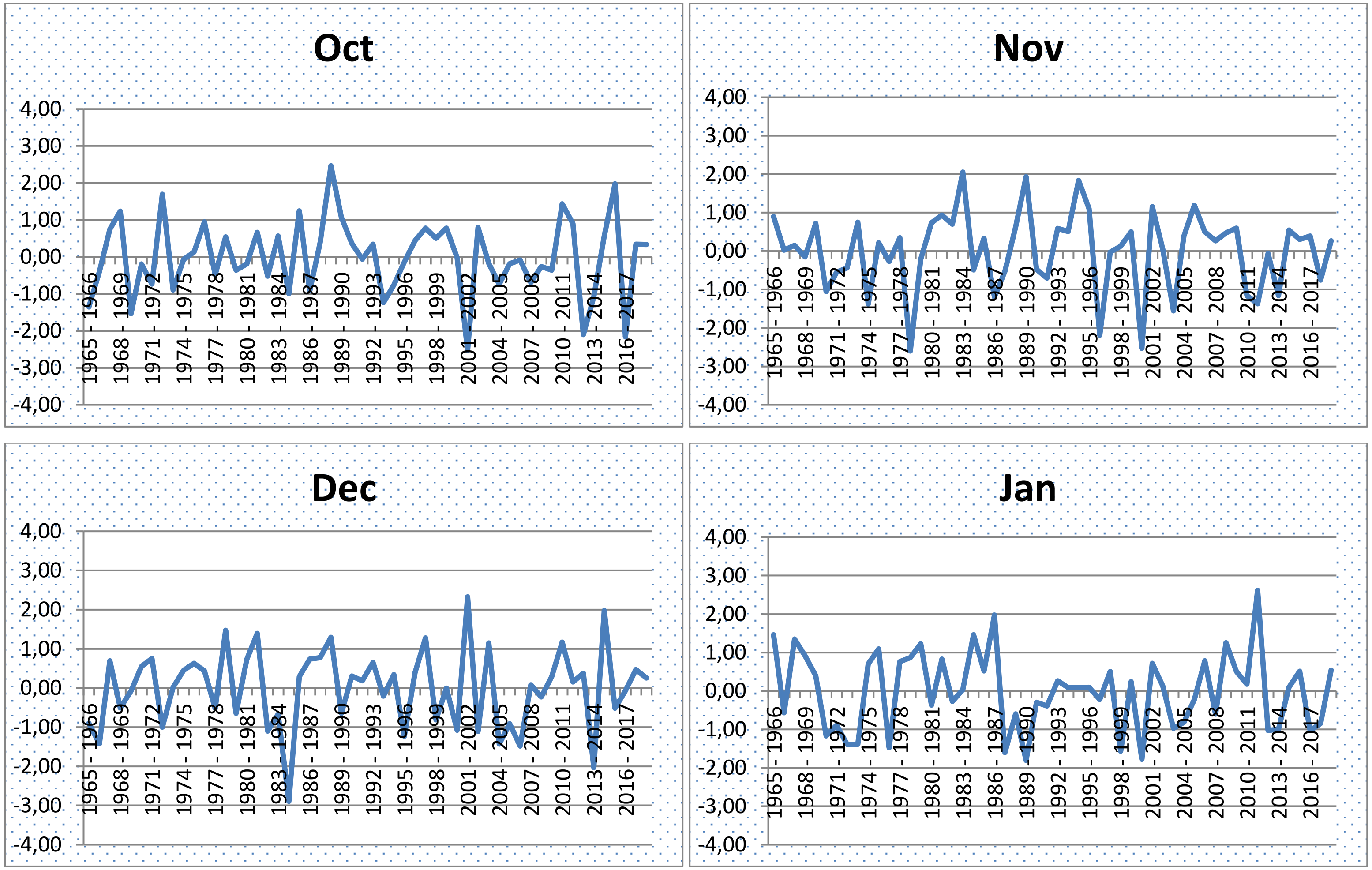


Figure 4.31. Temporal distribution of monthly SPI values of the Kastamonu Station (No.17074) from 1965 to 2019.

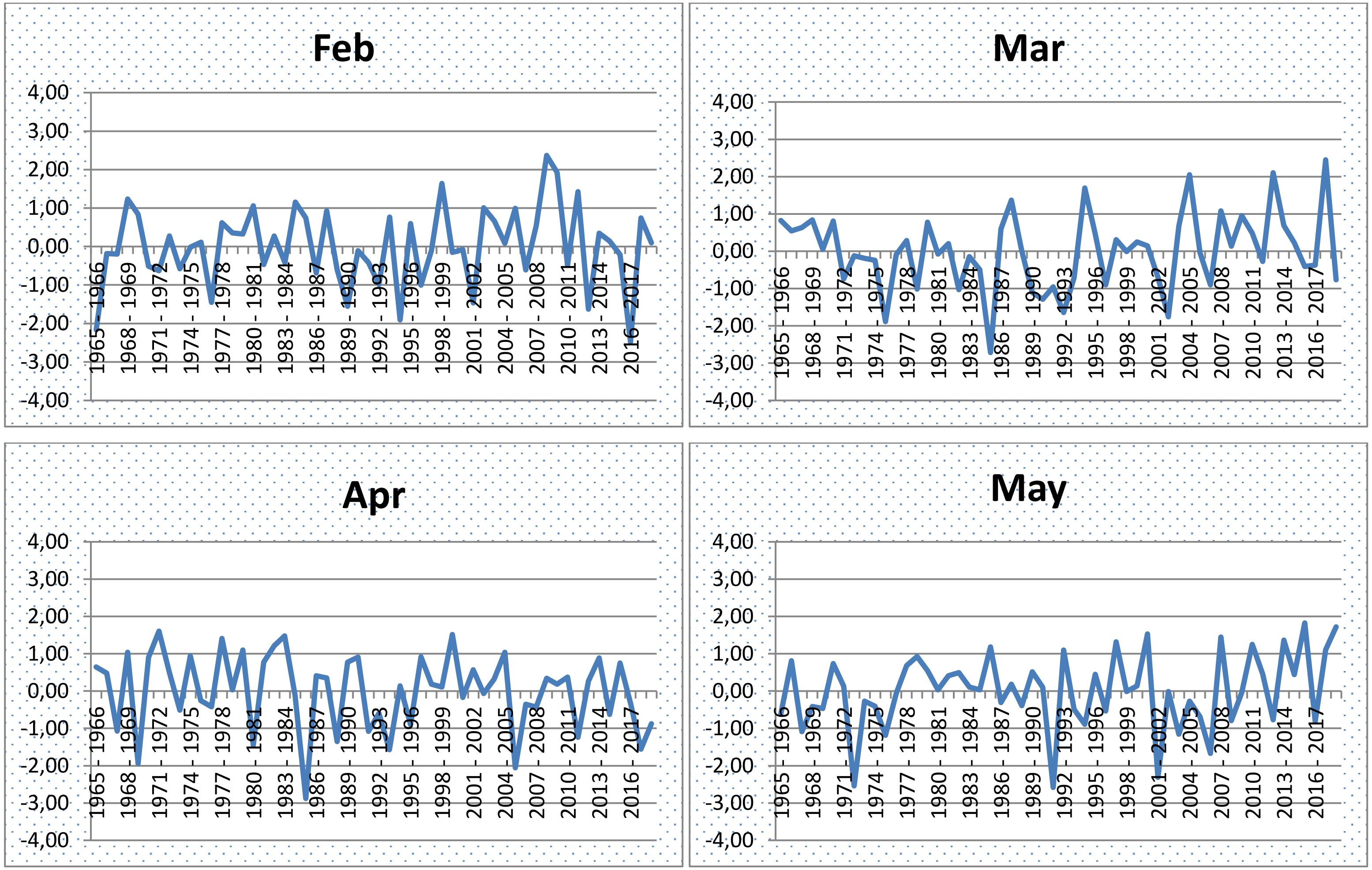


Figure 4.32. (Continued).

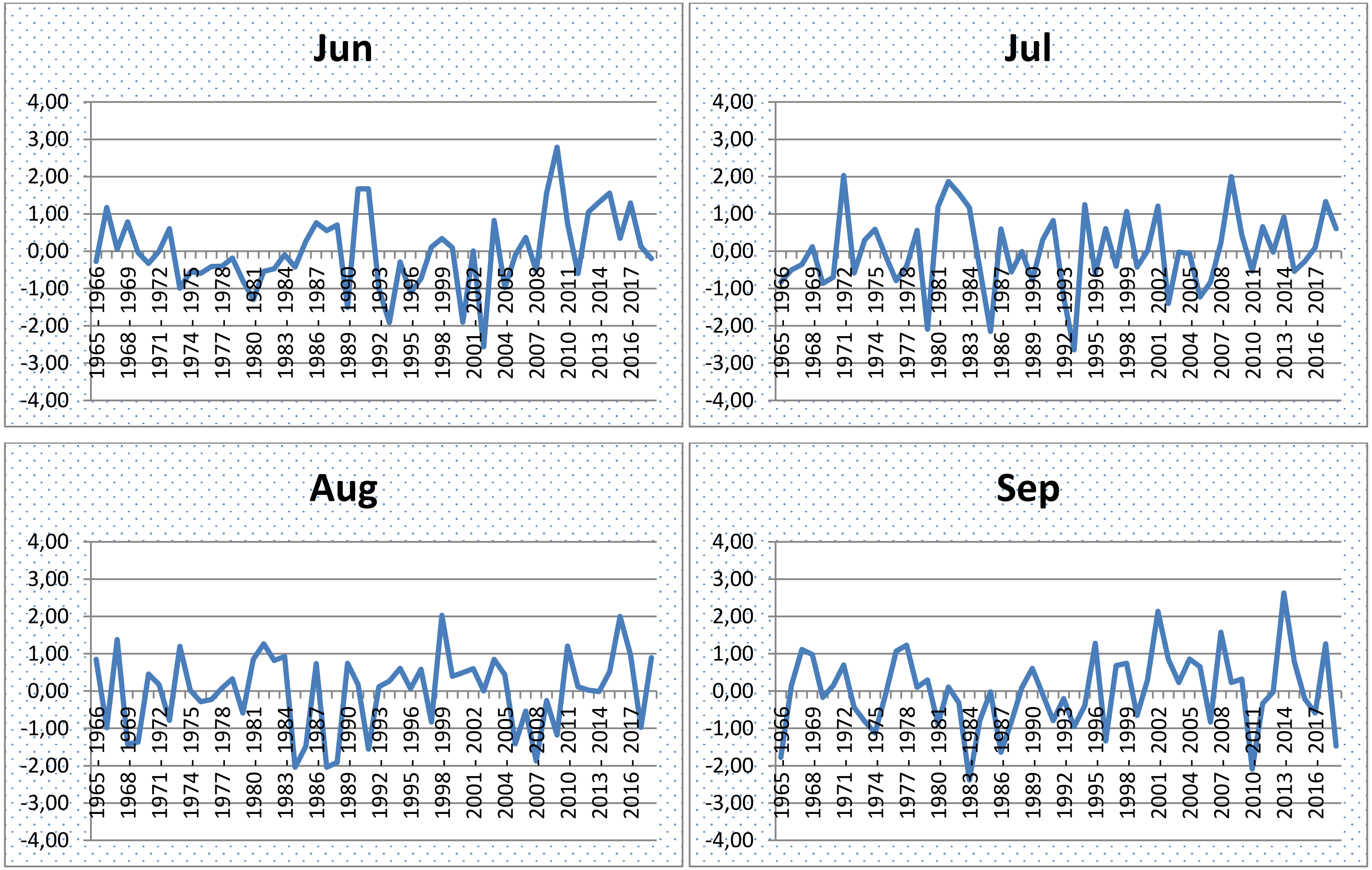


Figure 4.33. (Continued).

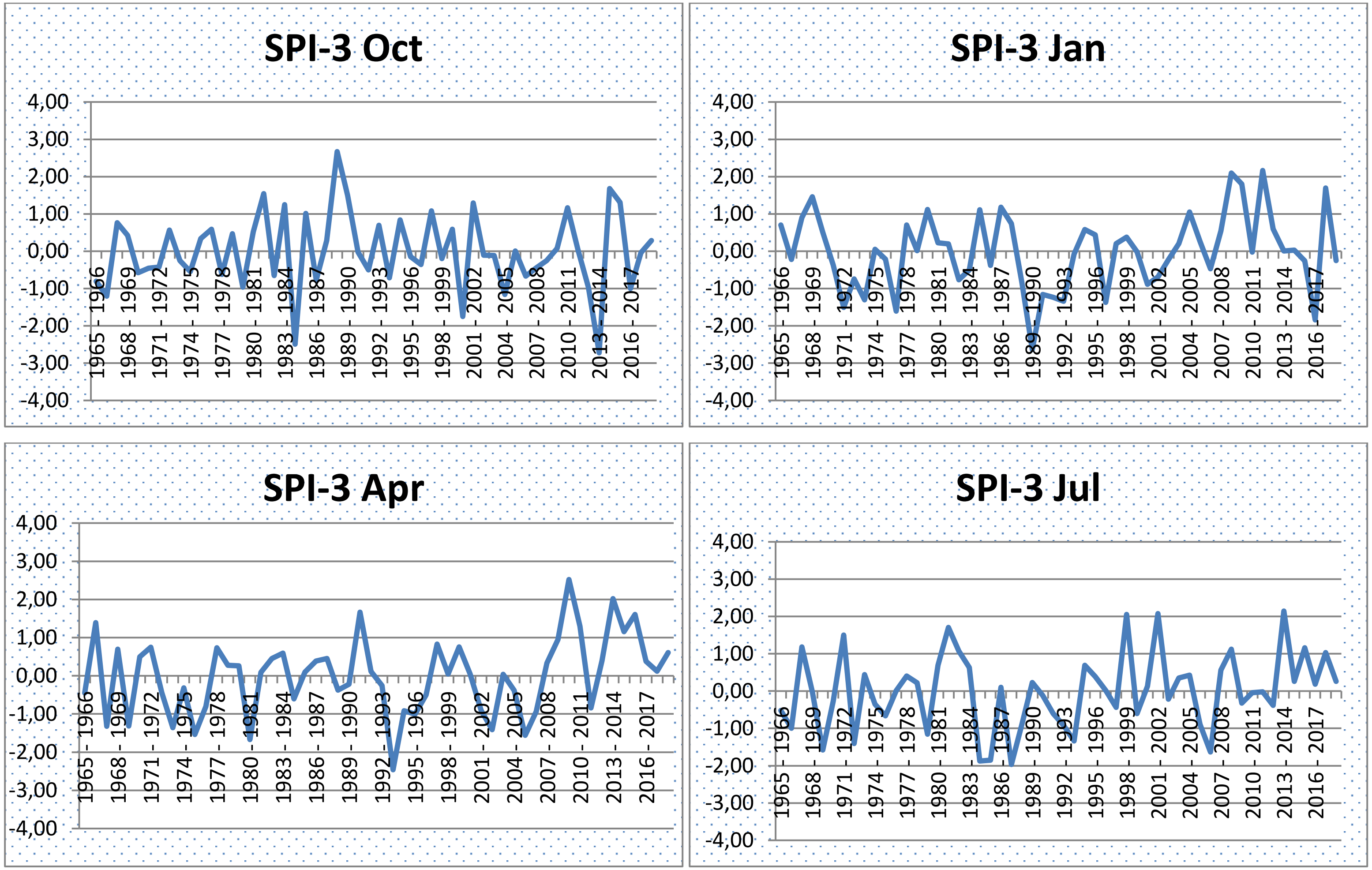


Figure 4.34. Temporal distribution of 3-, 6-, and 12 month SPI values of the Kastamonu Station (No.17074) from 1965 to 2019.

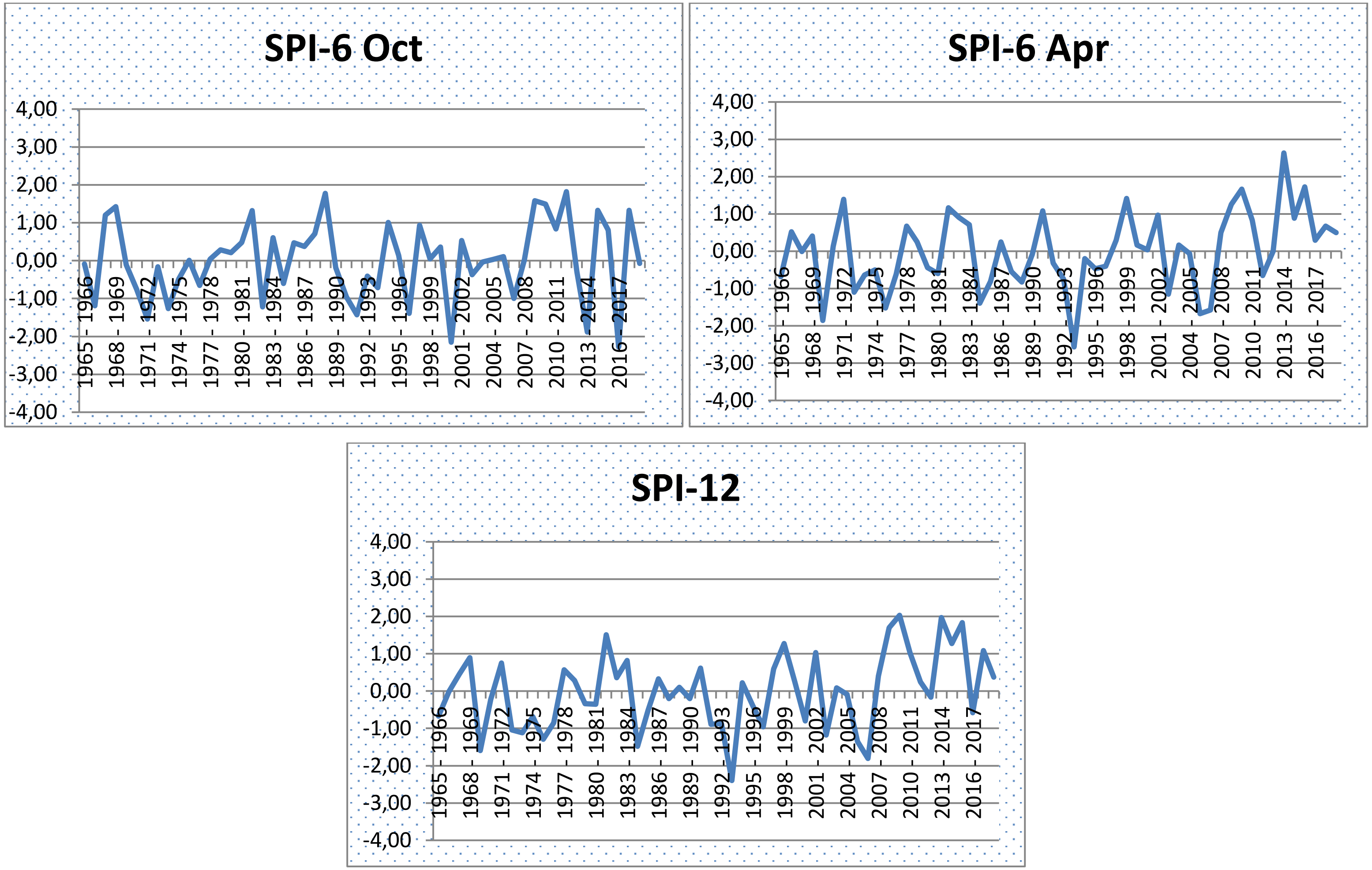


Figure 4.35. (Continued).

4.2.6. Sinop Precipitation Monitoring Station (17026) Meteorological Drought Analysis (SPI)

SPI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation data measured between 1965-2019 of the Sinop Station. The rate of dryness and humidity of monthly is shown in the Figure 4.21 and Table 4.1. The figure hereby shows that the monthly dryness ranged between 41% and 54% according to SPI values. The highest drought ratio was 54% March and the lowest drought ratio was 41% in January and September. The period of drought and moisture for each of 3, 6, and 12 months for the SPI values are shown in Figure 4.22. The driest periods with the highest SPI-3 values are in January and July of 50% and the lowest dry period is in October and April at 46%. The driest periods with the highest SPI-6 values are in April at 56%. SPI-12 calculated according to 12-month values dryness is 44% and moisture is 56%.

According to Figure 4.23 and Table 4.2, when examining 1-month SPI values from 54-year monthly precipitation data at Sinop Station. The highest dry month was in January 1970-1971; the highest month period was in October 1988-1989. Figure 4.24 shows the time distribution of the SPI values for 3, 6 and 12 months to examine the SPI values, the highest dry period was at SPI-3 in October in the year 1982-1983, the highest moist period was at SPI-3 in October in the year 1988-1989. The highest dry period at SPI-6 was in April in the year 2006-2007, and the highest dry period was at SPI-12 in the year 1993-1994, the highest moist period was in the year 1967-1968.

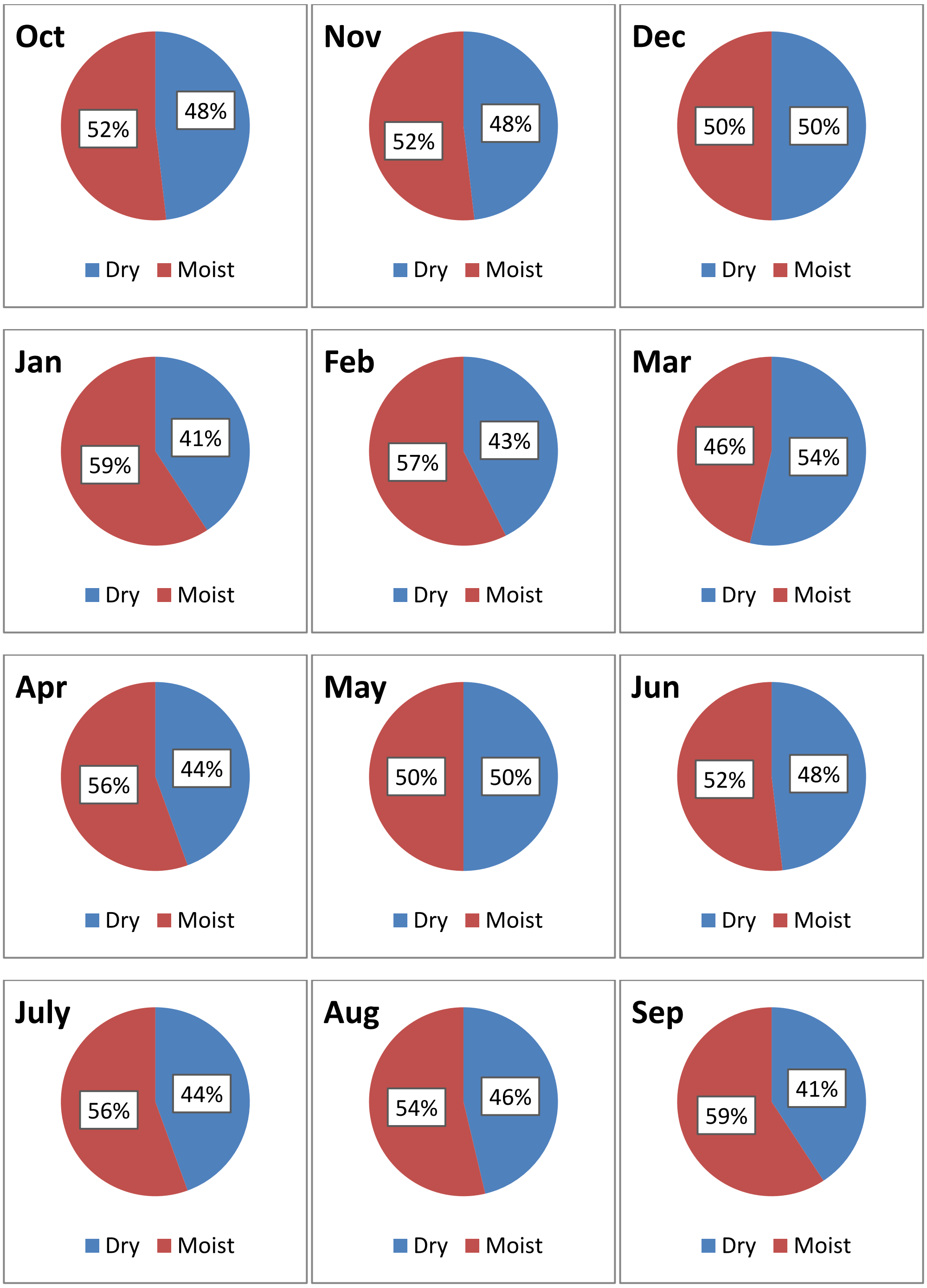


Figure 4.36. Dry - moist period distributions according to the monthly SPI values for the Sinop Station (No. 17026) form 1965 to 2019.

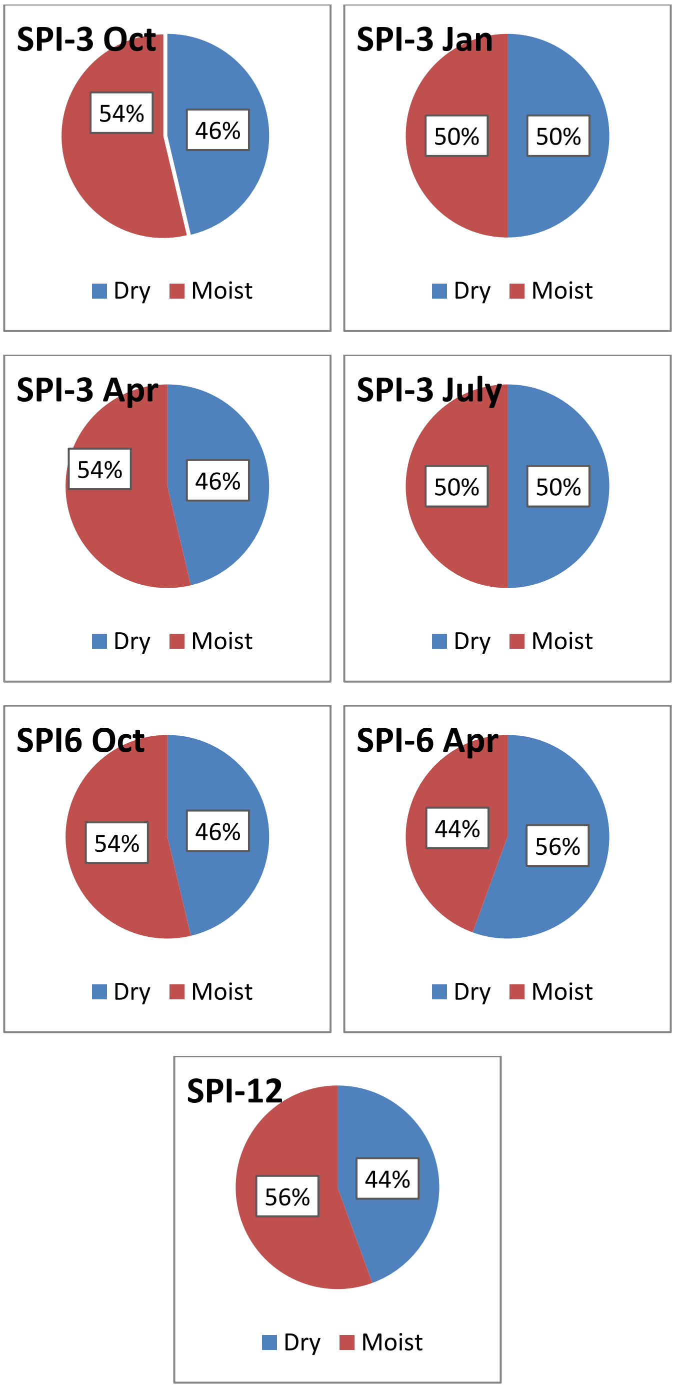


Figure 4.37. Dry - moist period distributions according to the 3,6,12 month SPI values for the Sinop Station (No. 17026) from 1965 to 2019.

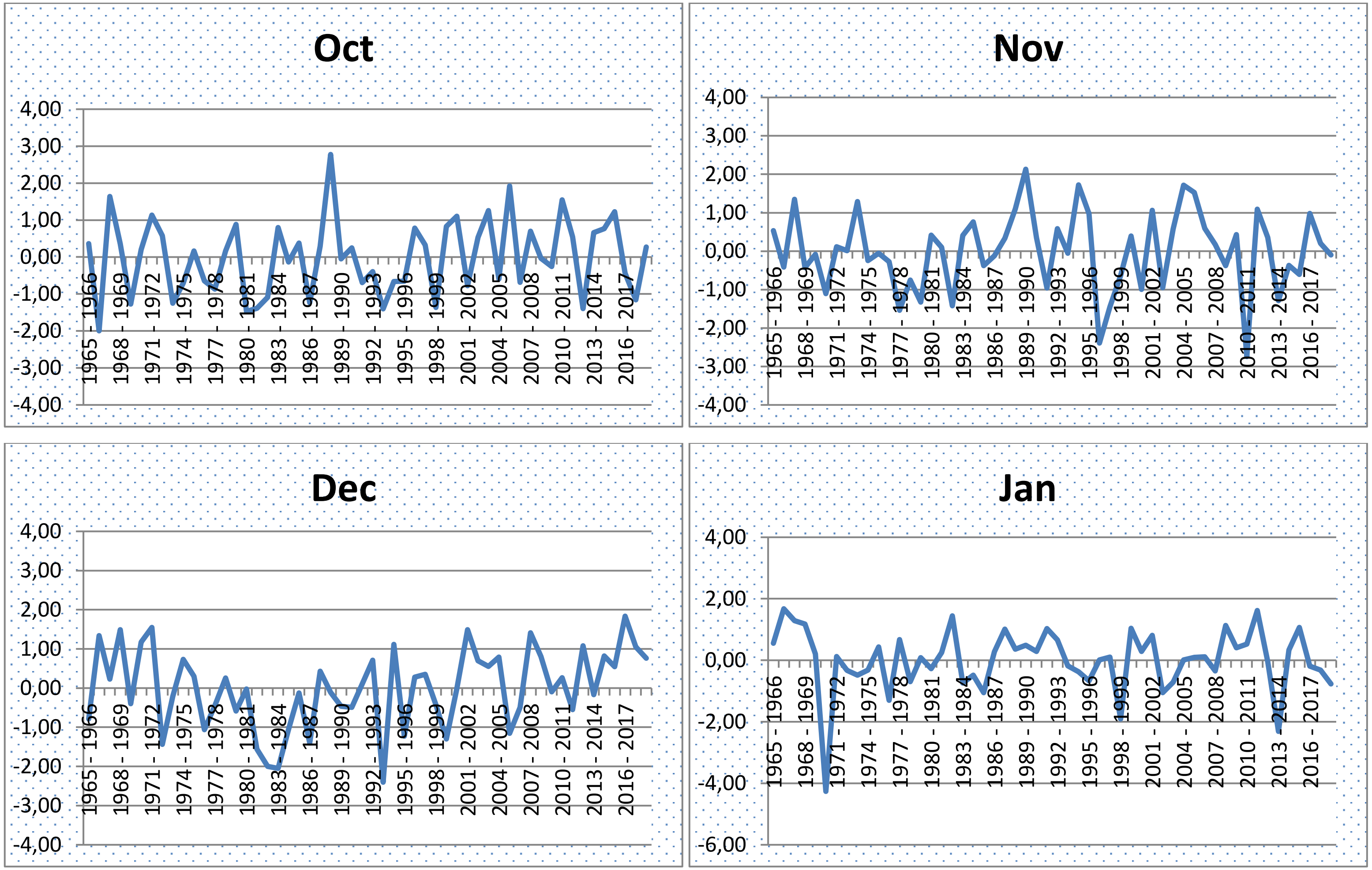


Figure 4.38. Temporal distribution of monthly SPI values of the Sinop Station (No.17026) from 1965 to 2019.

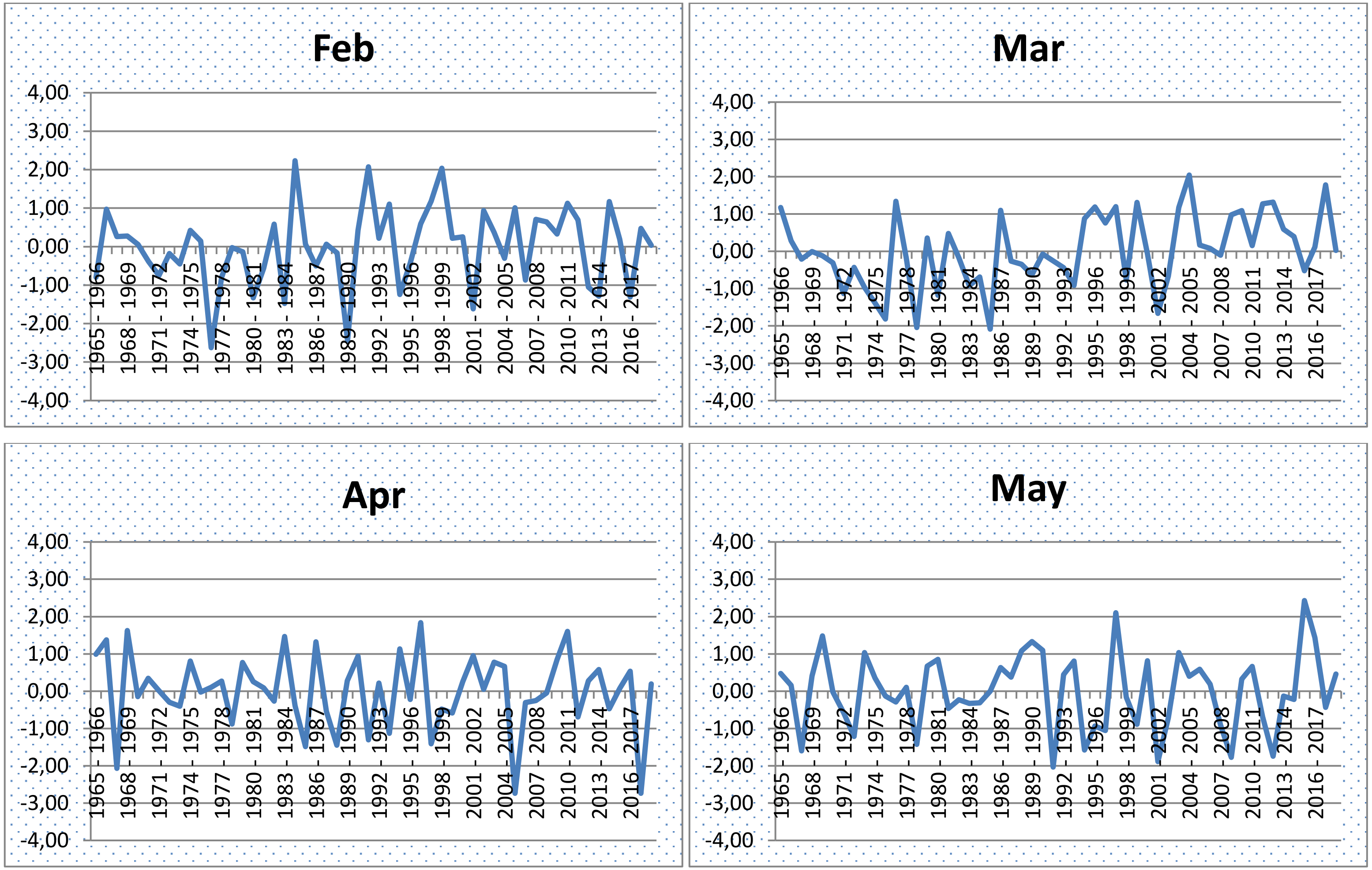


Figure 4.39. (Continued).

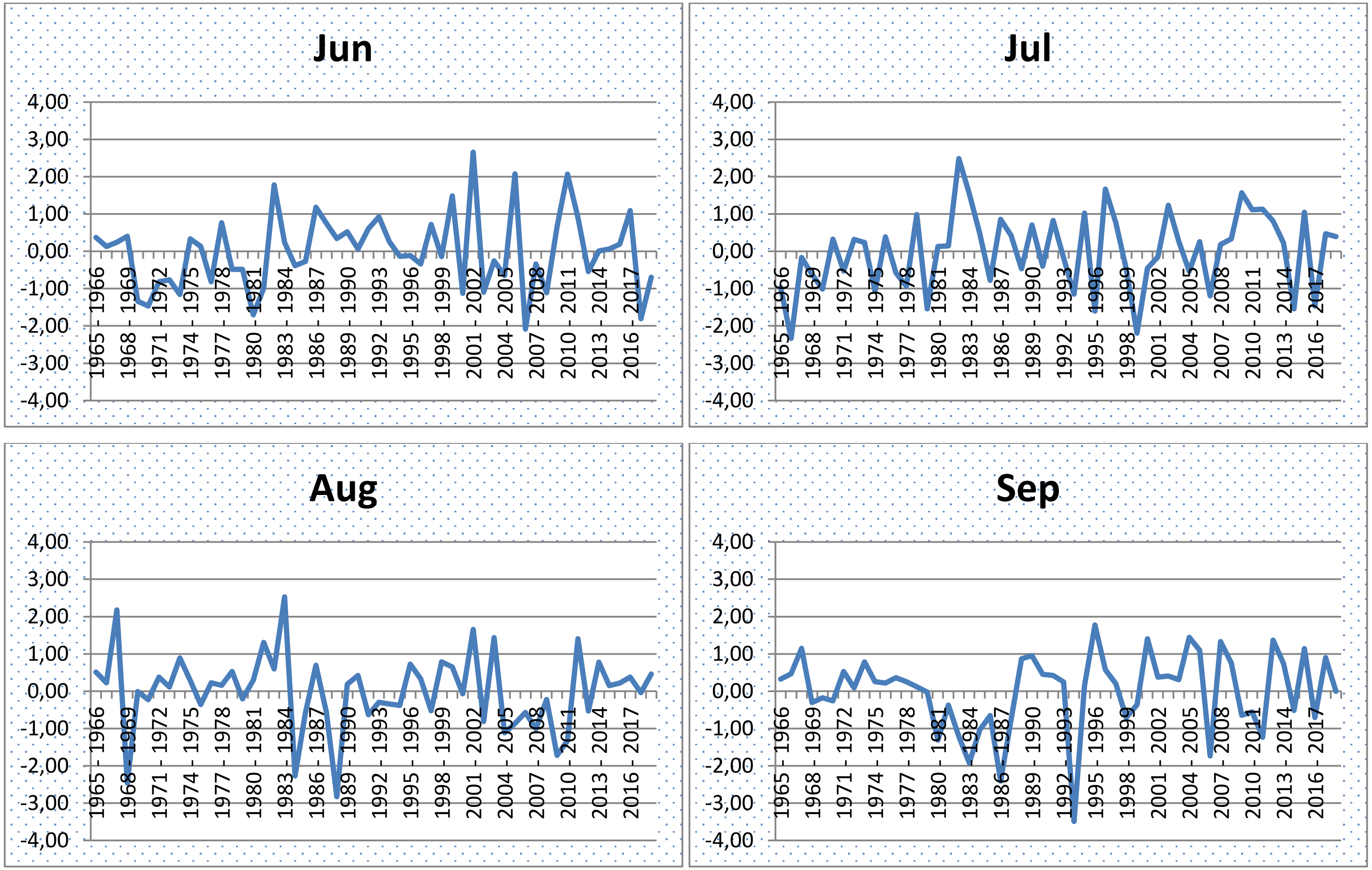


Figure 4.40. (Continued).

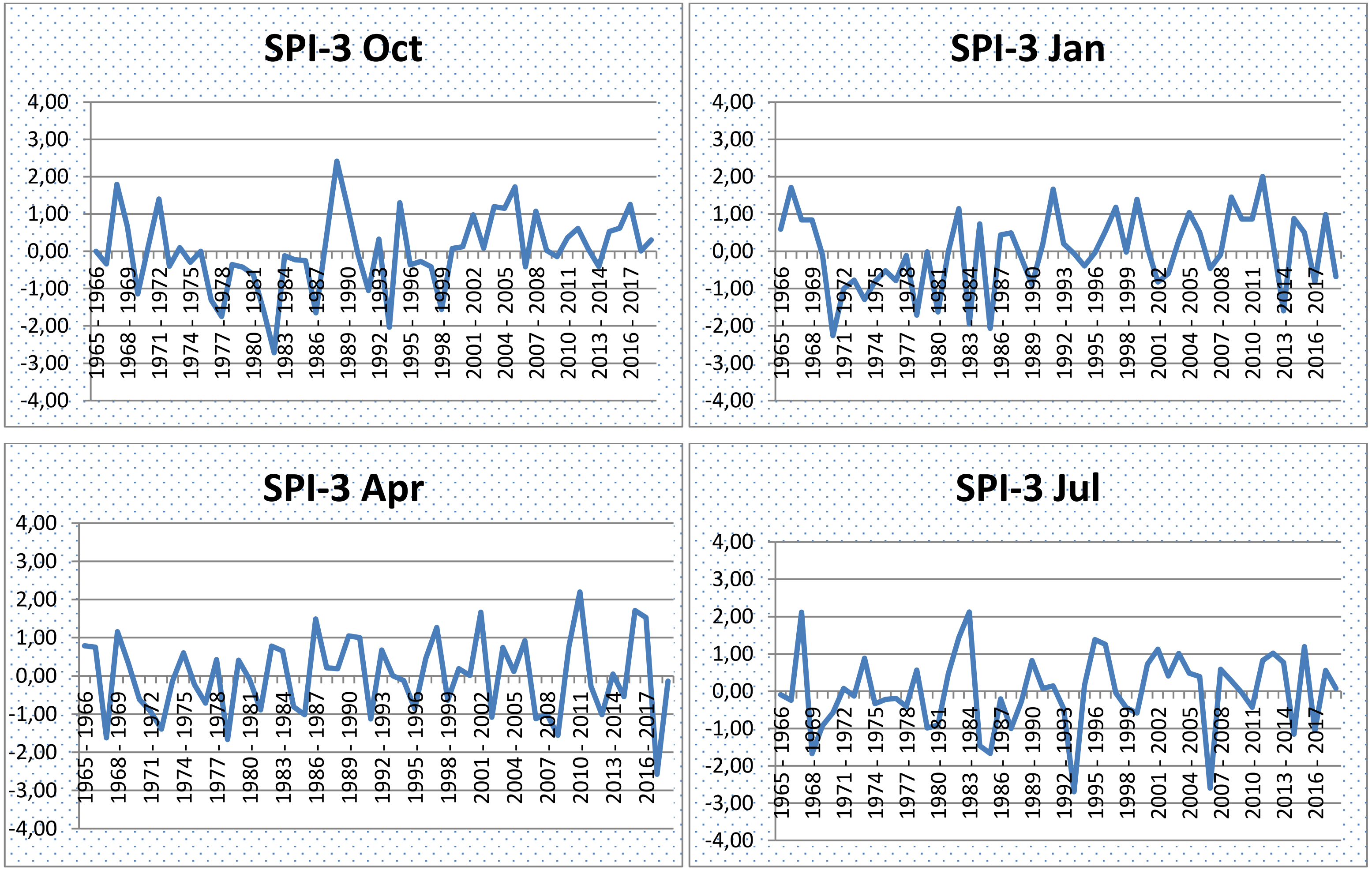


Figure 4.41. Temporal distribution of 3-, 6-, and 12 month SPI values of the Sinop Station (No.17026) from 1965 to 2019.

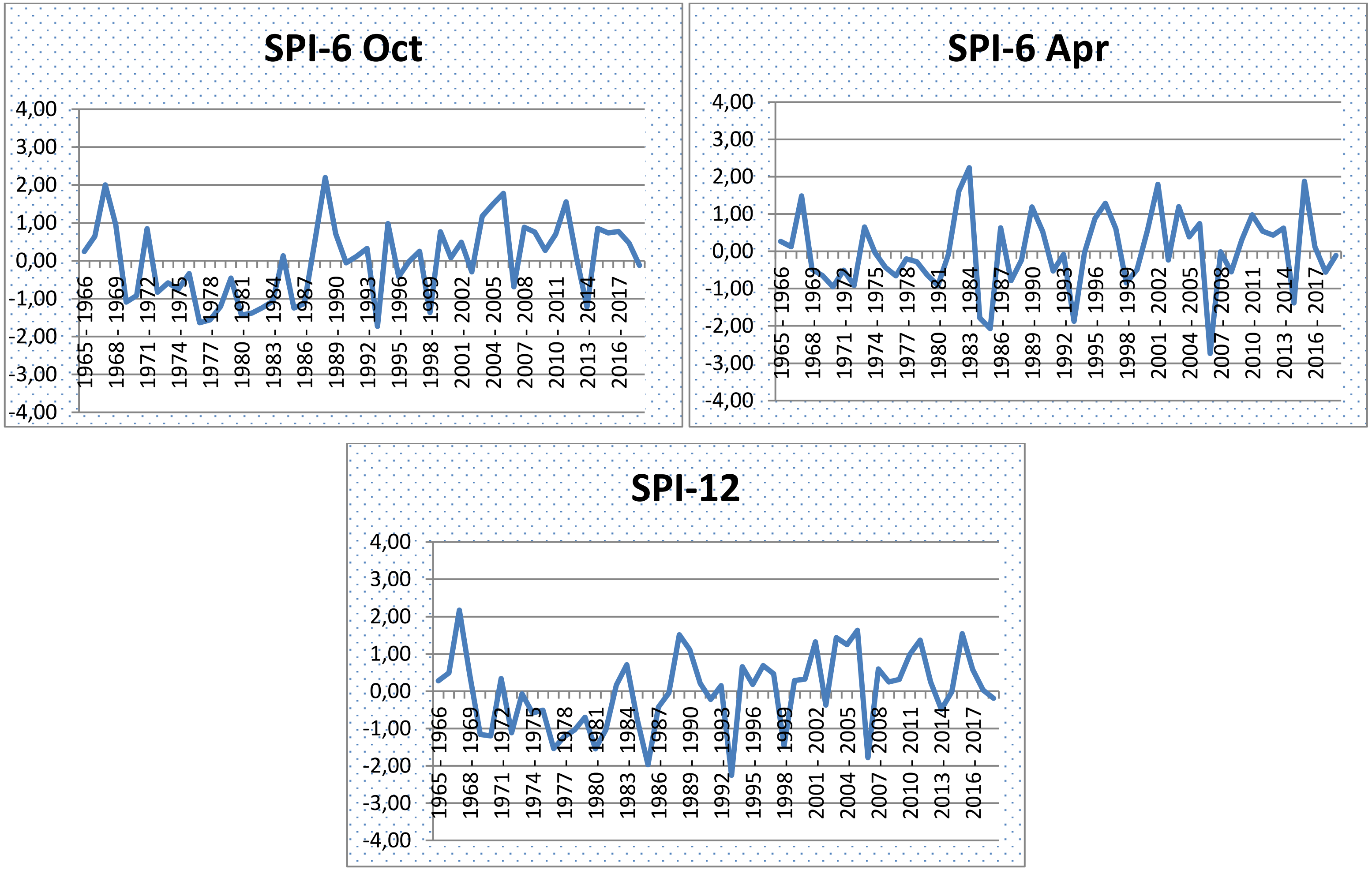


Figure 4.42. (Continued).

4.2.7. Bozkurt Precipitation Monitoring Station (17606) Meteorological Drought Analysis (SPI)

SPI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation data measured between 1965-2019 of the Bozkurt Station. The rate of dryness and humidity of monthly is shown in the Figure 4.25 and Table 4.1. The figure hereby shows that the monthly dryness ranged between 41% and 57% according to SPI values. The highest drought ratio was 57% August and the lowest drought ratio was in 41% January, April and Jun. The period of drought and moisture for each of 3, 6, and 12 months for the SPI values are shown in Figure 4.26. The driest periods with the highest SPI-3 values are in October and July of 48% and the lowest dry period is January at 43%. The driest periods with the highest SPI-6 values are in October at 52%. SPI-12 calculated according to 12-month values dryness is 50% and moisture is 50%.

According to Figure 4.27 and Table 4.2, when examining 1-month SPI values from 54-year monthly precipitation data at Bozkurt Station. The highest dry month was in March 2016-2017; the highest moist month was February 1984-1985. Figure 4.28 shows the time distribution of the SPI values for 3, 6 and 12 months to examine the SPI values, the highest dry period was at SPI-3 in January in the year 2016-2017, the highest moist period was at SPI-3 in April in the year 2003-2004. The highest dry period at SPI-6 was in January in the year 2017-2018, and the highest dry period was at SPI-12 in the year 2017-2018 and the highest moist period was in the year 1999-2000 .

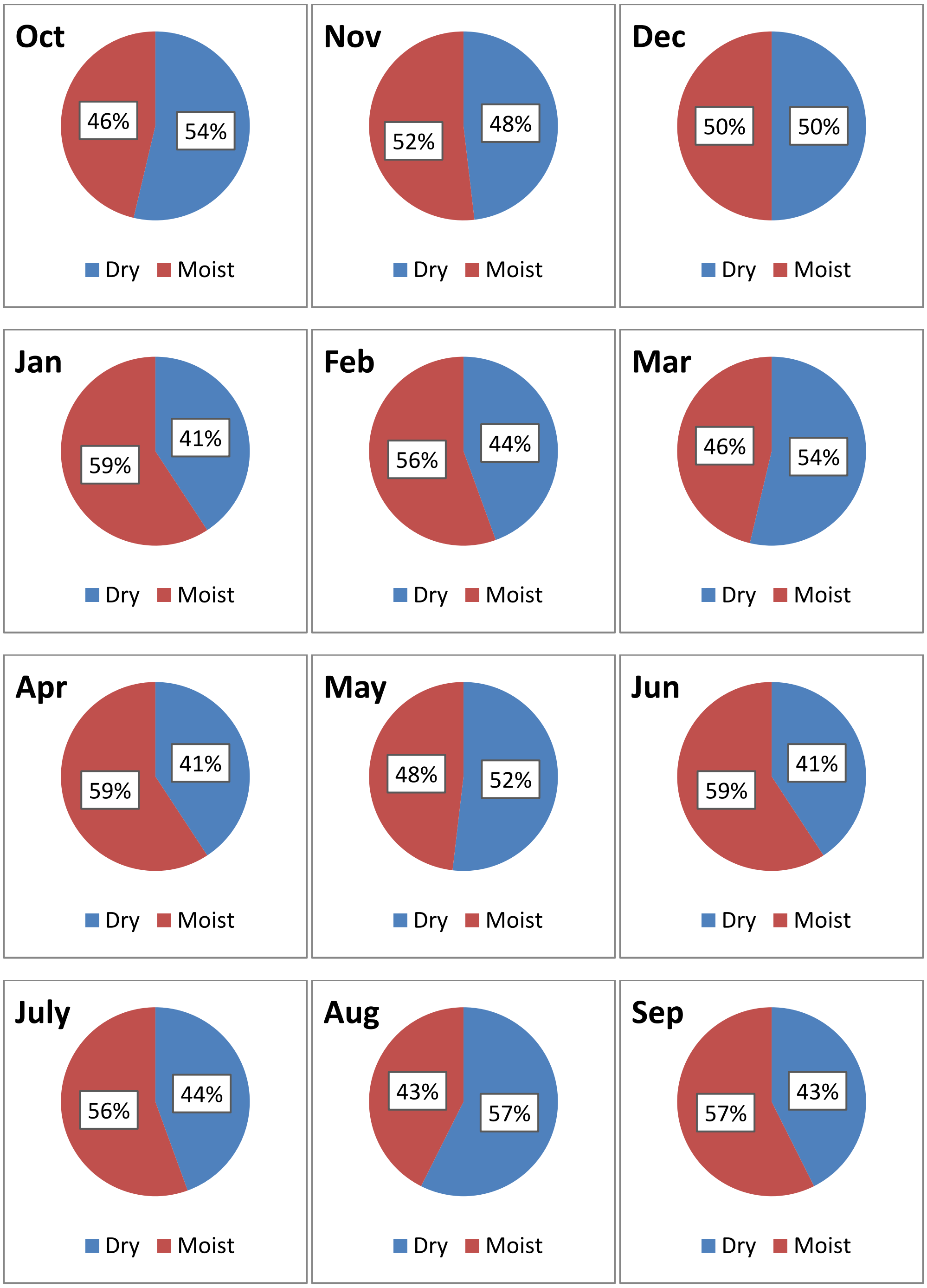
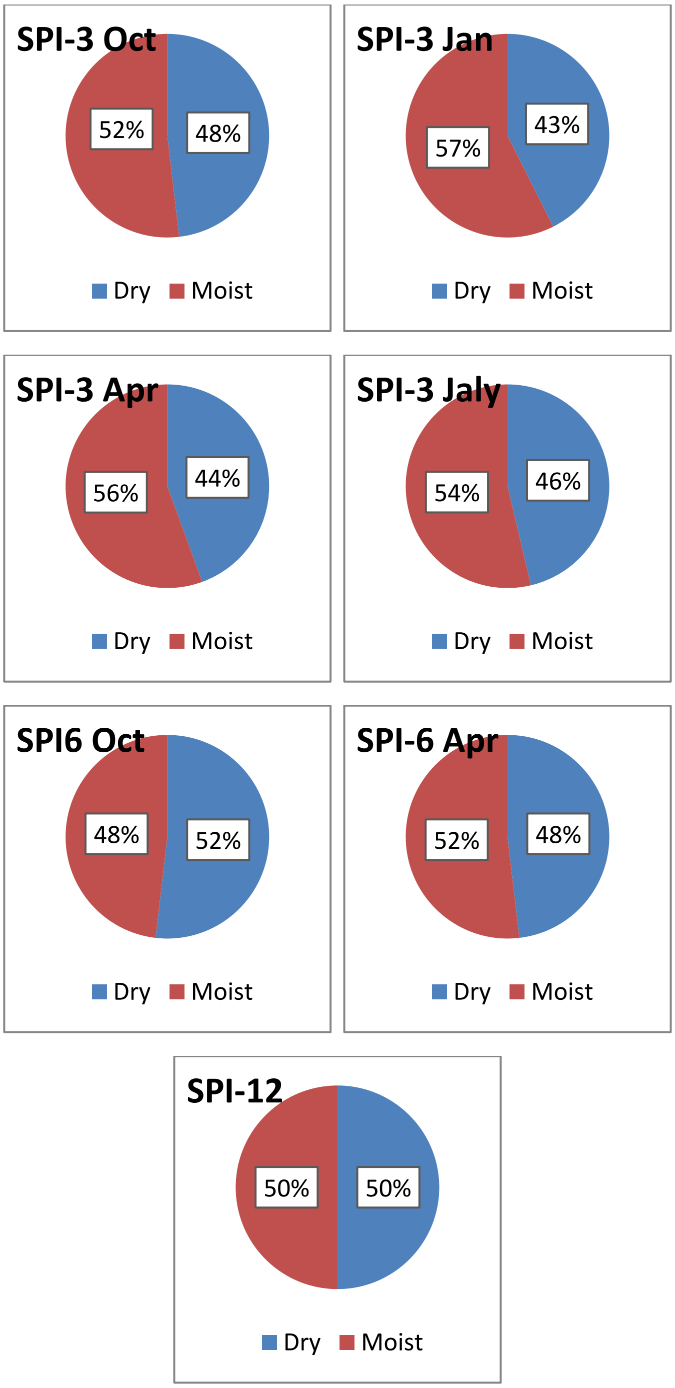


Figure 4.43. Dry - moist period distributions according to the monthly SPI values for the Bozkurt Station (No. 17606) from 1965 to 2019.



SPI-3 Oct

SPI-3 Jan

SPI-3 Apr

SPI-3 Jaly

SPI6 Oct

SPI-6 Apr

SPI-12

Figure 4.44. Dry - moist period distributions according to the 3,6,12month SPI values for the Bozkurt Station (No. 17606) from 1965 to 2019.

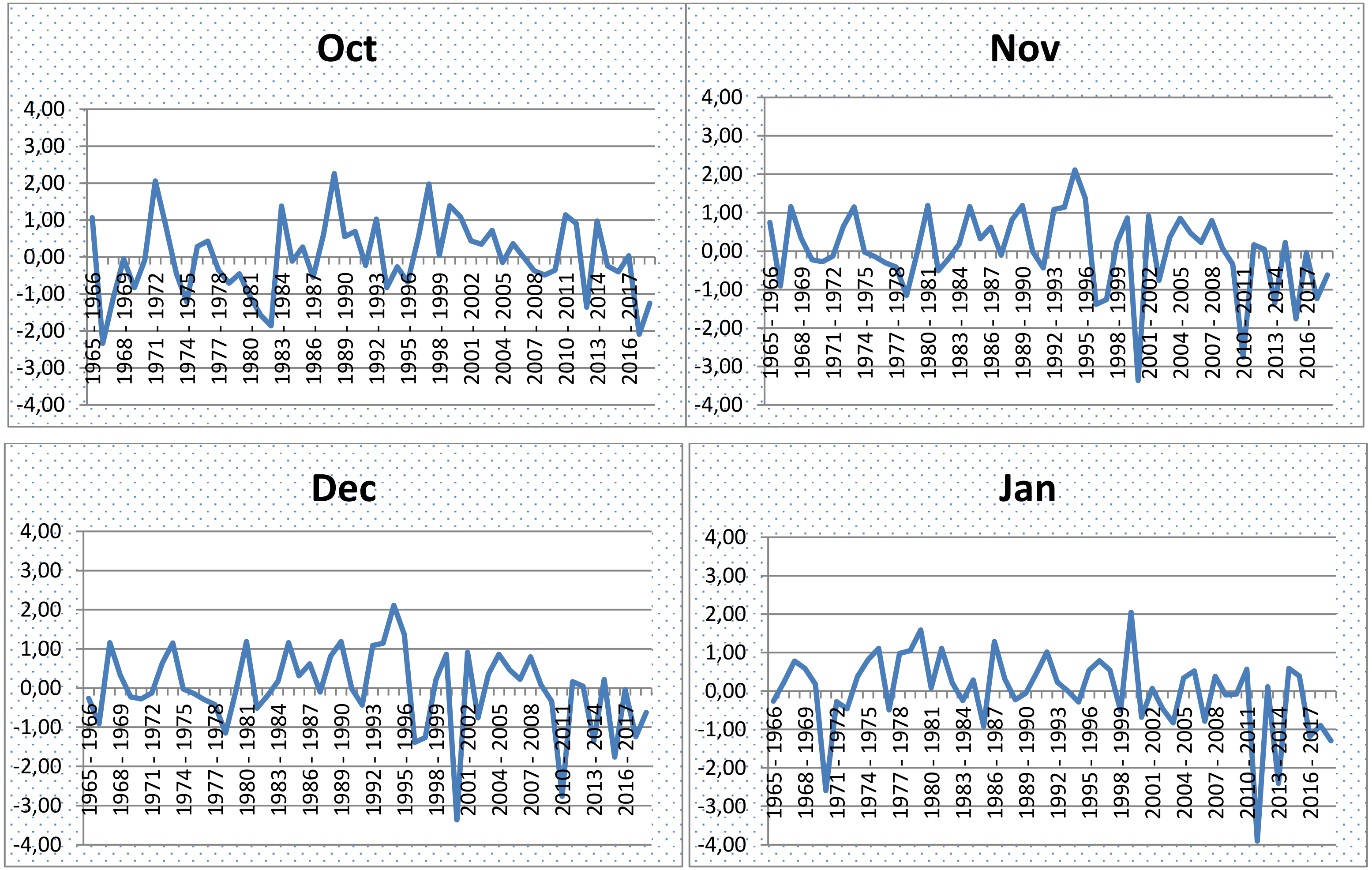


Figure 4.45. Temporal distribution of monthly SPI values of the Bozkurt Station (No.17606) from 1965 to 2019.

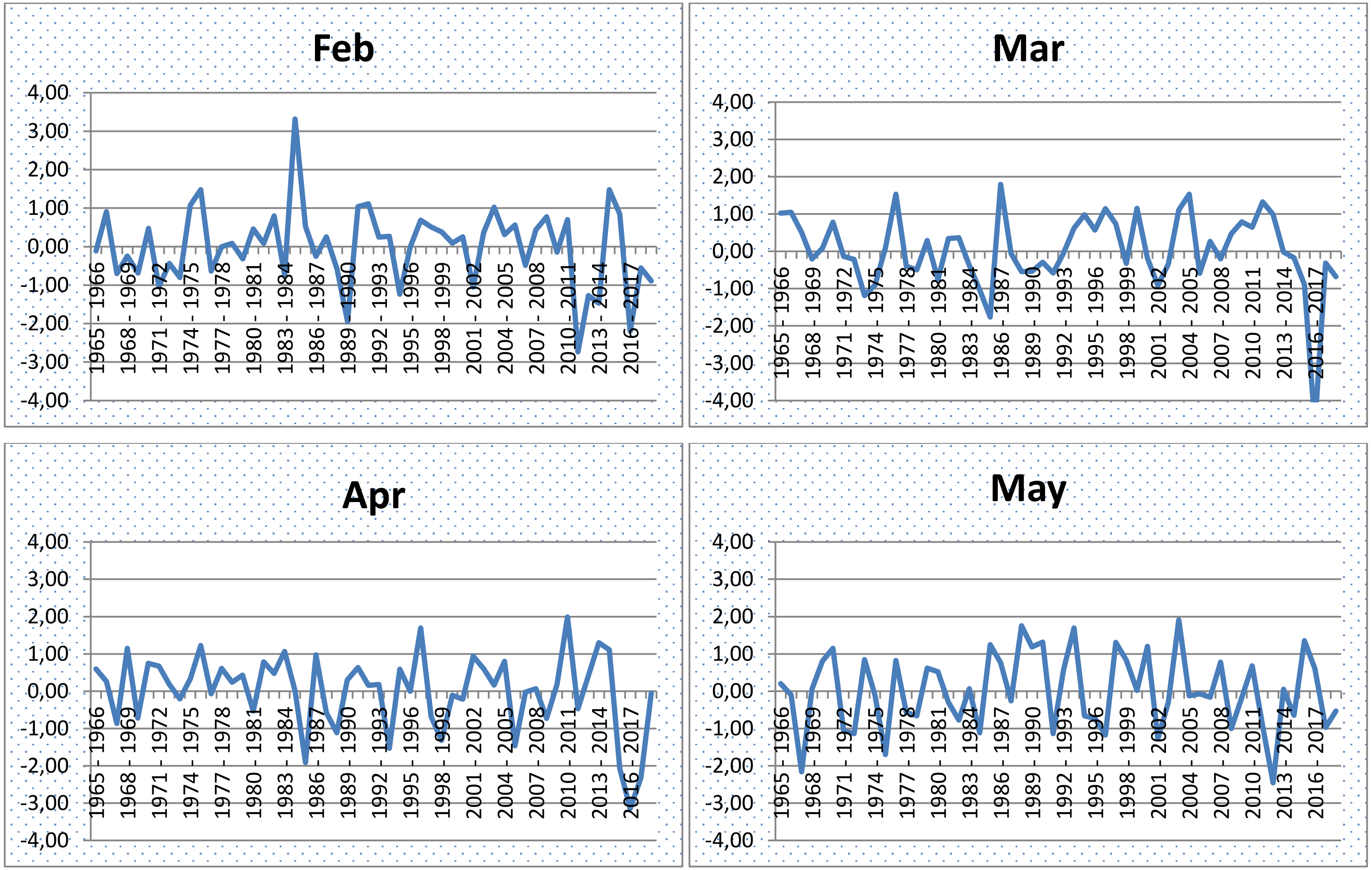


Figure 4.46. Contunied.

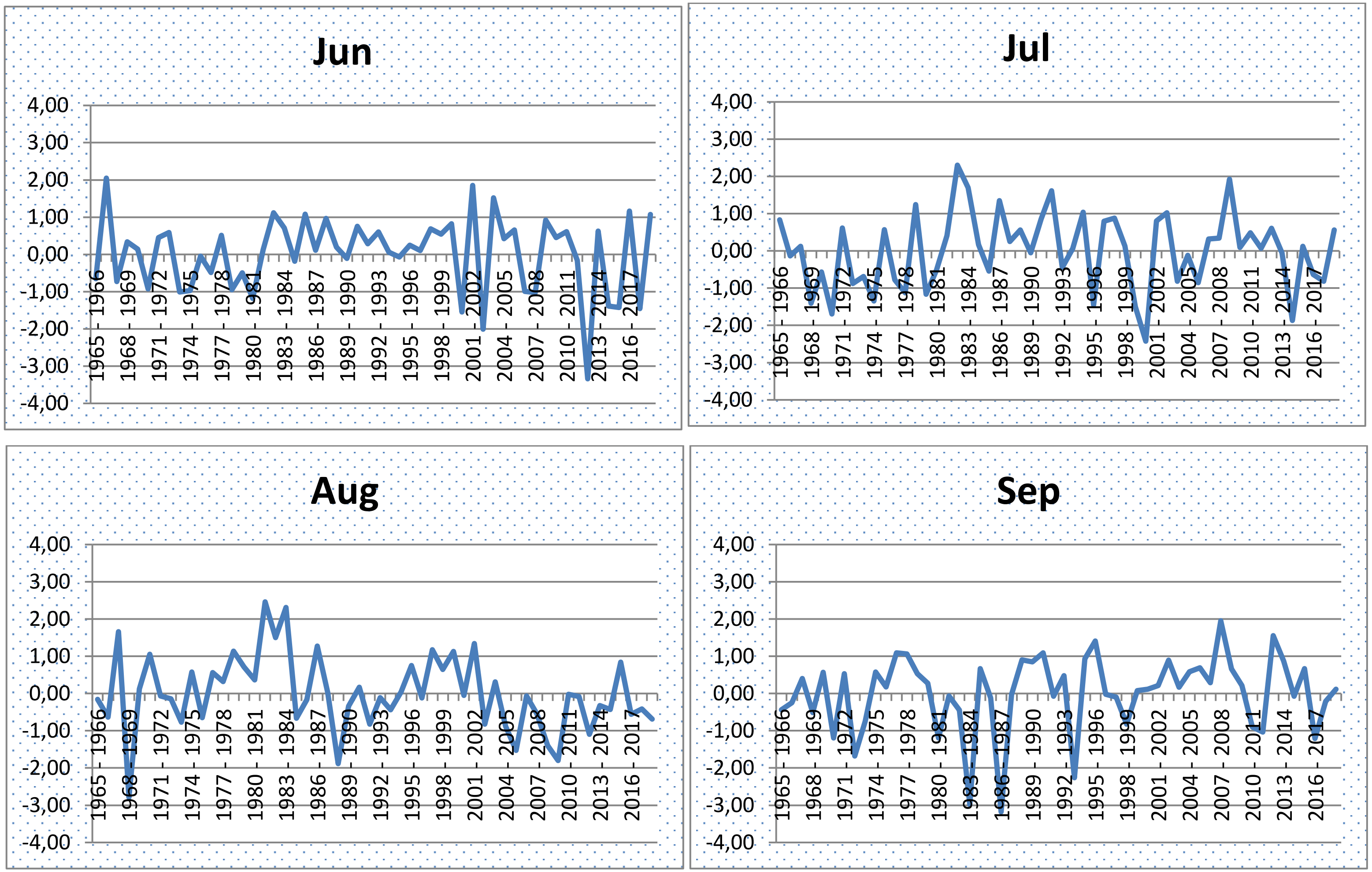


Figure 4.47. (Continued).

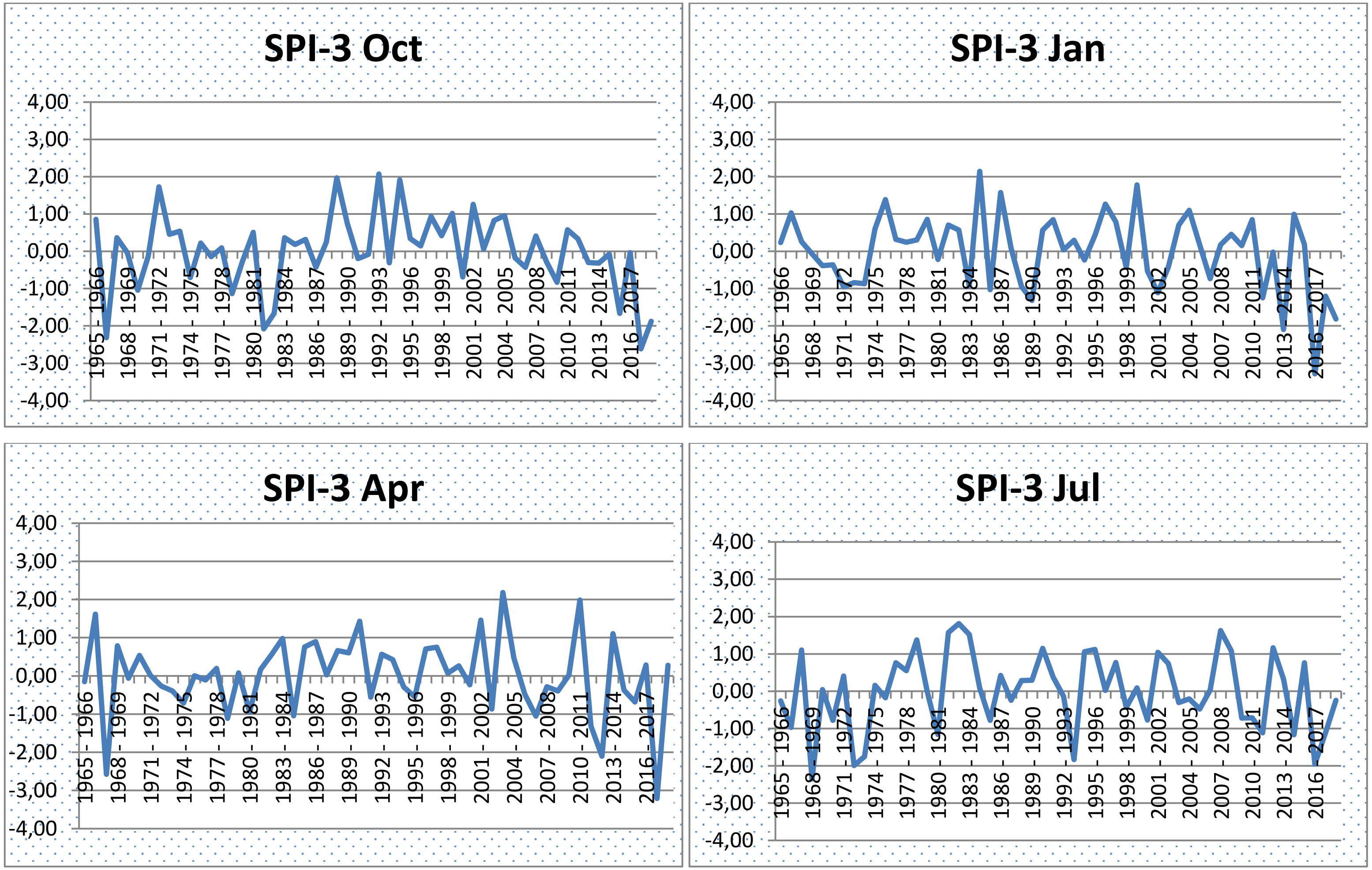


Figure 4.48. Temporal distribution of 3-, 6-, and 12 month SPI values of the Bozkurt Station (No.17606) from 1965 to 2019.

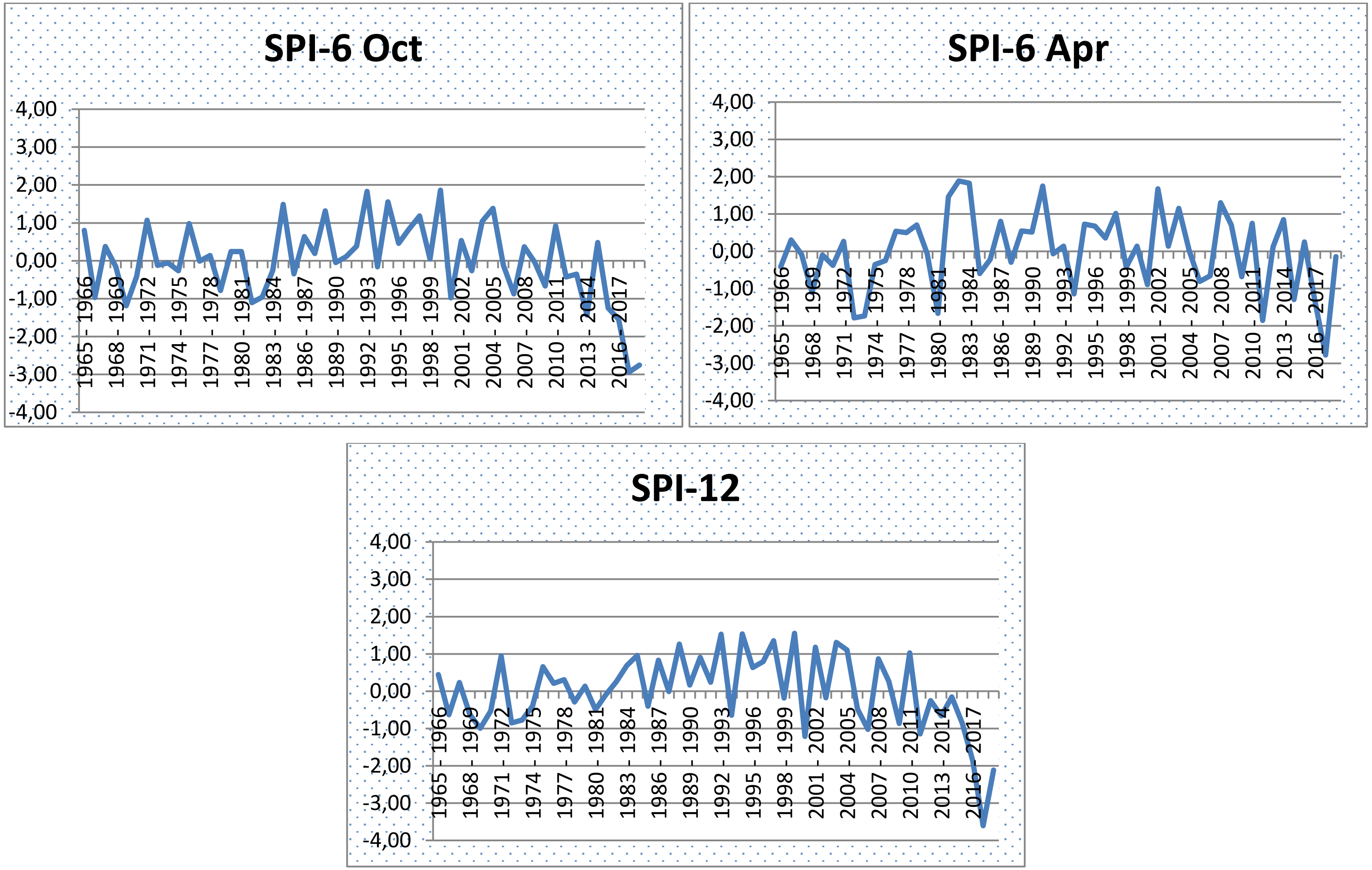


Figure 4.49. (Continued).

4.2.8. Ulus Precipitation Monitoring Station (17615) Meteorological Drought Analysis (SPI)

SPI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation data measured between 1965-2019 of the Ulus Station. The rate of dryness and humidity of monthly is shown in the Figure 4.29 and Table 4.1. The figure hereby shows that the monthly dryness ranged between 43% and 56% according to SPI values. The highest drought ratio was 56% in February and May and the lowest drought ratio was 43% in October. The period of drought and moisture for each of 3, 6 and 12 months for the SPI values are shown in Figure 4.30. The driest periods with the highest SPI-3 values are in October with 56% and the lowest dry period is in January with 46%. The driest periods with the highest SPI-6 values are in April with 59%. SPI-12 calculated according to 12-month values dryness is 46% and moisture is 54%.

According to Figure 4.31 and Table 4.2, when examining 1-month SPI values from 54-year monthly precipitation data at Ulus Station. The highest dry month was in April 2005-2006; the highest moist months were January 1967-1968, and May (1997-1998). Figure 4.32 shows the time distribution of the SPI values for 3, 6 and 12 months to examine the SPI values, the highest dry period was at SPI-3 in October in the year 2011-2012, the highest moist period was at SPI-3 in Apr in the year 1990-1991. The highest dry period at SPI-6 was in April 2006-2007, and the highest dry period was at SPI-12 in the year 2006-2007, the highest moist period was in the year 1967-1968.

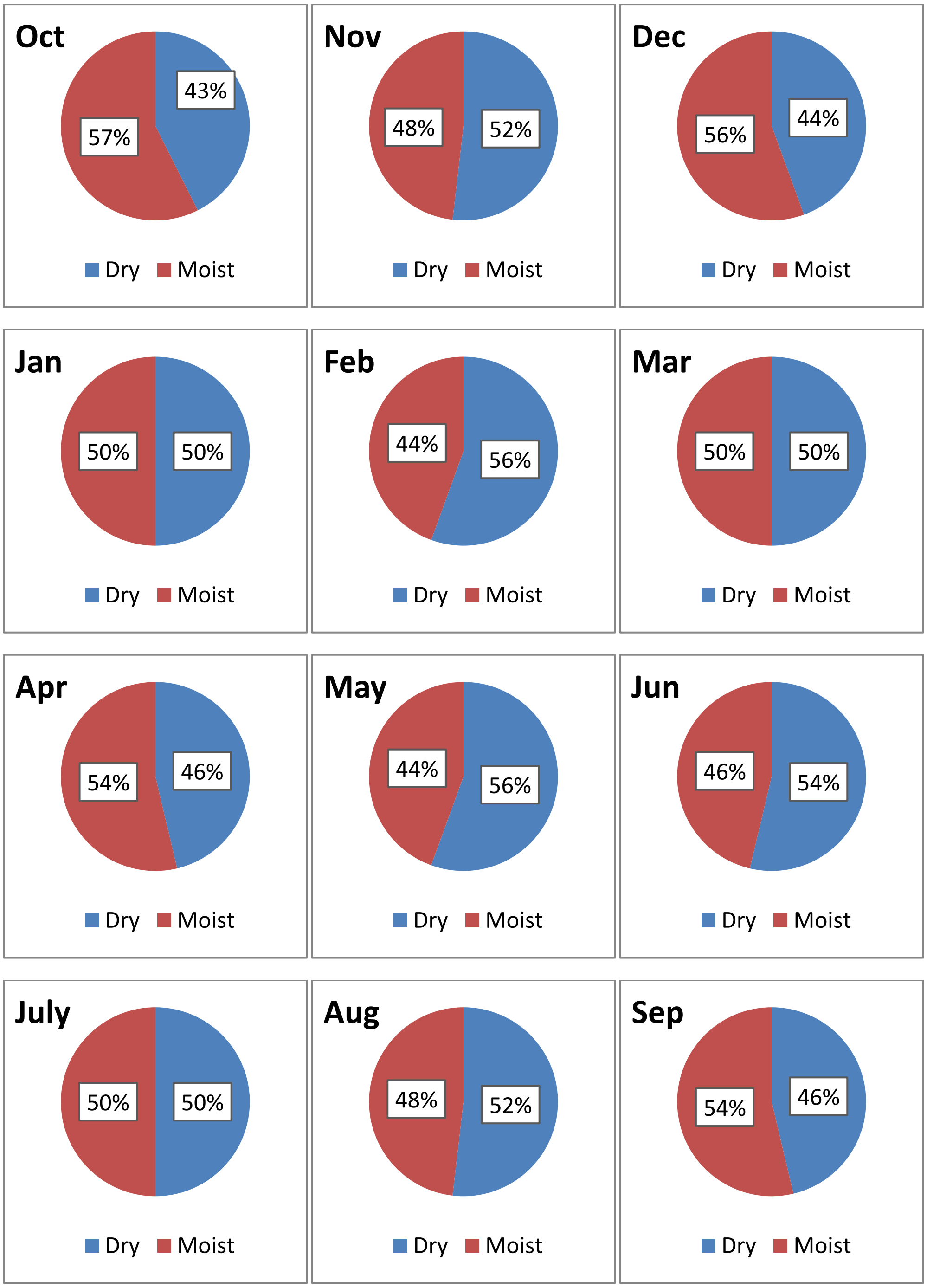


Figure 4.50. Dry - moist period distributions according to the monthly SPI values for the Ulus Station (No. 17615) from 1965 to 2019.

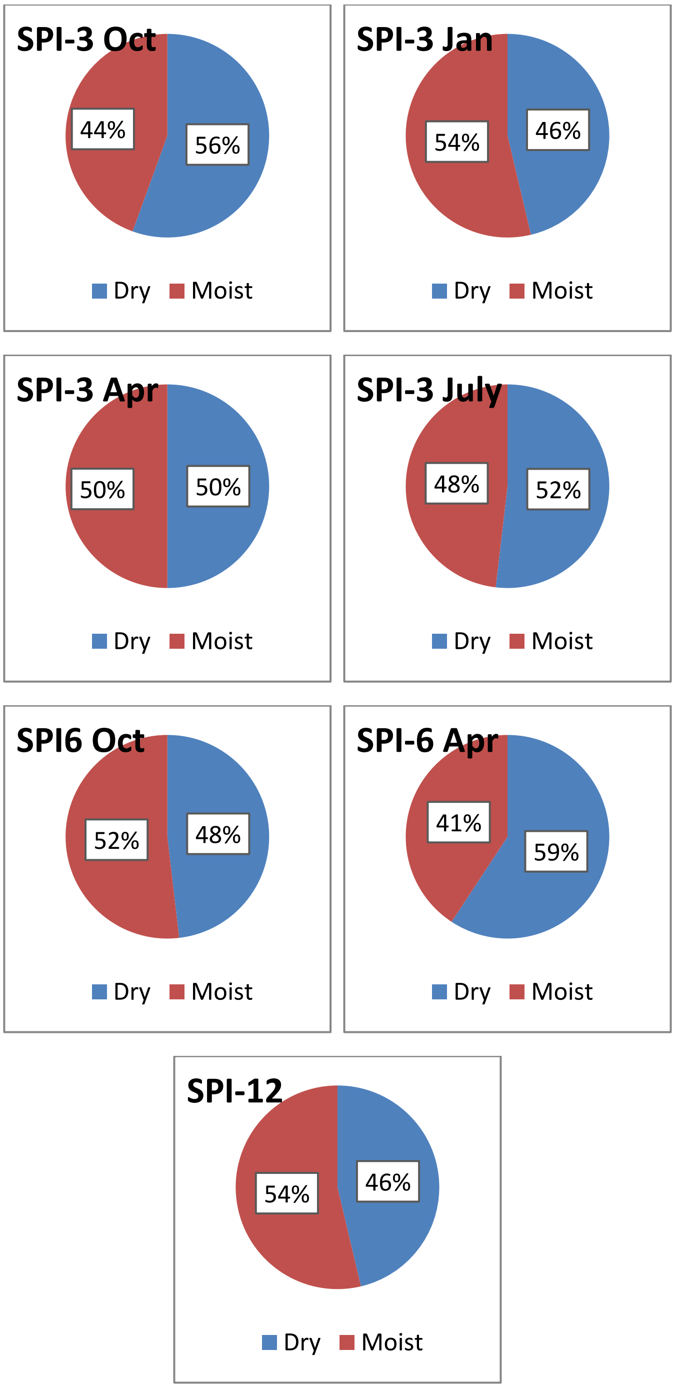


Figure 4.51. Dry - moist period distributions according to the 3,6,12 month SPI values for the Ulus Station (No. 17615) from 1965 to 2019.

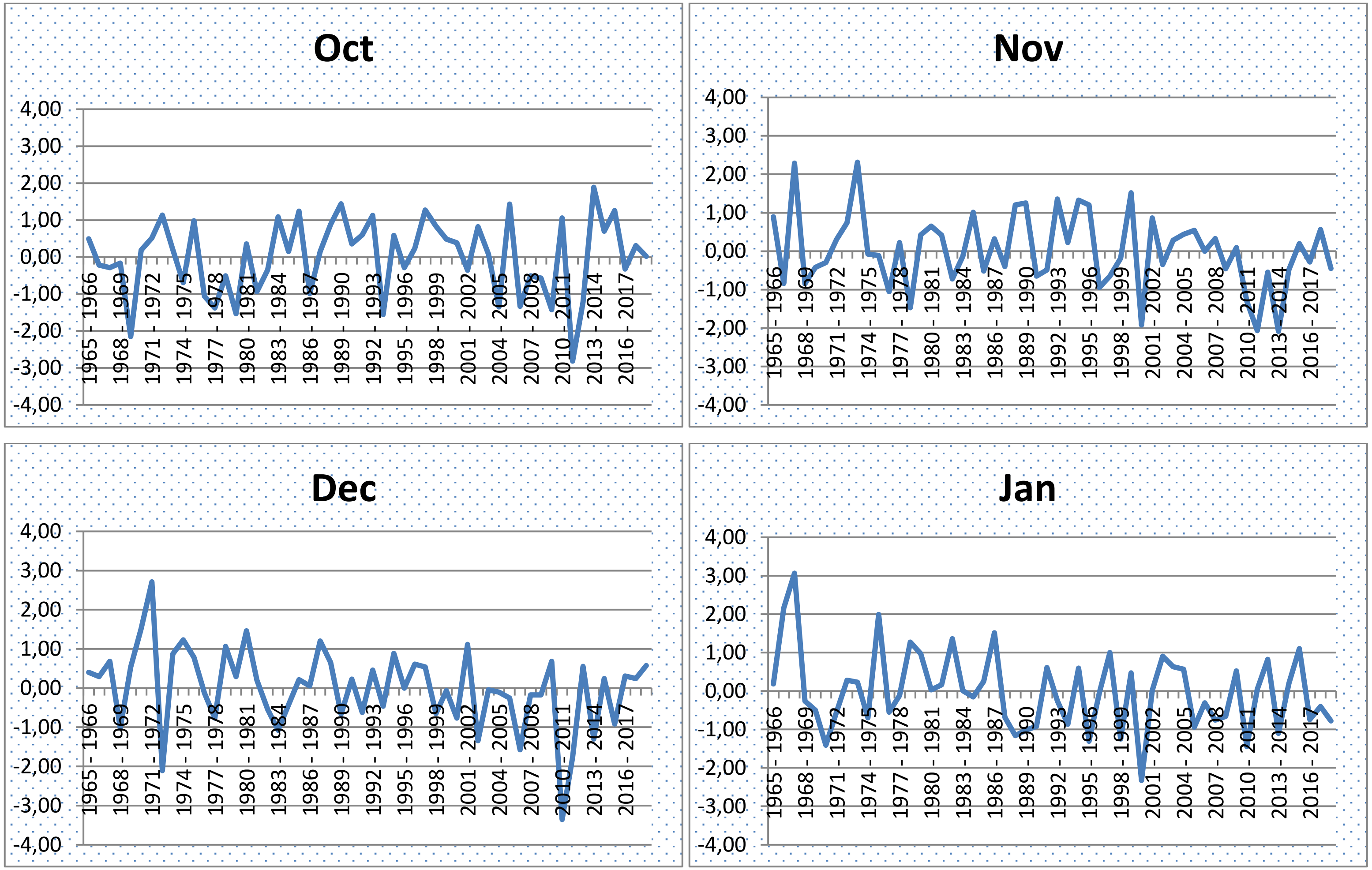


Figure 4.52. Temporal distribution of monthly SPI values of the Ulus Sation (No.17615) from 1965 to 2019.

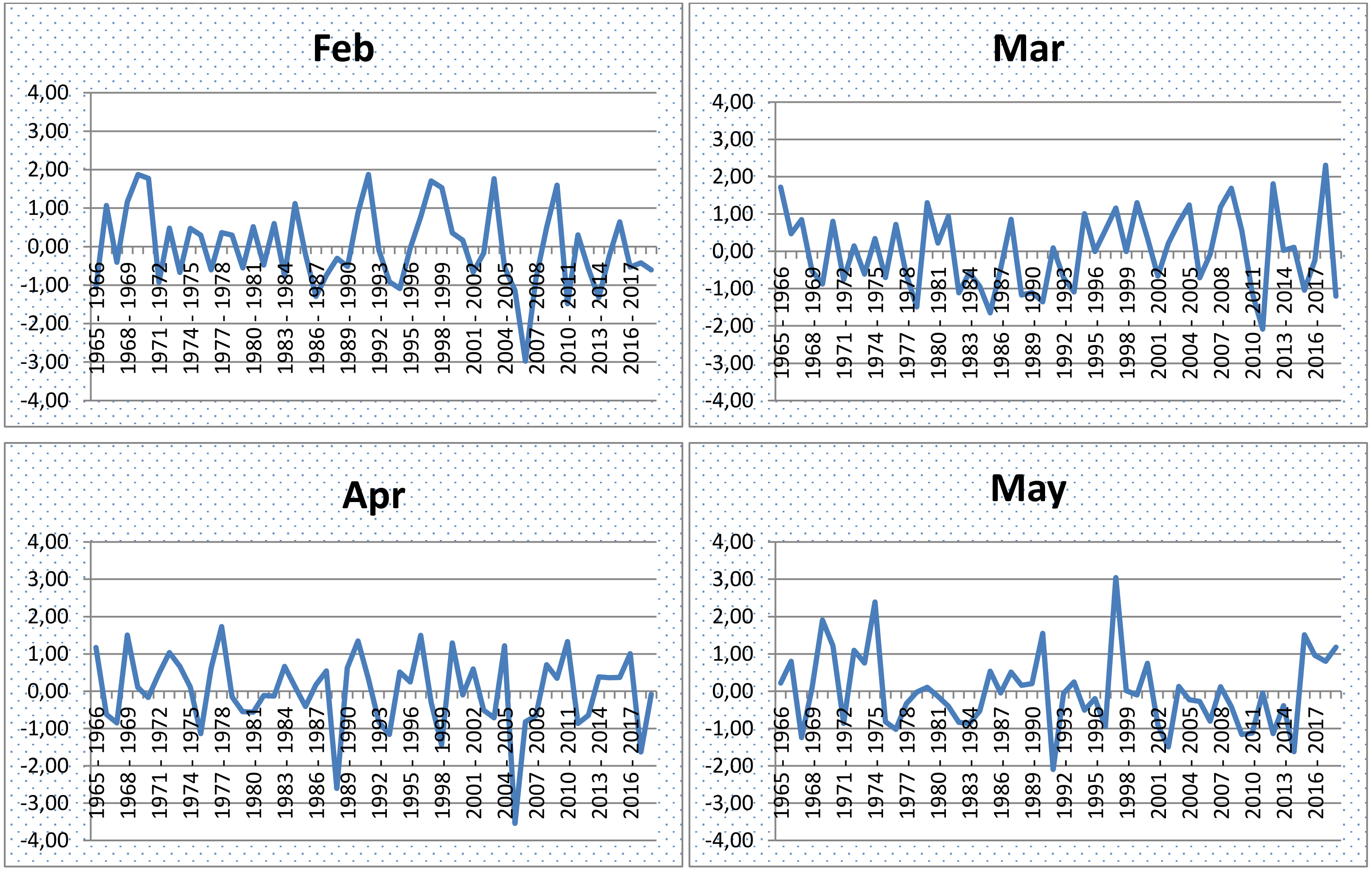
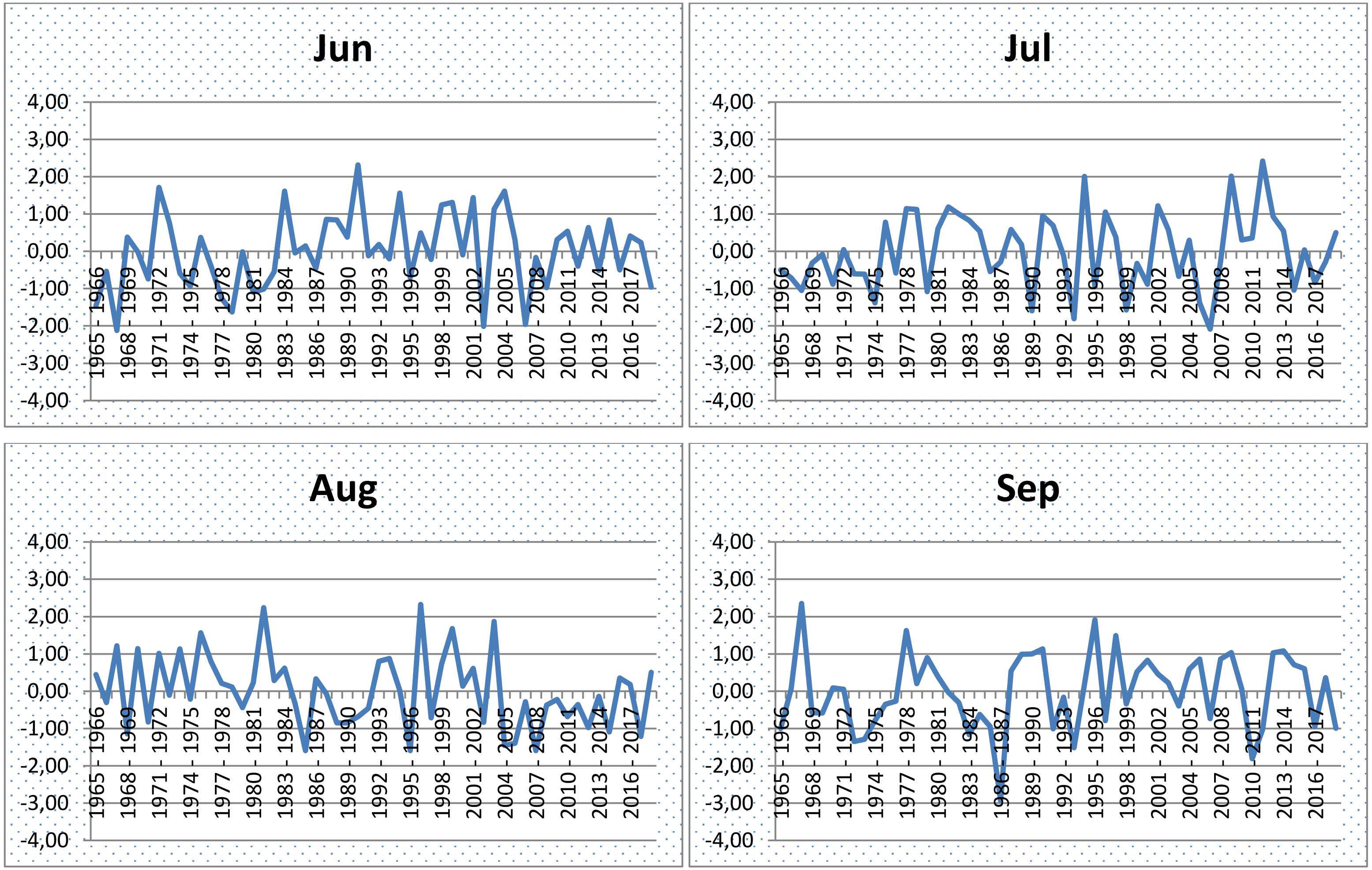


Figure 4.53. (Continued).



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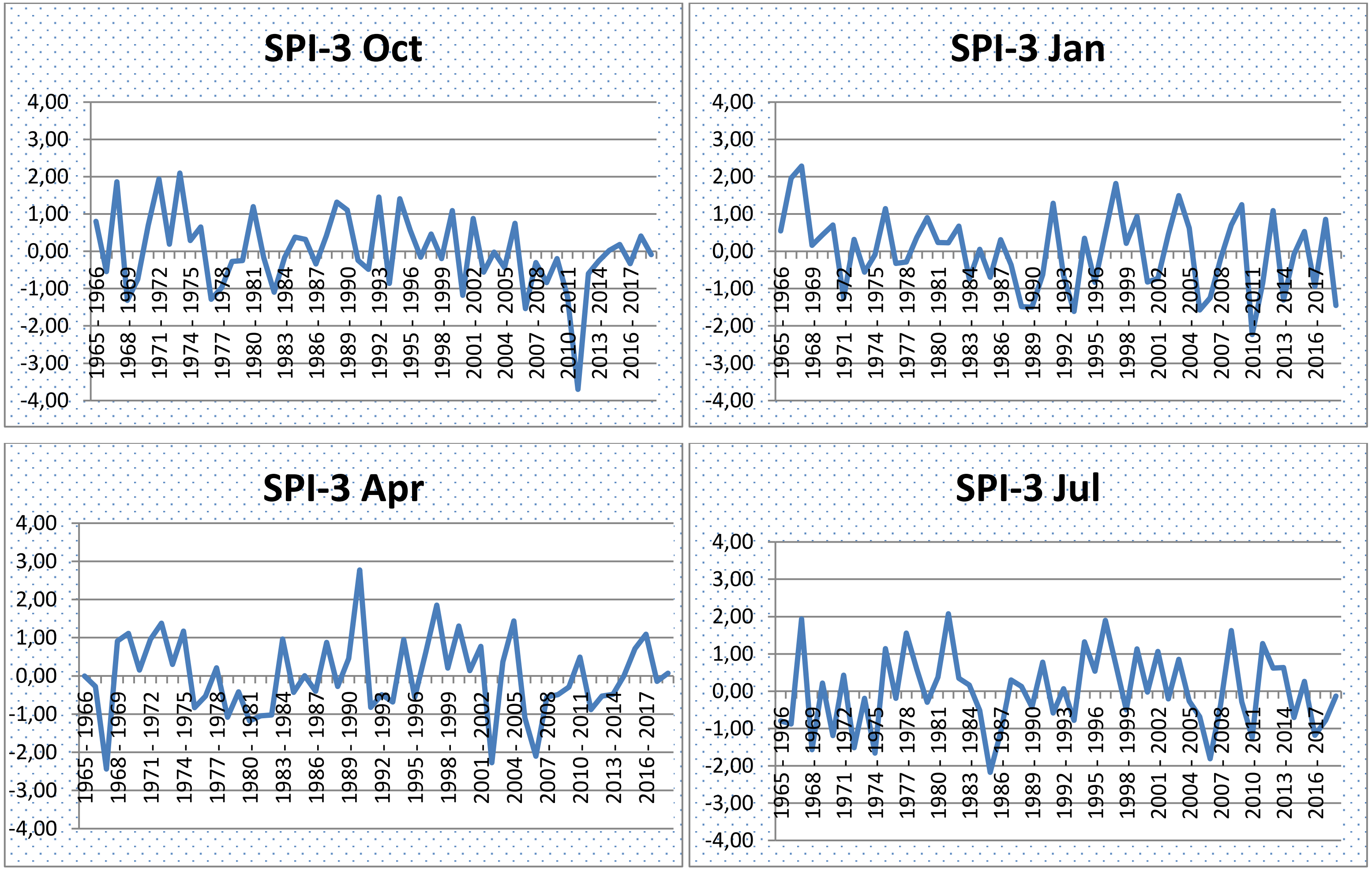

Figure 4.55. Temporal distribution of 3-, 6-, and 12 month SPI values of the Ulus station (No.17615) from 1965 to 2019.

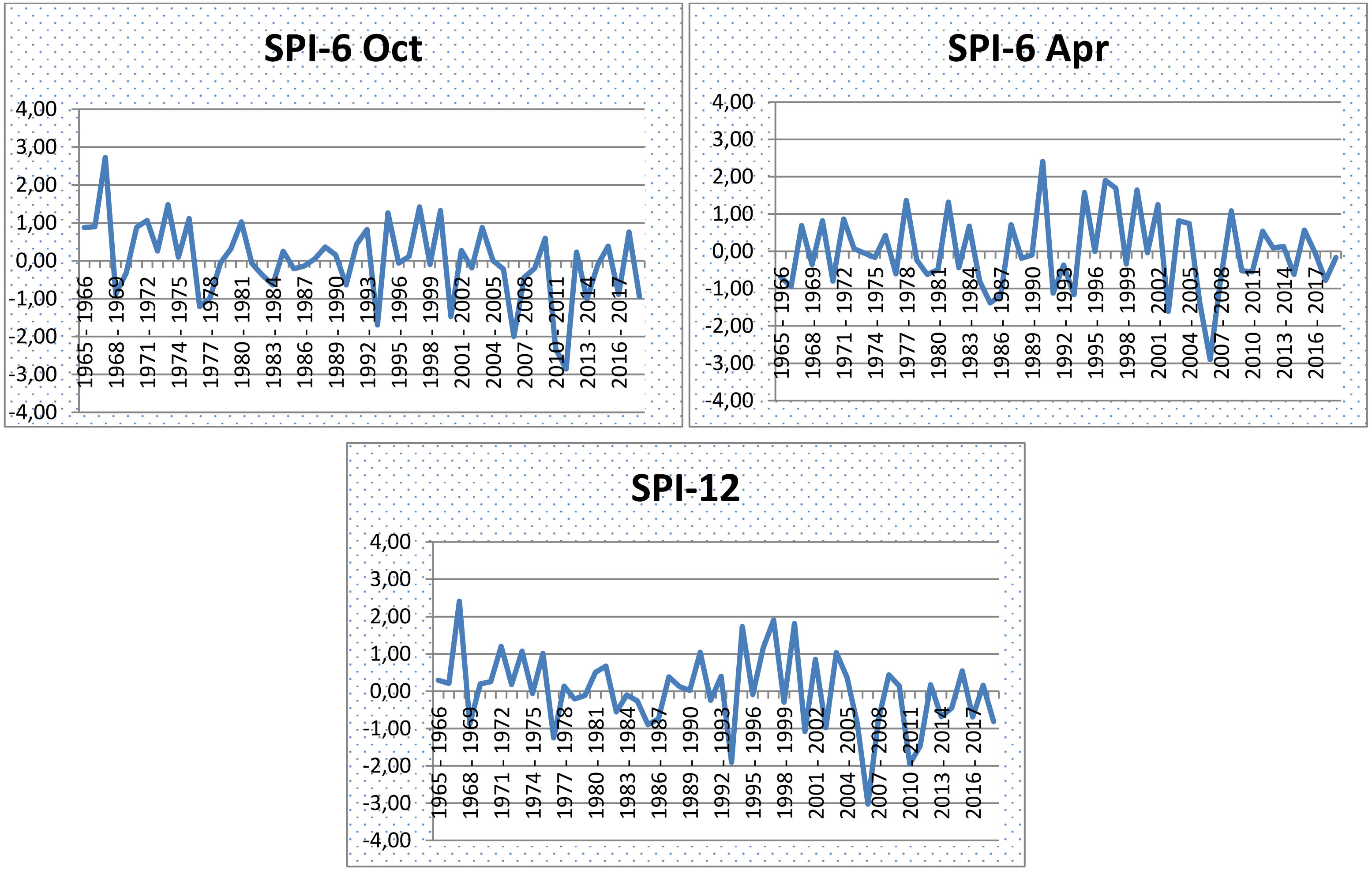

Figure 4.56. (Continued).

4.2.9. Amasra Precipitation Monitoring Station (17602) Meterological / Agricultural Drought Analysis (RDI).

RDI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation and monthly mean temperature data measured between 1965-2019 of the Amasra Station. According to Figure 4.33 and Table 4.3, the highest dry month was at May in 2013-2014 period, and the highest moist month was at February in 1984-1985 period.

According to Figure 4.34 showing time distributions of RDI values for 3, 6 and 12 months, the highest dry period was at RDI-3 in April in the year 2011-2012, and the highest moist period was at RDI-3 in Jan in the year 1973-1974, The highest dry period at RDI-6 was in October 1976-1977. The highest dry period was RDI-6 in October in the year 1976-1977, and the highest dry period was at RDI-12 in the year 1993-1994, the highest moist period was in the year 1967-1968.

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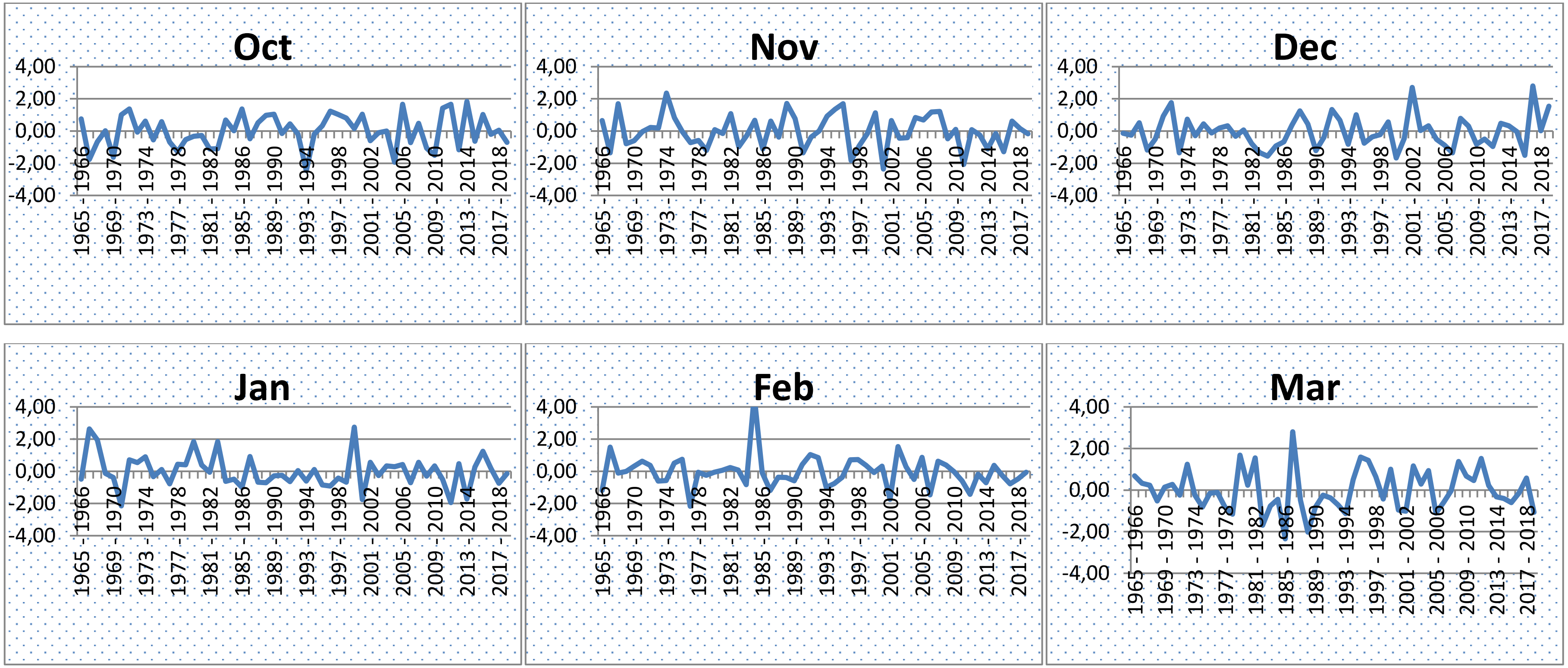

Figure 4.57. Dry - moist period distributions according to the monthly RDI values for the Amasra Station from 1965 to 2019.

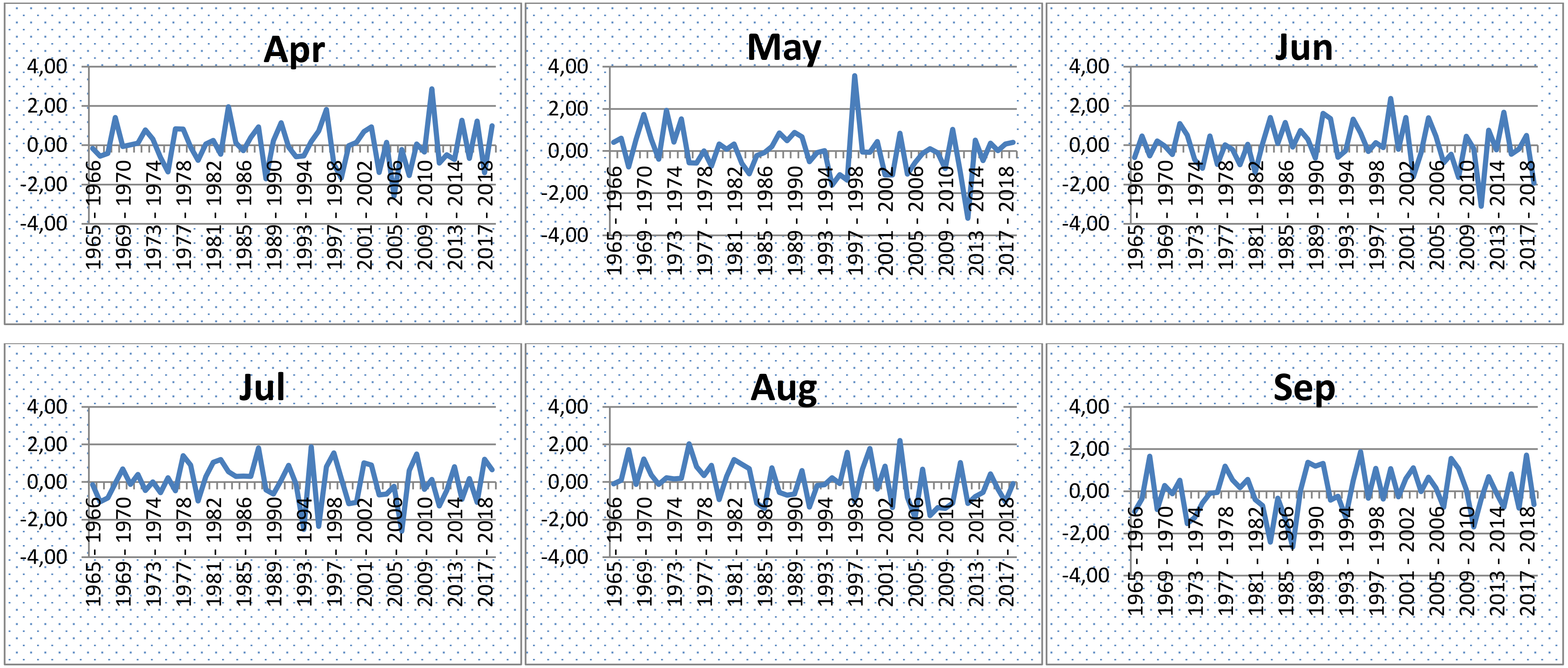

Figure 4.58. (Continued).

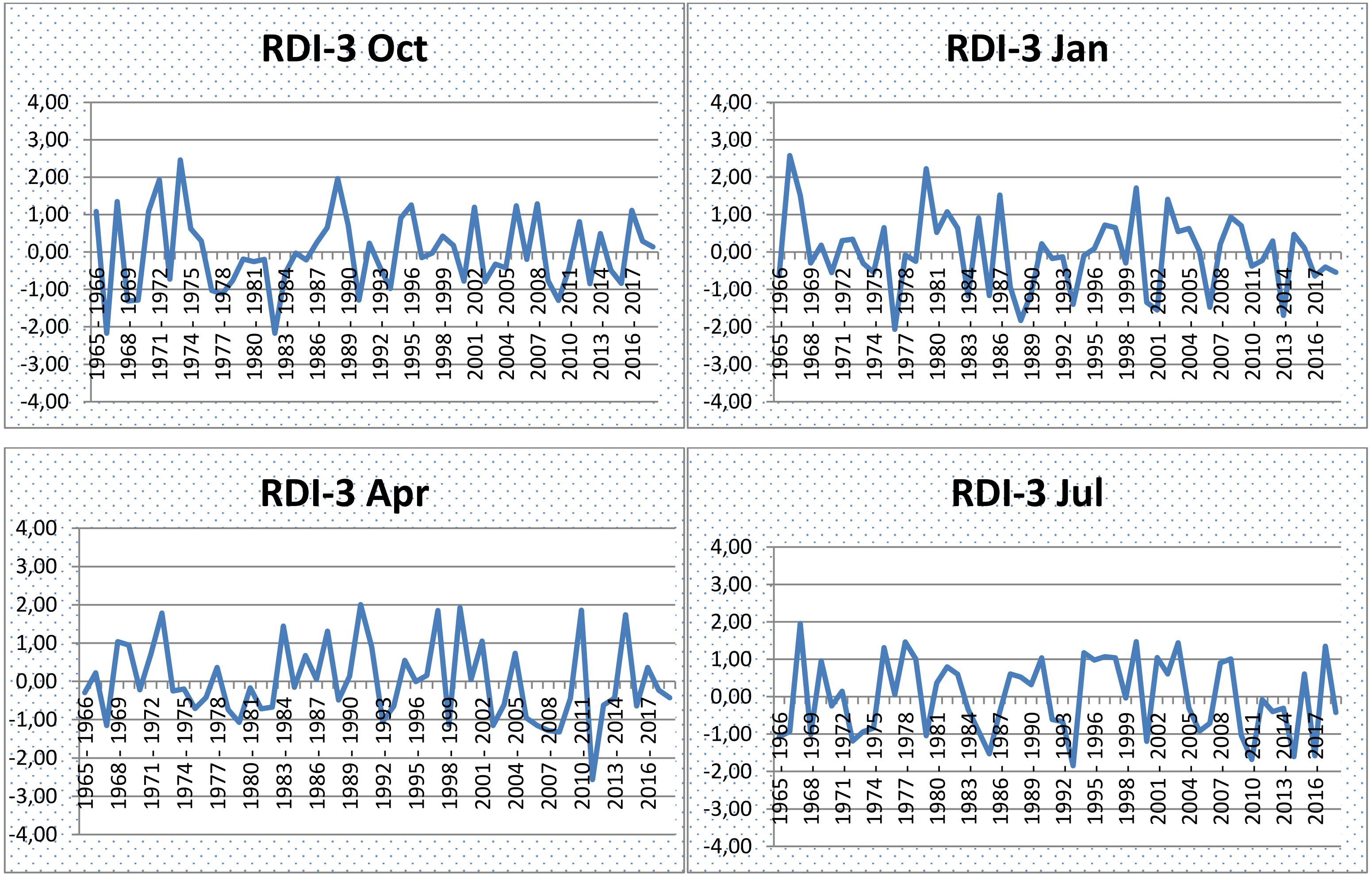

Figure 4.59. Dry - moist period distributions according to the 3-,6-,12 months RDI values for the Amasra Station from 1965 to 2019.

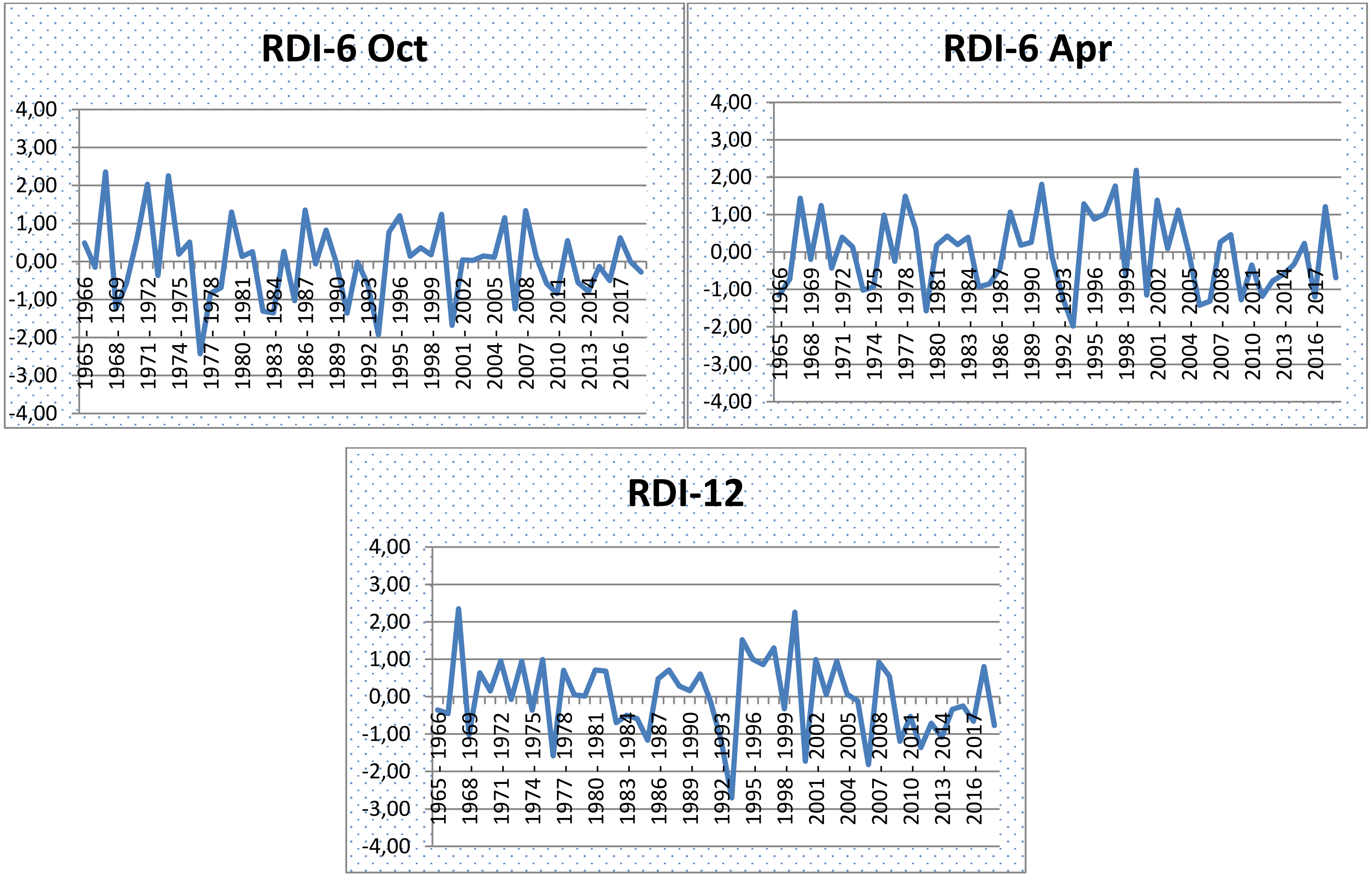

Figure 4.60. (Continued).

4.2.10. Bartın Precipitation Monitoring Station (17020) Meterological / Agricultural Drought Analysis (RDI).

RDI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation and monthly mean temperature data measured between 1965-2019 of the Bartın Station. According to Figure 4.35 and Table 4.3, the highest dry month was at April in 2005-2006 period, and the highest moist month was at January in 1971-1972 period.

Figure 4.36 time distributions of RDI values for 3, 6, and 12 months, the highest dry period was at RDI-3 in October in the year 1966-1967, the highest moist period was at RDI-3 in January in the year 2011-2012. The highest dry period at RDI-6 was in October and April 1993-1994, and the highest dry period was at RDI-12 in the year 1993-1994, the highest moist period was in the year 1967-1968.

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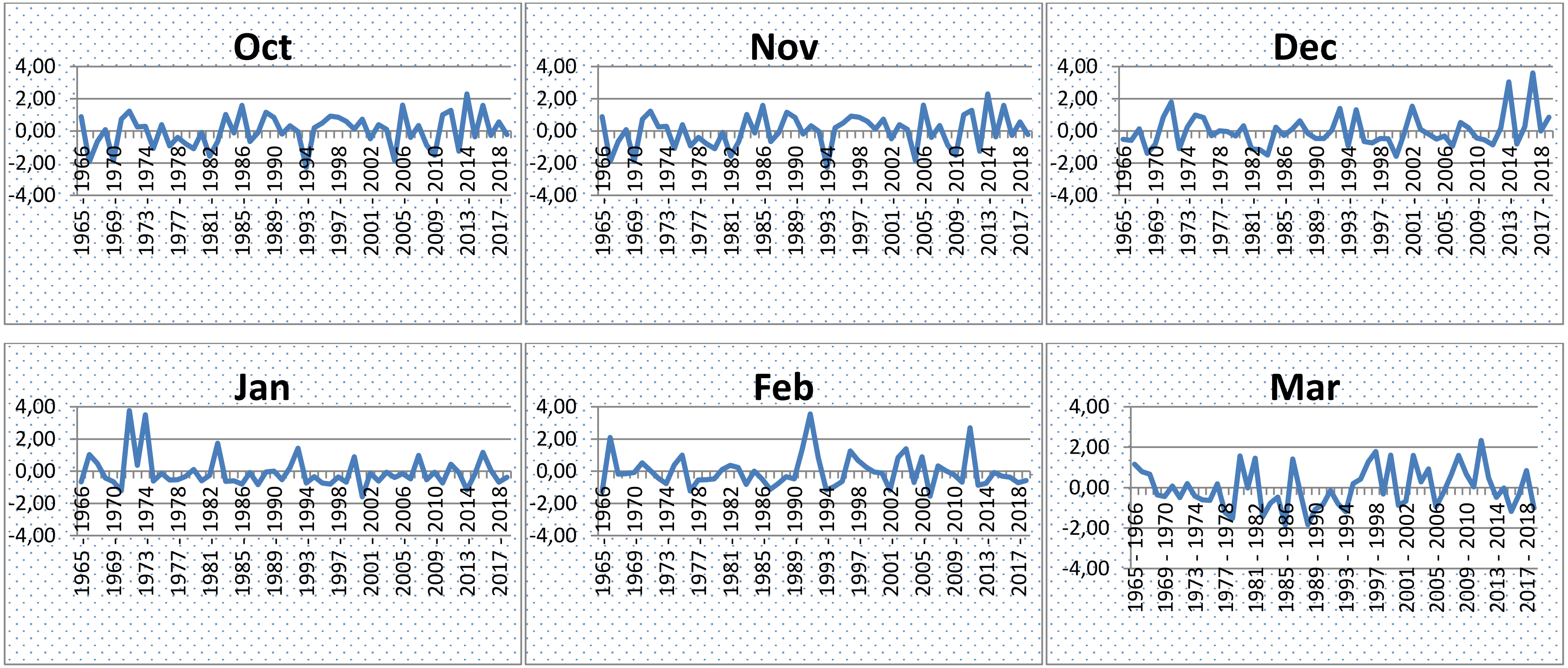

Figure 4.61. Dry - moist period distributions according to the monthly RDI values for the Bartın Station from 1965 to 2019.

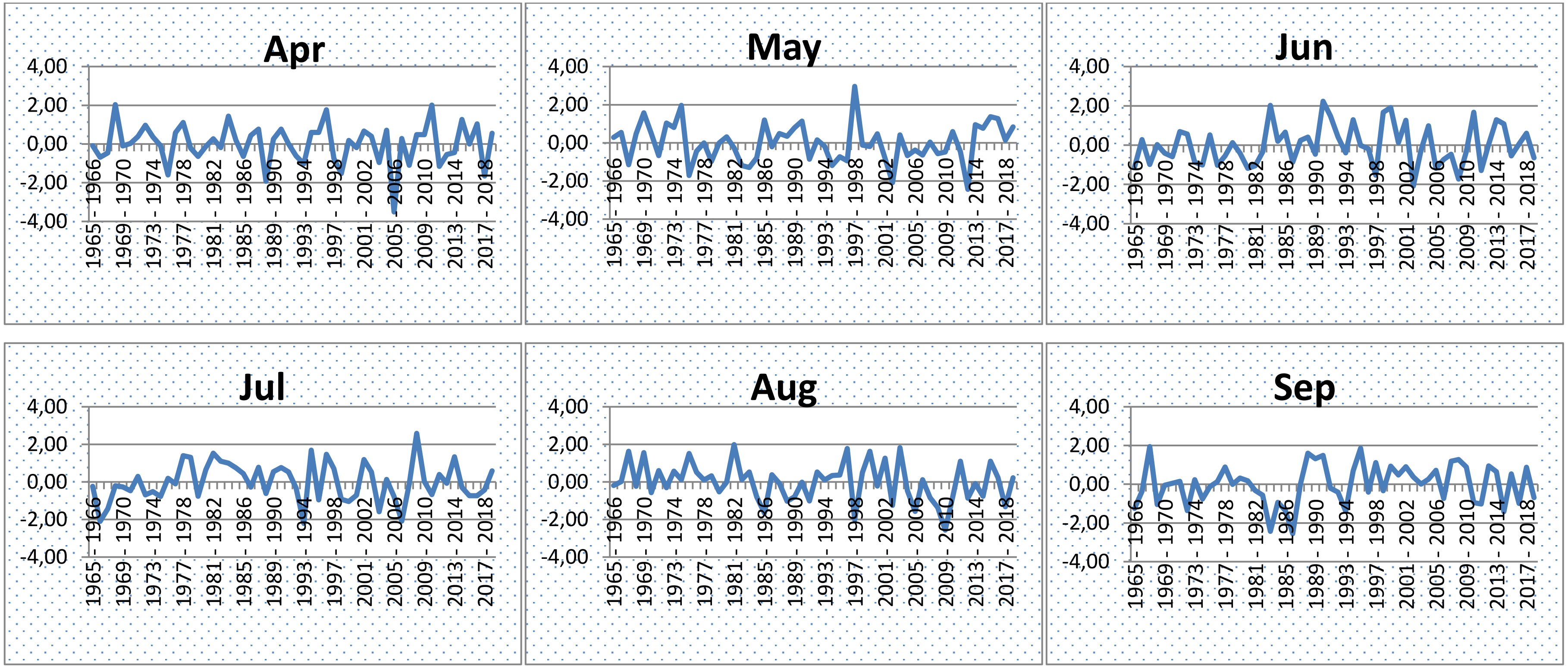

Figure 4.62. (Continued).

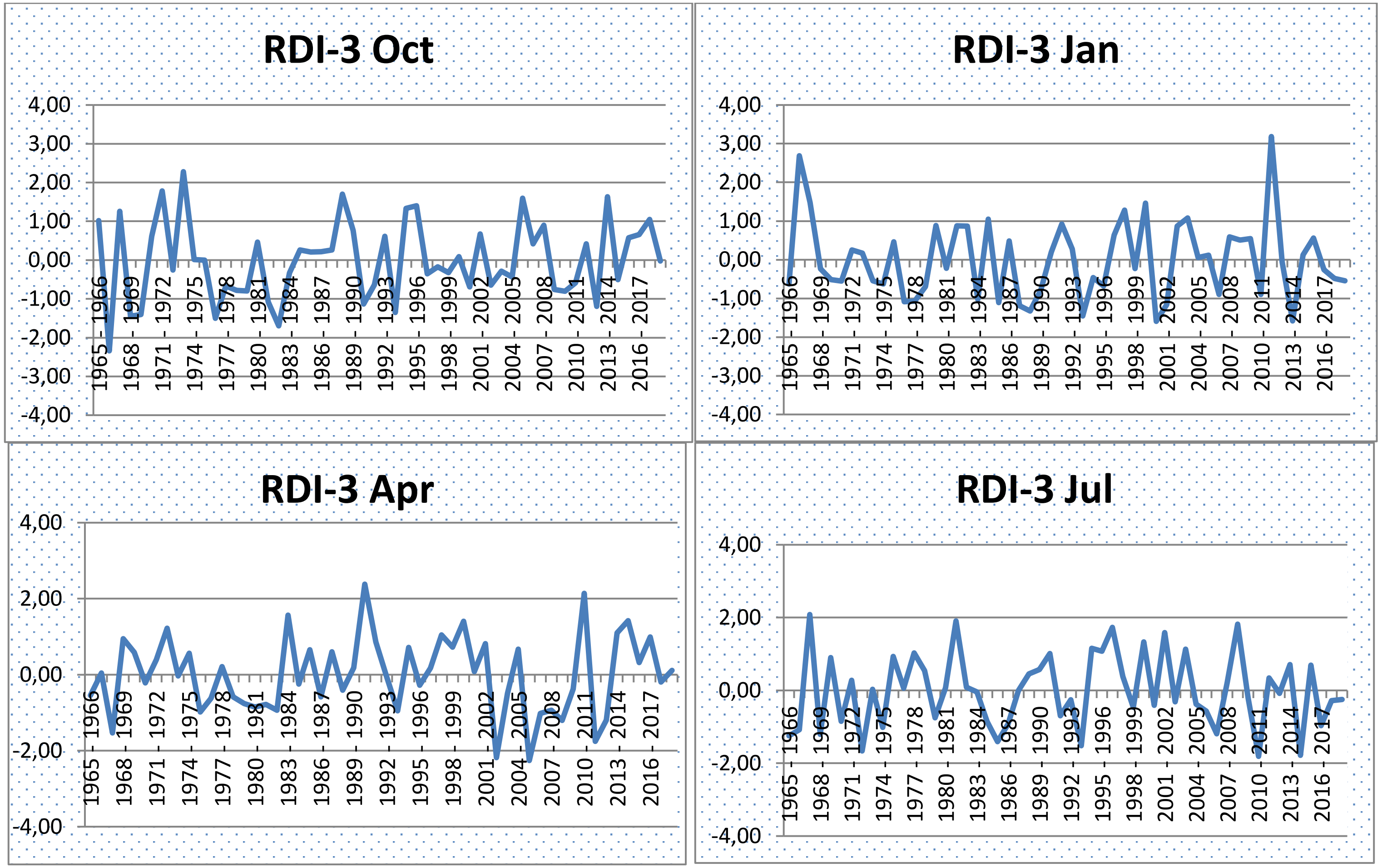

Figure 4.63. Dry - moist period distributions according to the 3-,6-,12 months RDI values for the Bartın Station from 1965 to 2019.

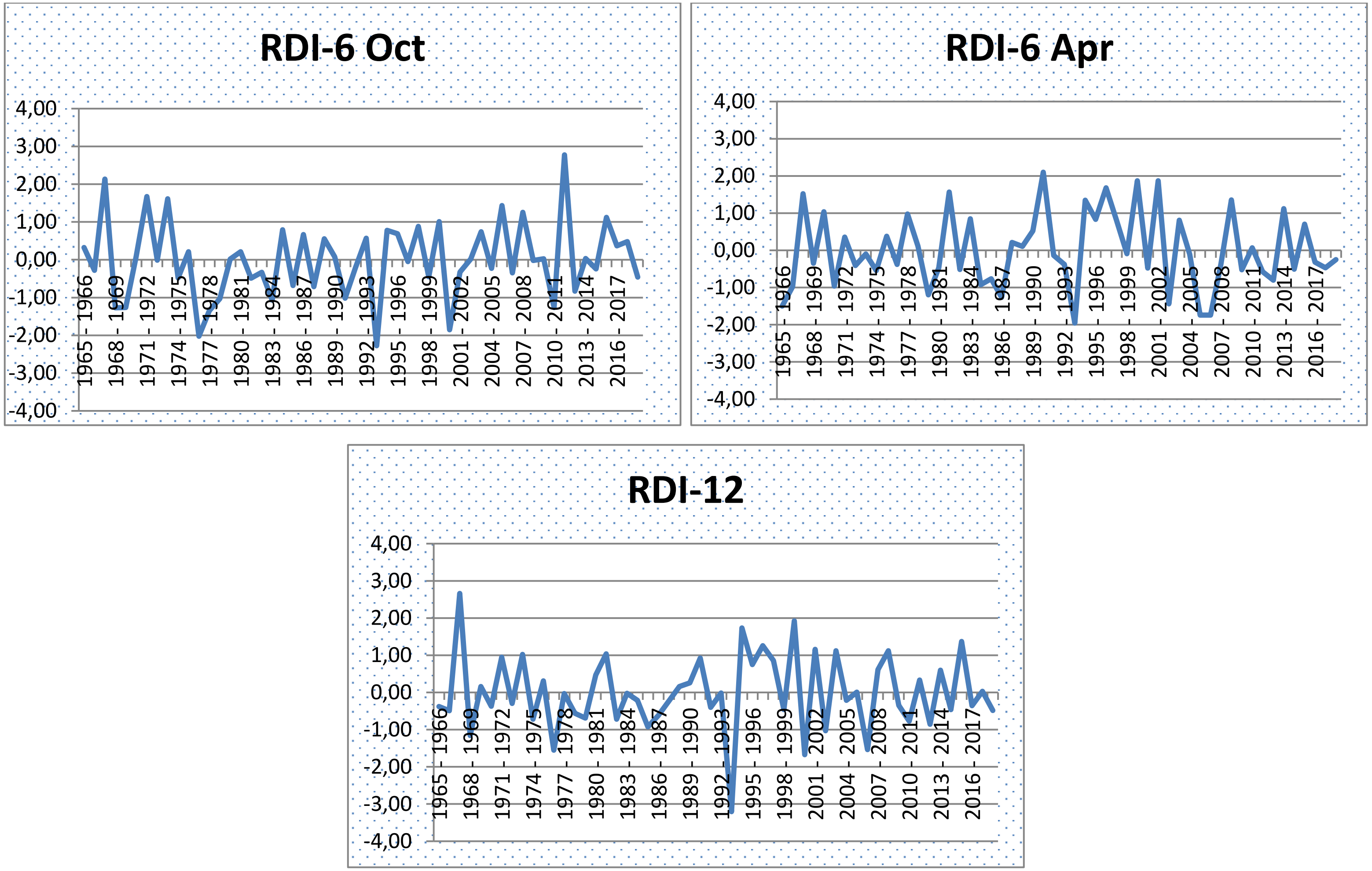

Figure 4.64. (Continued).

4.2.11. Devrekani Precipitation Monitoring Station (17618) Meterological / Agricultural Drought Analysis (RDI).

RDI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation and monthly mean temperature data measured between 1965-2019 of the Devrekani Station. According to Figure 4.37 and Table 4.3, the highest dry months were at April 2011-2012 period and at May in 1991-1992 period, and the highest moist month was at March in 1966-1967 period.

Figure 4.38 time distributions of RDI values for 3, 6, and 12 months, the highest dry period was at RDI-3 in April in the year 2002-2003, the highest moist period was at RDI-3 in January in the year 1966-1967. The highest dry period at RDI-6 was in April 1993-1994, and the highest dry period was at RDI-12 in the year 2005-2006, the highest moist period was in the year 1981-1982.

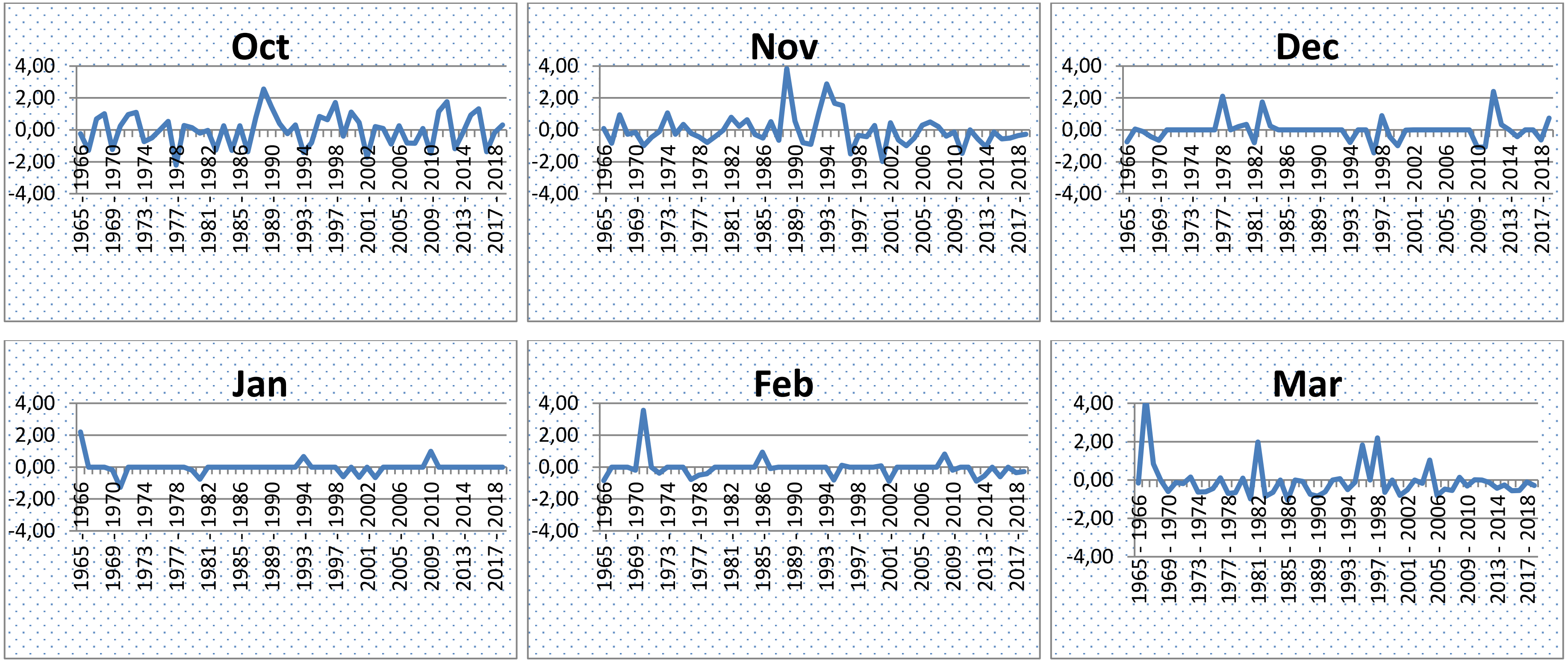

Figure 4.65. Dry - moist period distributions according to the monthly RDI values for the Devrekani Station from 1965 to 2019.

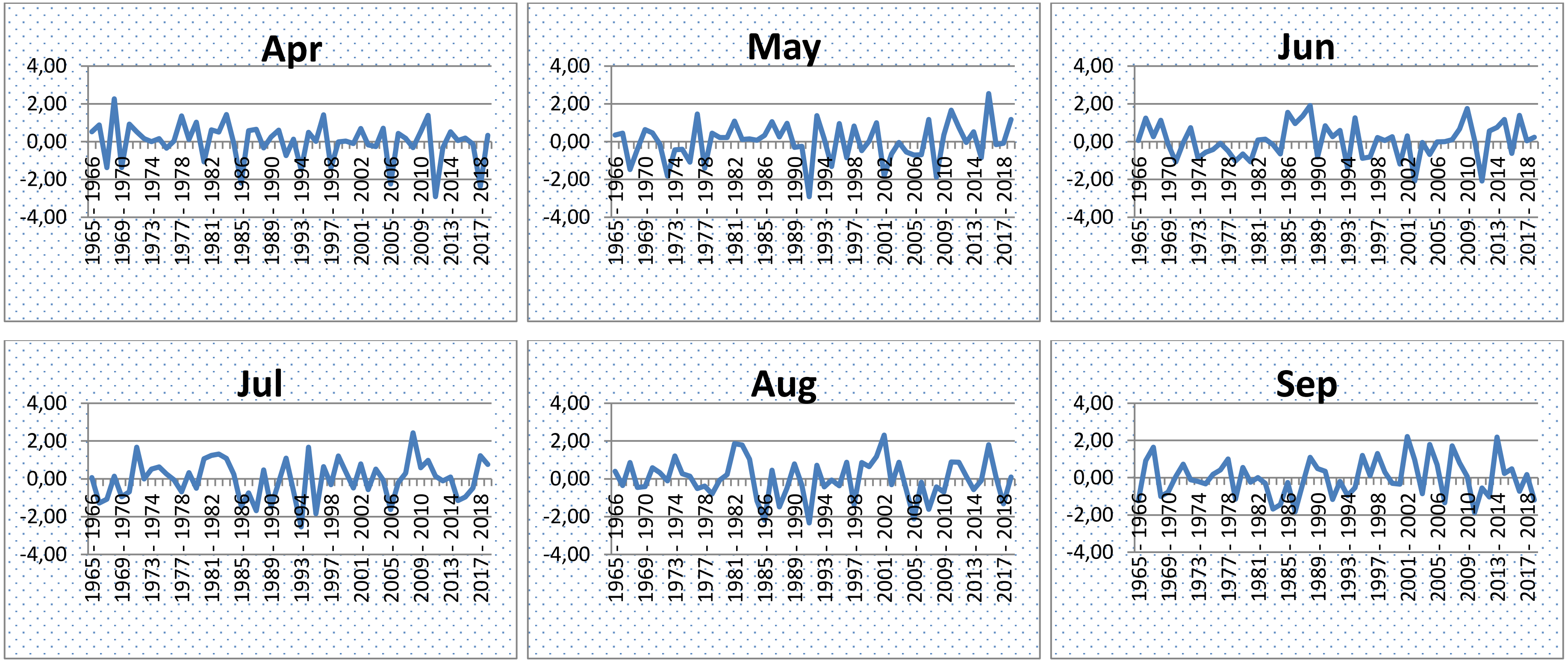

Figure 4.66. (Continued).

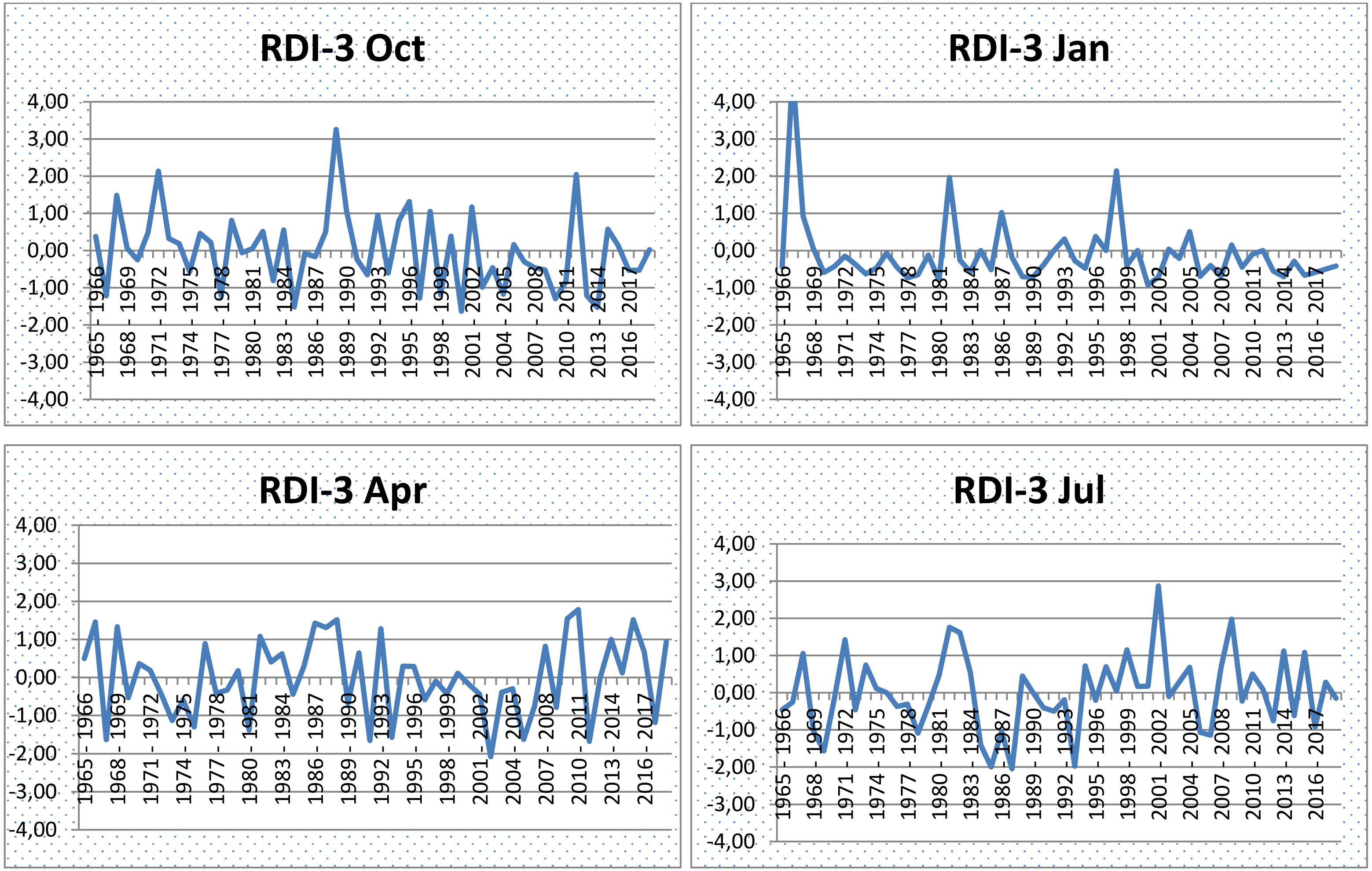

Figure 4.67. Dry - moist period distributions according to the 3-,6-,12 months RDI values for the Devrekani Station from 1965 to 2019.

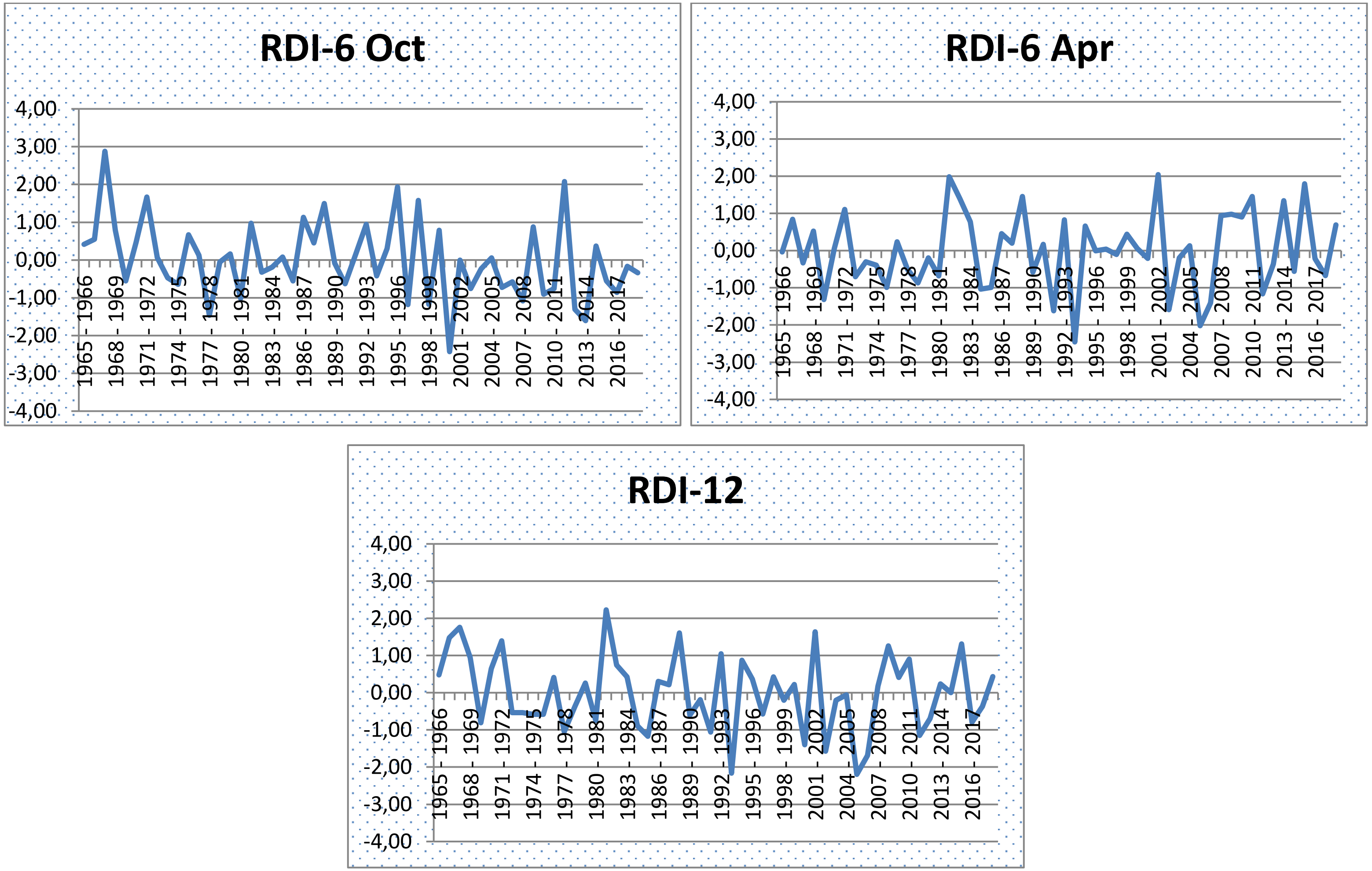

Figure 4.68. (Continued).

4.2.12. İnebolu Precipitation Monitoring Station (17024) Meterological / Agricultural Drought Analysis (RDI).

RDI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation and monthly mean temperature data measured between 1965-2019 of the İnebolu Station. According to Figure 4.39 and Table 4.3, the highest dry month was at Jun in 2002-2003 period, and the highest moist month was at February in 1984-1985 period.

Figure 4.40 time distributions of RDI values for 3, 6, and 12 months, the highest dry period was at RDI-3 in October in the year 1966-1967, the highest moist period was at RDI-3 in January in the year 2011-2012. The highest dry period at RDI-6 was in April 1973-1974, and the highest dry period was at RDI-12 in the year 1974-1975, the highest moist period was in the year 1999-2000.

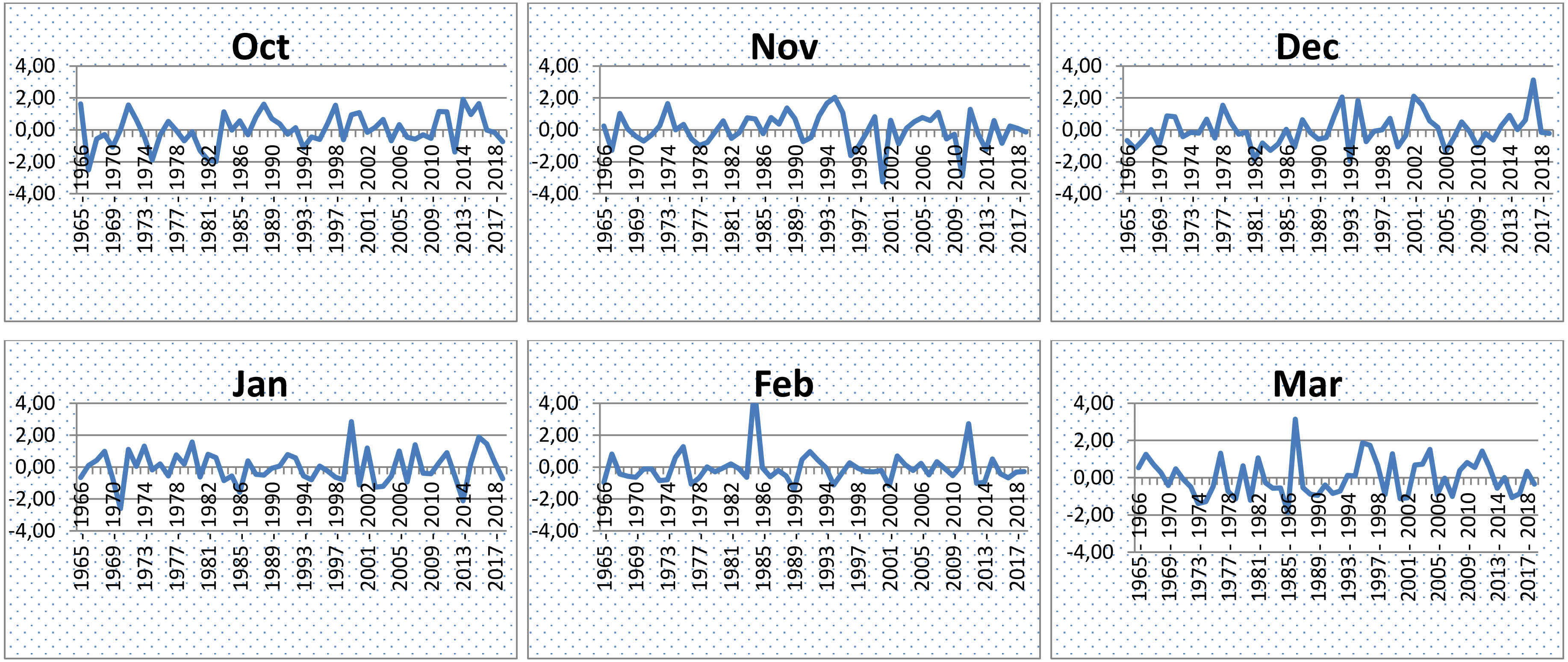

Figure 4.69. Dry - moist period distributions according to the monthly RDI values for the İnebolu Station from 1965 to 2019.

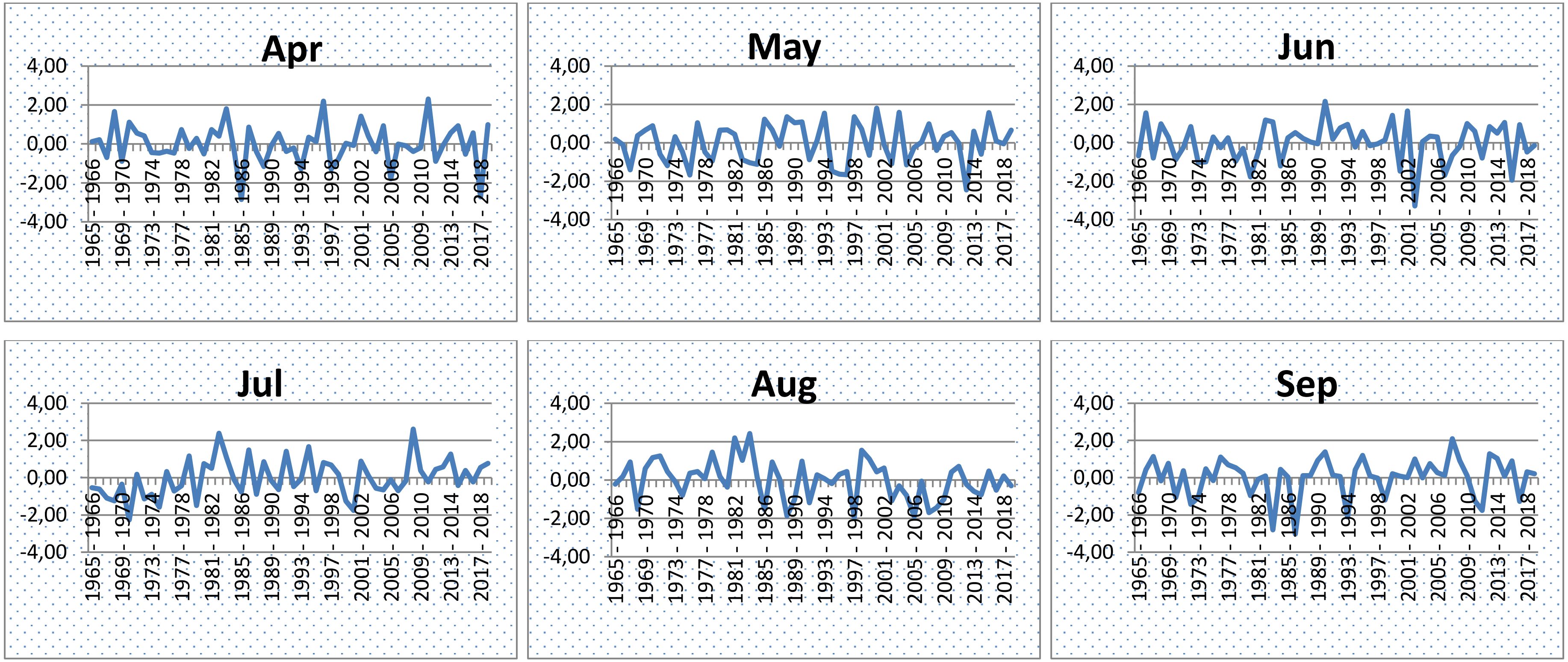

Figure 4.70. (Continued).

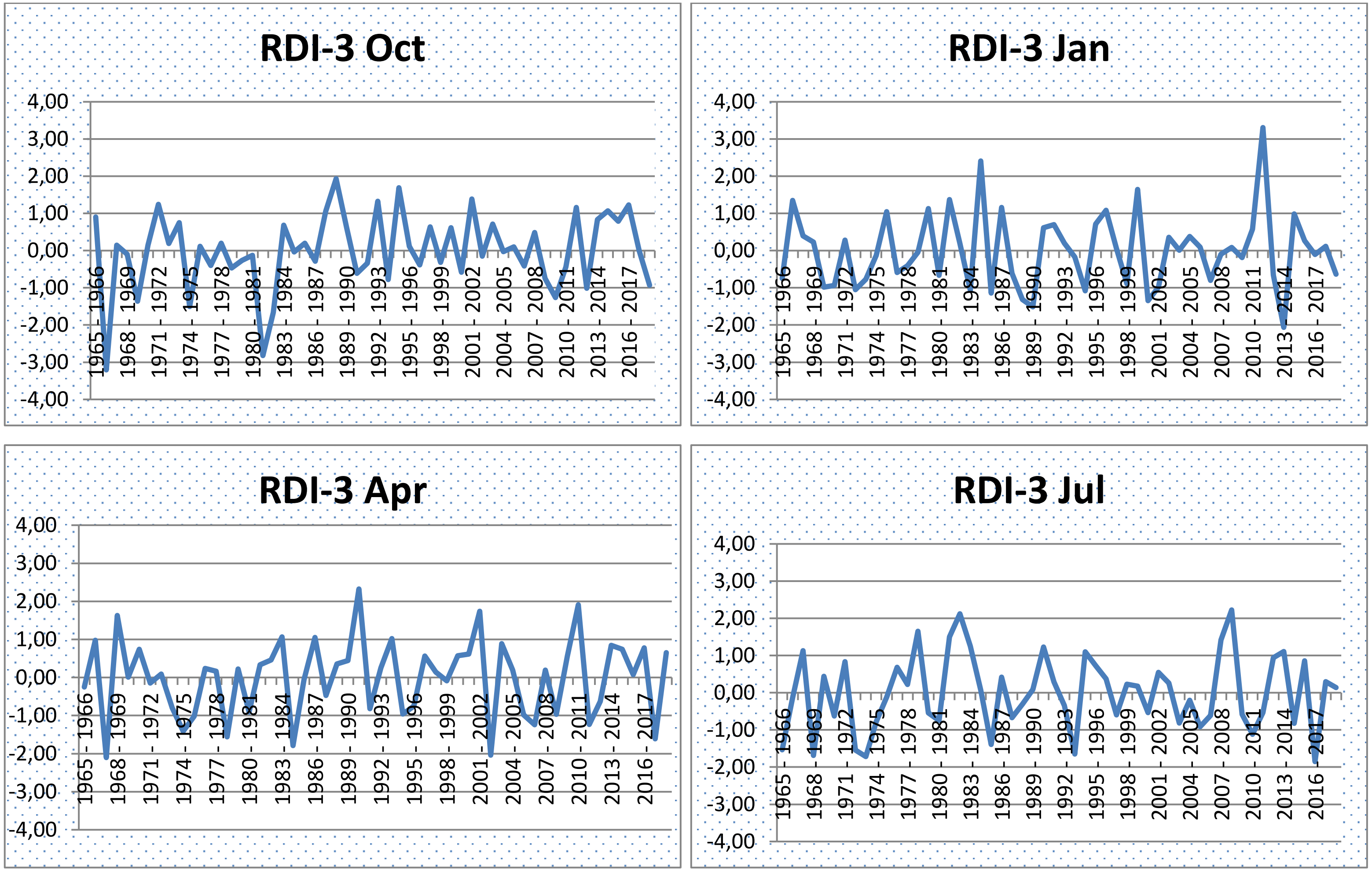

Figure 4.71. Dry - moist period distributions according to the 3-,6-,12 months RDI values for the İnebolu Station from 1965 to 2019.

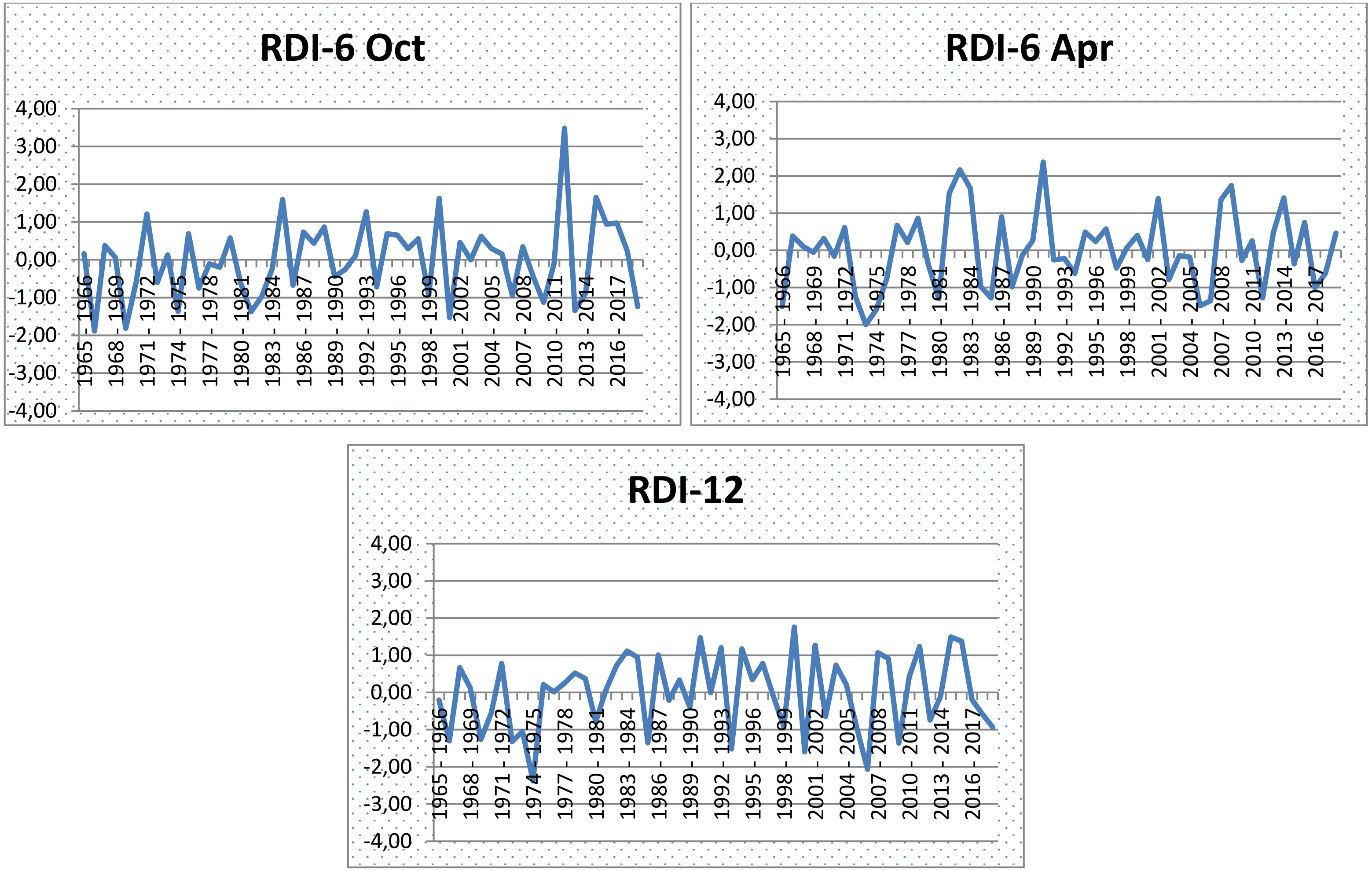

Figure 4.72. (Continued).

4.2.13. Kastamonu Precipitation Monitoring Station (17074) Meterological / Agricultural Drought Analysis (RDI).

RDI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation and monthly mean temperature data measured between 1965-2019 of the Kastamonu Station. According to Figure 4.41 and Table 4.3, the highest dry month was at April in 1985-1986 period, and the highest moist month was at December in 1974-1975 period.

Figure 4.42 time distributions of RDI values for 3, 6, and 12 months, the highest dry period was at RDI-3 in April in the year 1993-1994, the highest moist period was at RDI-3 in January in the year 2011-2012. The highest dry period at RDI-6 was in April 1993-1994, and the highest dry period was at RDI-12 in the year 1993-1994, the highest moist period was in the year 2008-2009.

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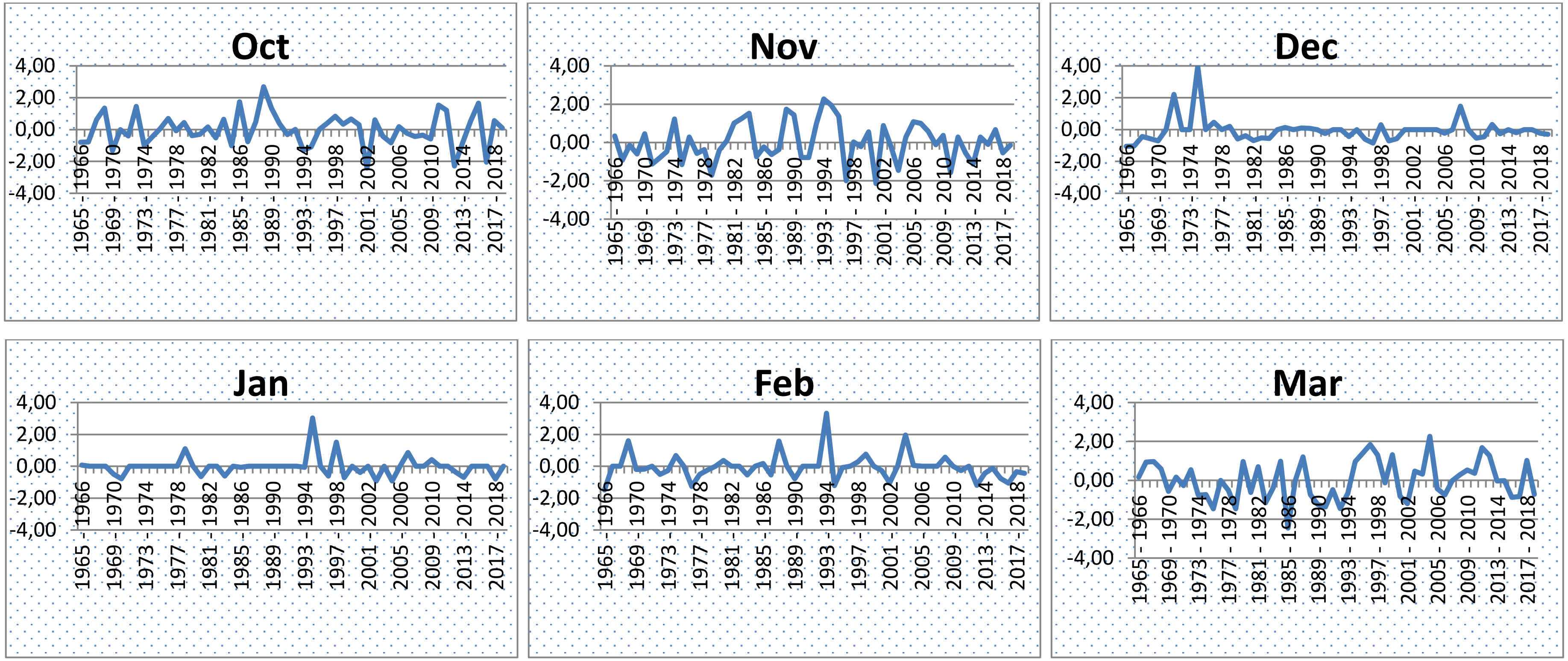

Figure 4.73. Dry - moist period distributions according to the monthly RDI values for the Kastamonu Station from 1965 to 2019.

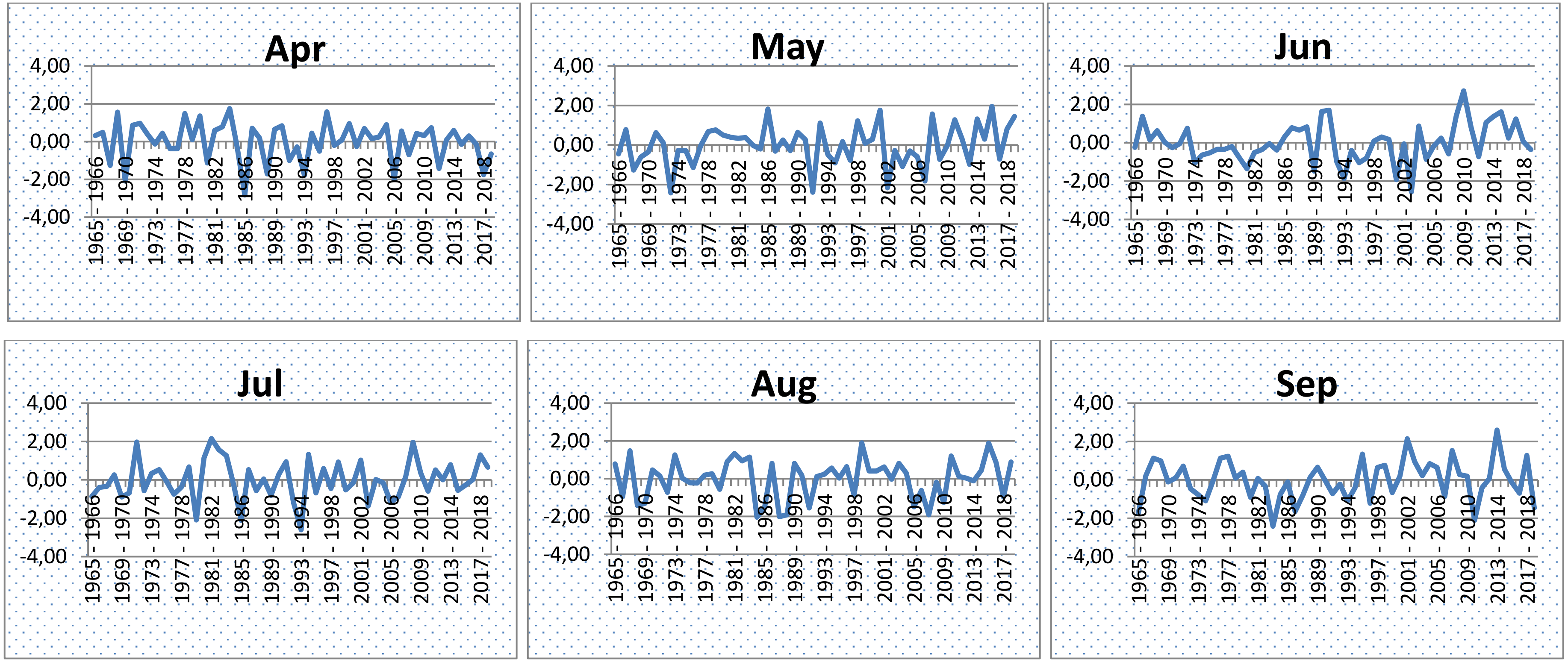

Figure 4.74. (Continued).

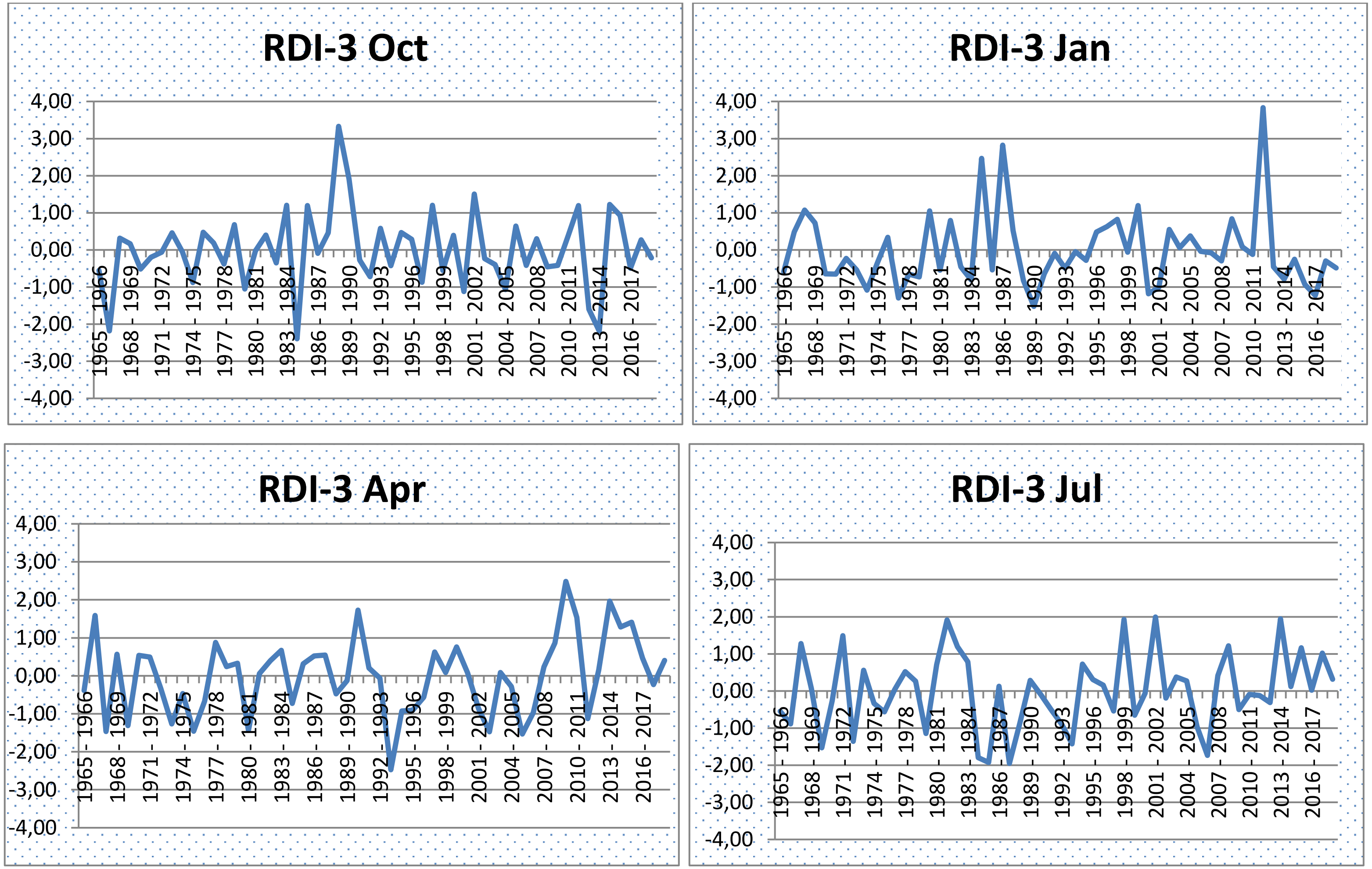

Figure 4.75. Dry - moist period distributions according to the 3-,6-,12 months RDI values for the Kastamonu Station from 1965 to 2019.

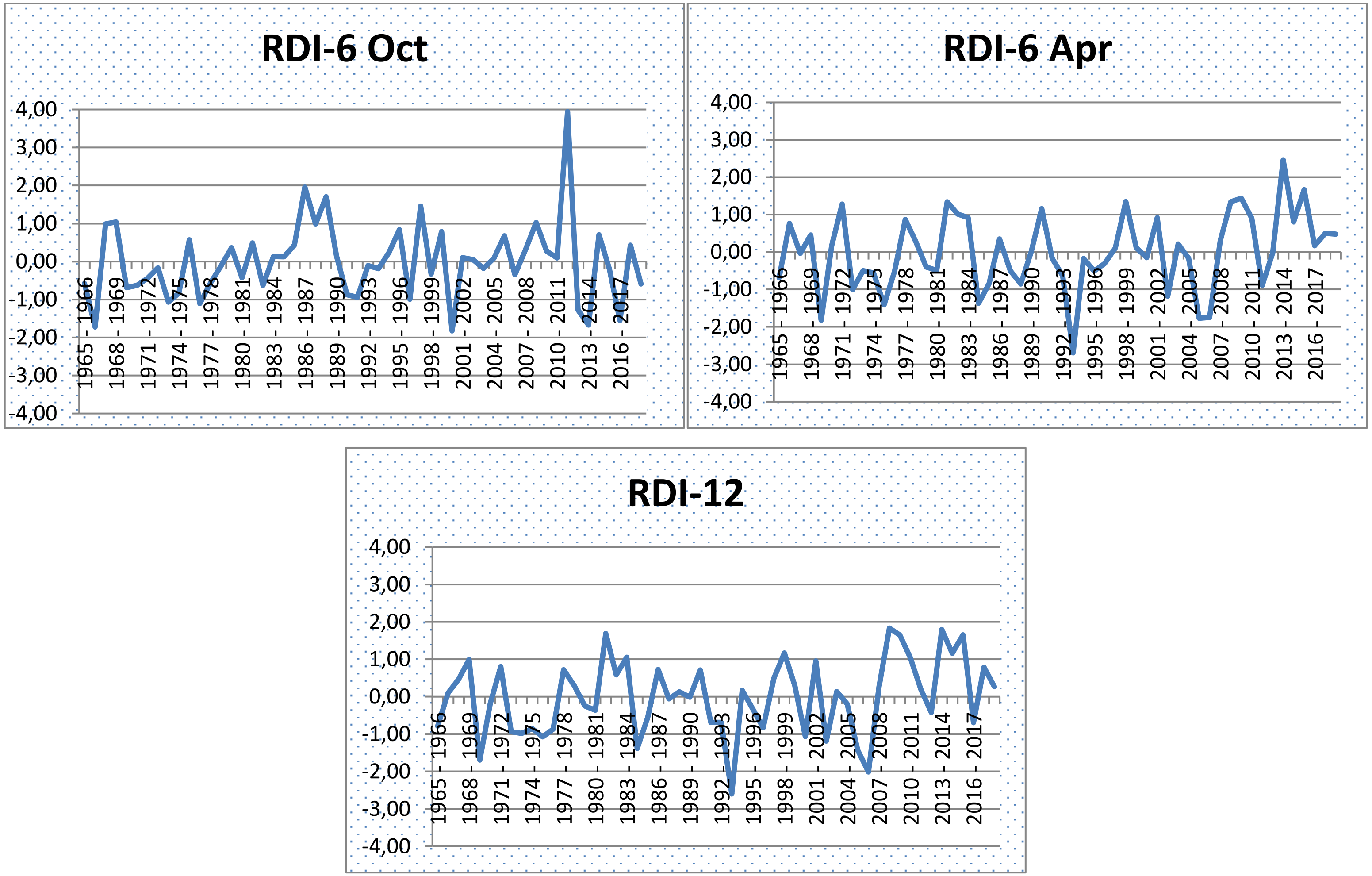

Figure 4.76. (Continued).

4.2.14. Sinop Precipitation Monitoring Station (17026) Meterological / Agricultural Drought Analysis (RDI).

RDI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation and monthly mean temperature data measured between 1965-2019 of the Sinop Station. According to Figure 4.43 and Table 4.3, the highest dry month was at January in 1970-1971 period, and the highest moist period was at February in 1984-1985 period.

Figure 4.44 time distributions of RDI values for 3, 6, and 12 months, the highest dry period was at RDI-3 in July in the year 1993-1994, the highest moist period was at RDI-3 in January in the year 2011-2012. The highest dry period at RDI-6 was in April 2006-2007, and the highest dry period was at RDI-12 in the year 1993-1994, the highest moist period was in the year 1967-1968.

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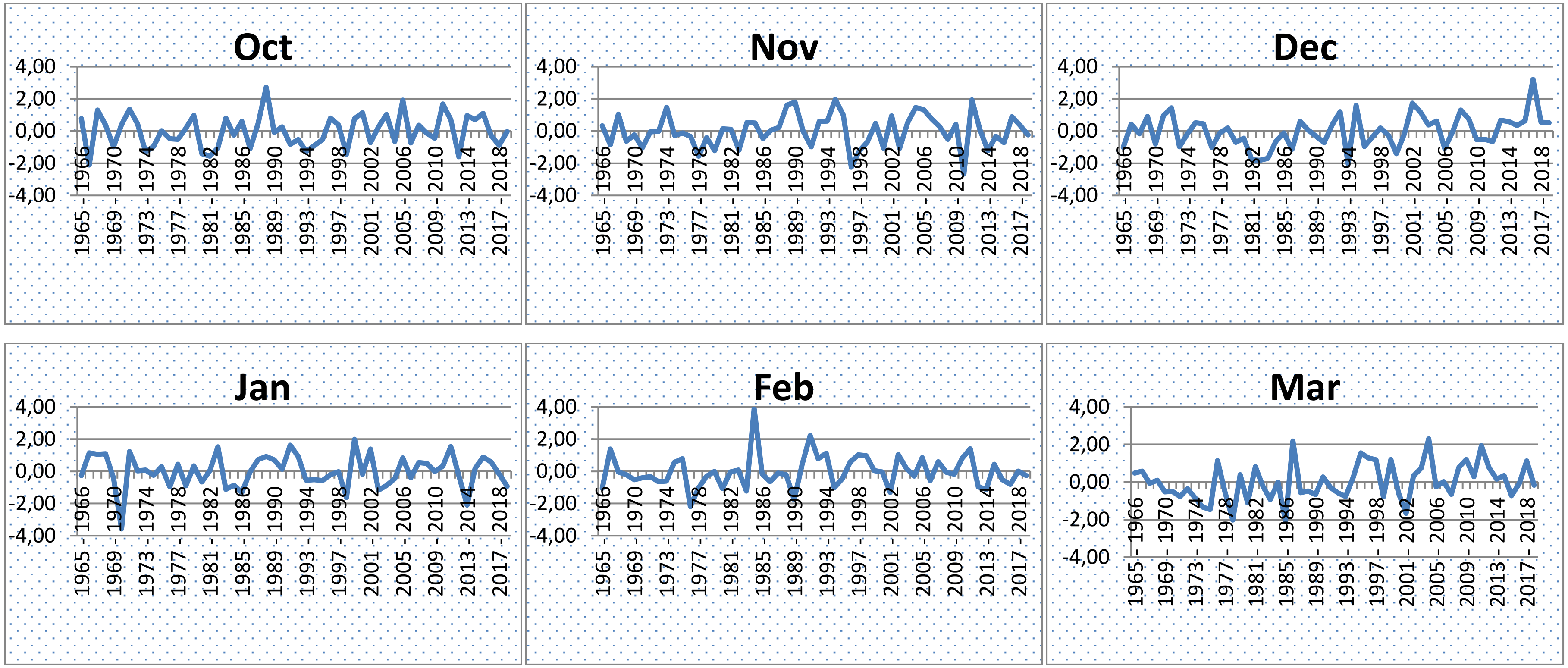


Figure 4.77. Dry - moist period distributions according to the monthly RDI values for the Sinop Station from 1965 to 2019.

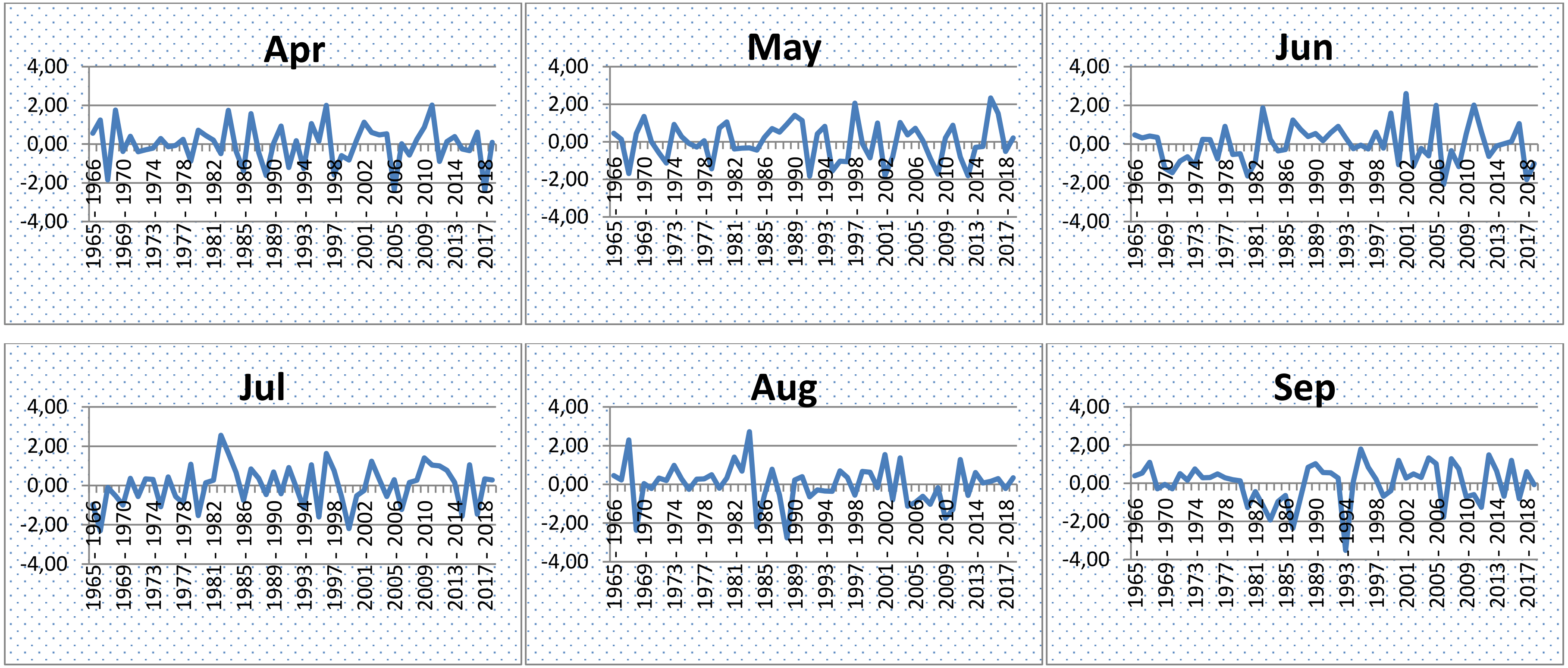


Figure 4.78. (Continued).

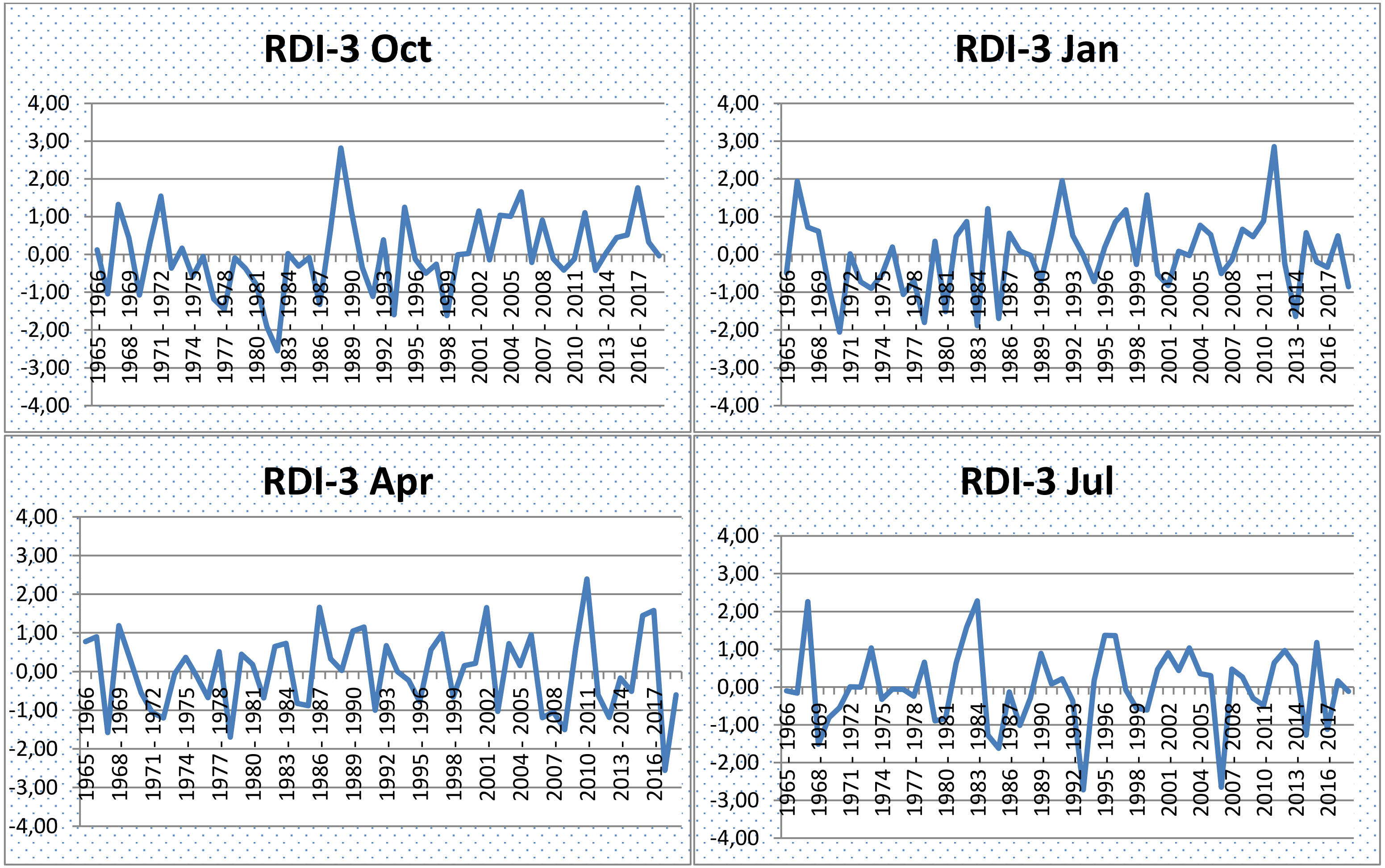


Figure 4.79. Dry - moist period distributions according to the 3-,6-,12 months RDI values for the Sinop Station from 1965 to 2019.

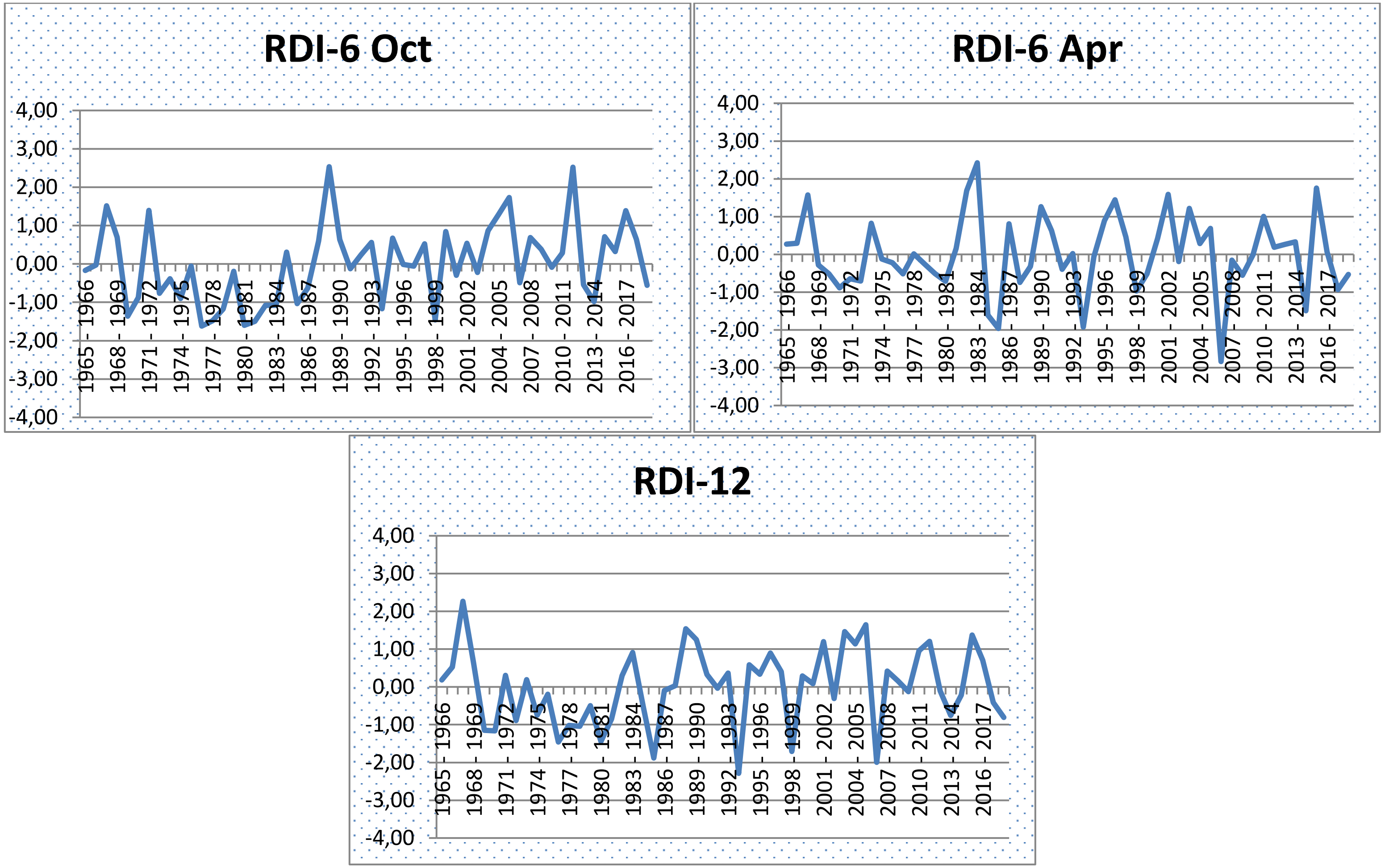


Figure 4.80. (Continued).

4.2.15. Bozkurt Precipitation Monitoring Station (17606) Meterological / Agricultural Drought Analysis (RDI).

RDI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation and monthly mean temperature data measured between 1965-2019 of the Bozkurt Station. According to Figure 4.45 and Table 4.3, the highest dry month was at March in 2016-2017 period, and the highest moist month was at February in 1984-1985 period.

Figure 4.46 time distributions of RDI values for 3, 6, and 12 months, the highest dry period was at RDI-3 in April in the year 2017-2018, the highest moist period was at RDI-3 in January in the year 1984-1985. The highest dry period at RDI-6 was in April 2017-2018, and the highest dry period was at RDI-12 in the year 2017-2018, the highest moist period was in the year 1992-1993.

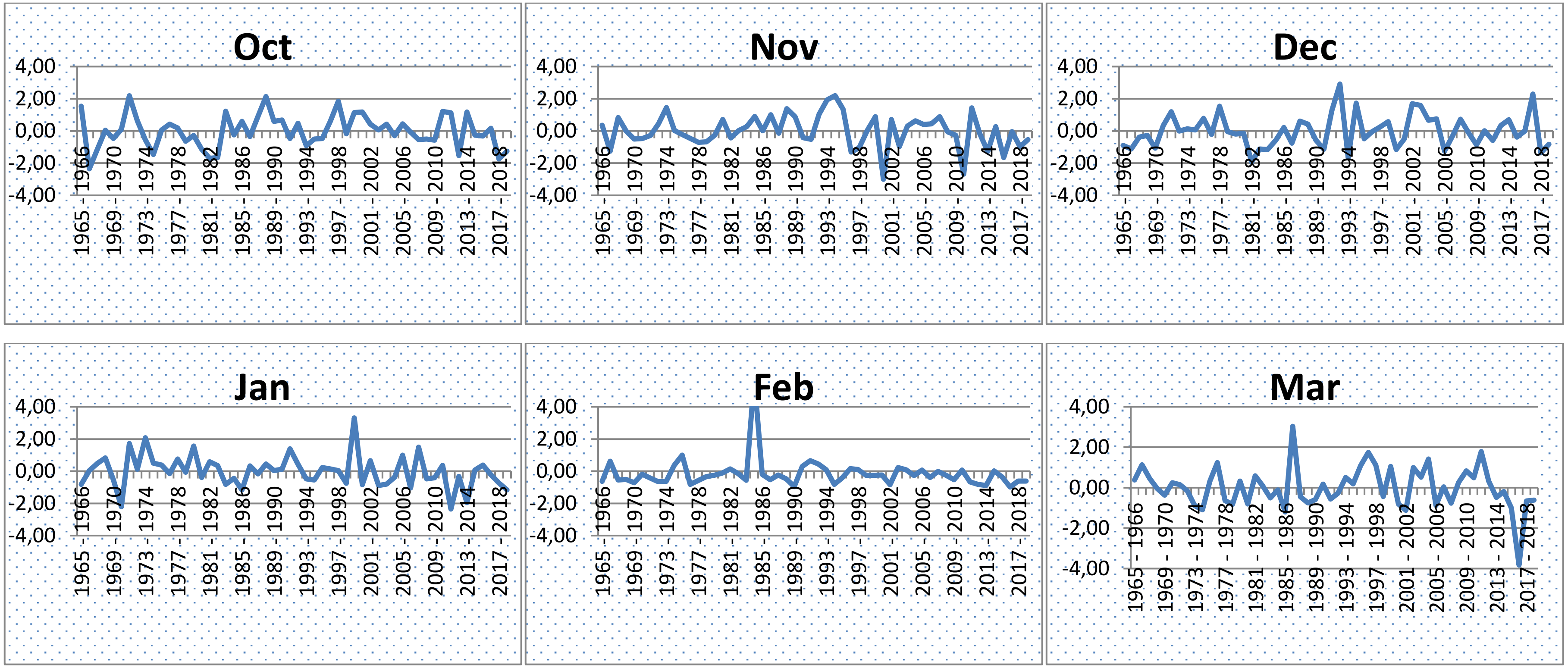


Figure 4.81. Dry - moist period distributions according to the monthly RDI values for the Bozkurt Station from 1965 to 2019.

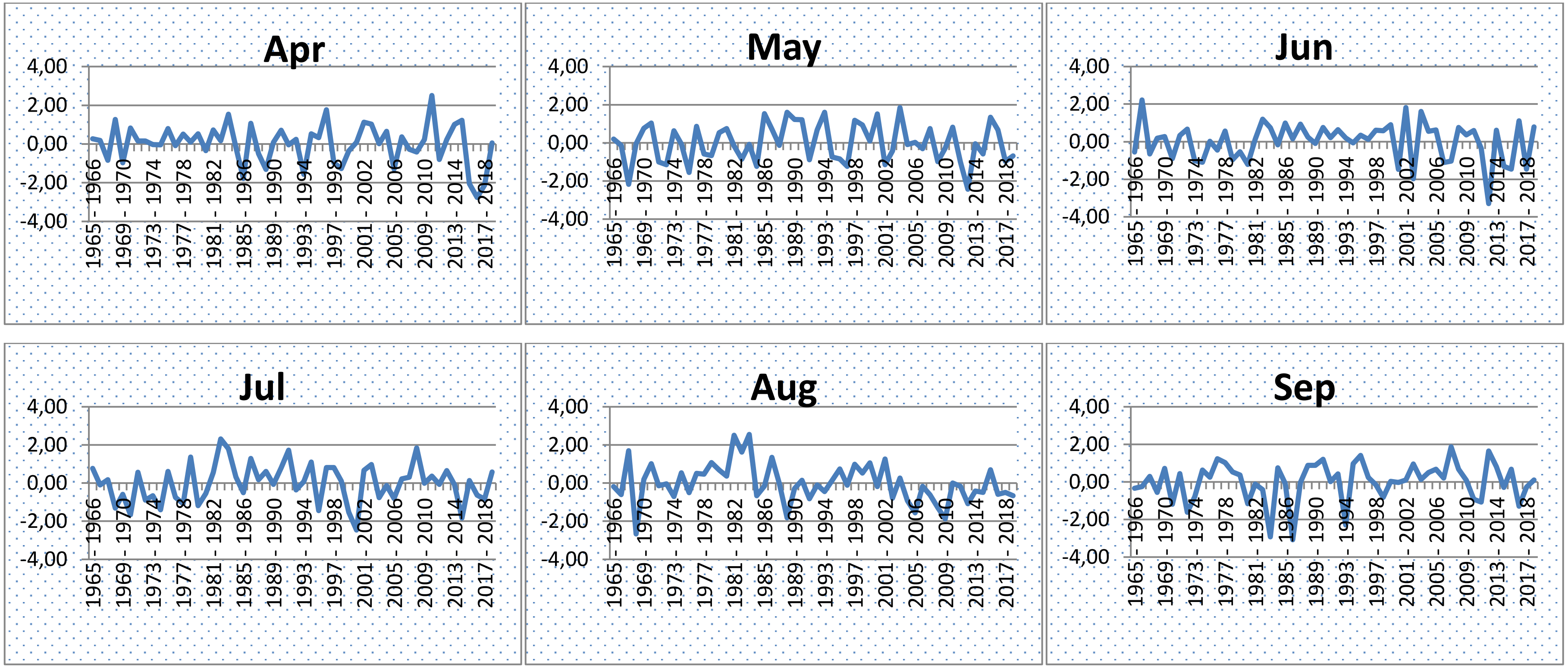


Figure 4.82. (Continued).

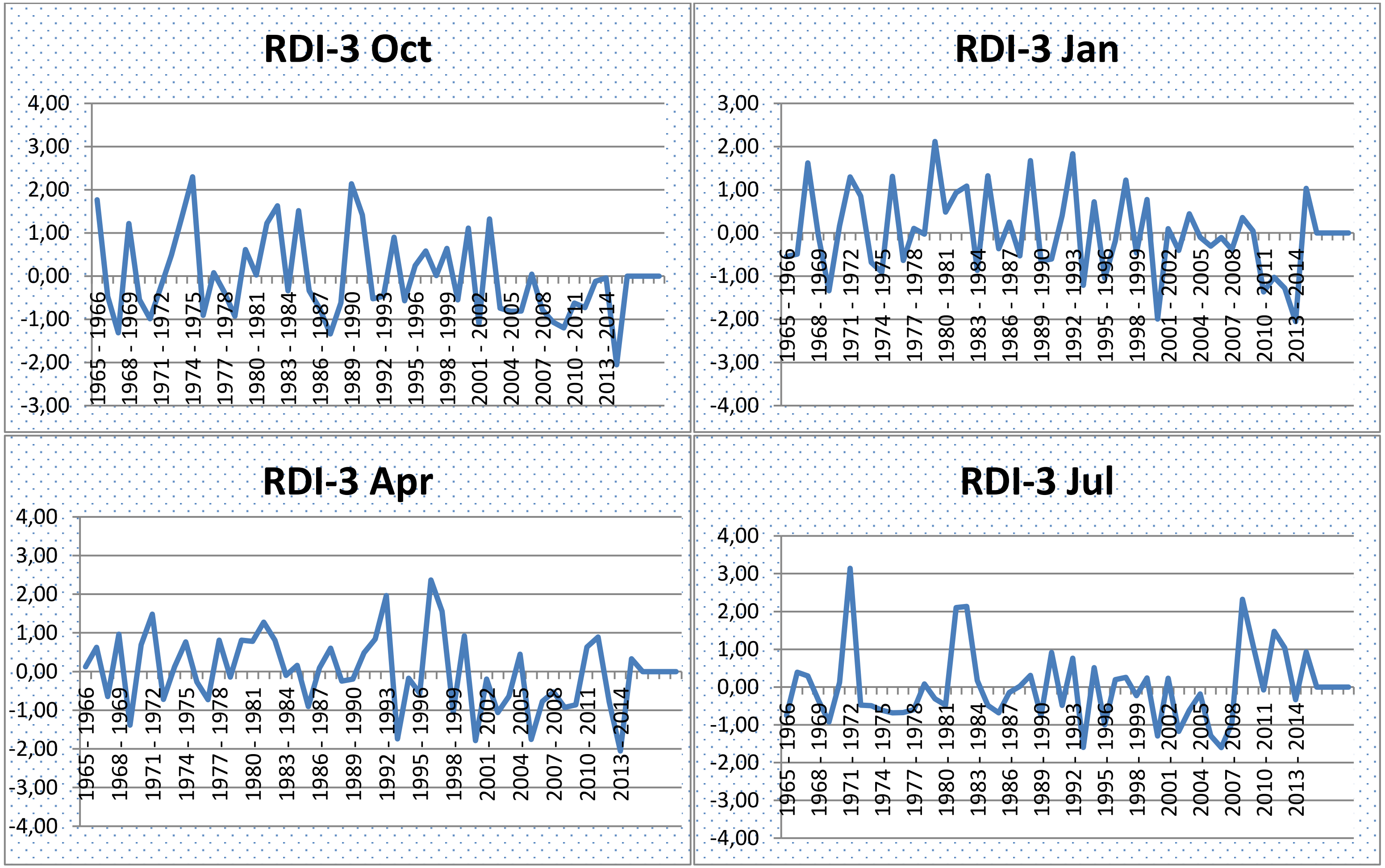


Figure 4.83. Dry - moist period distributions according to the 3-,6-,12 months RDI values for the Bozkurt Station from 1965 to 2019.

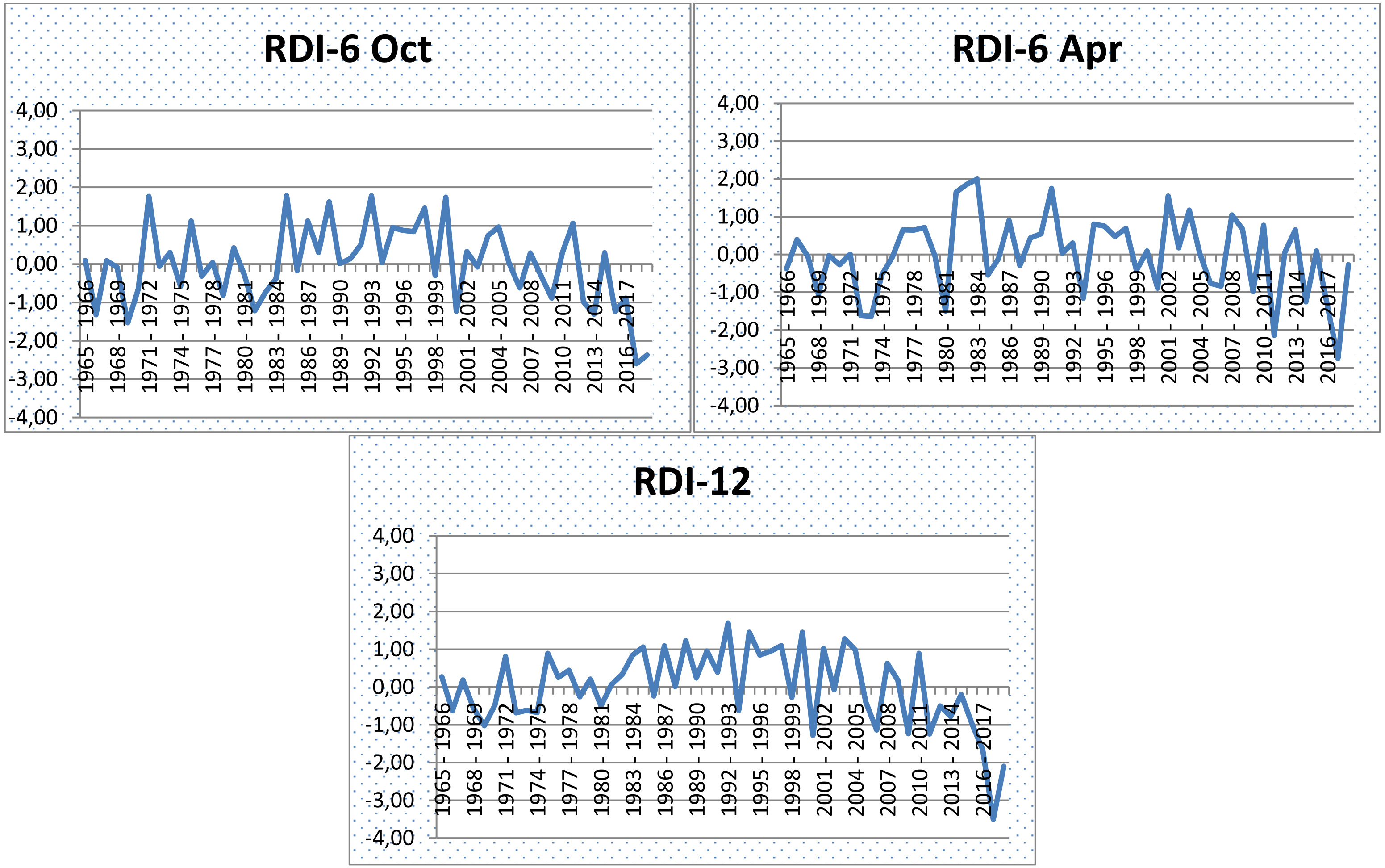


Figure 4.84. (Continued).

4.2.16. Ulus Precipitation Monitoring Station (17615) Meterological / Agricultural Drought Analysis (RDI).

RDI values were examined during periods 1, 3, 6, and 12 months using monthly total precipitation and monthly mean temperature data measured between 1965-2019 of the Ulus Station. According to Figure 4.47 and Table 4.3, the highest dry month was at April in 2005-2006 period, and the highest moist month was at January in 1966-1967 period.

Figure 4.48 time distributions of RDI values for 3, 6, and 12 months, the highest dry period was at RDI-3 in October in the year 2011-2012, the highest moist period was at RDI-3 in January in the year 1966-1967. The highest dry period at RDI-6 was in April 2006-2007, and the highest dry period was at RDI-12 in the year 2006-2007, the highest moist period was in the year 1967-1968.

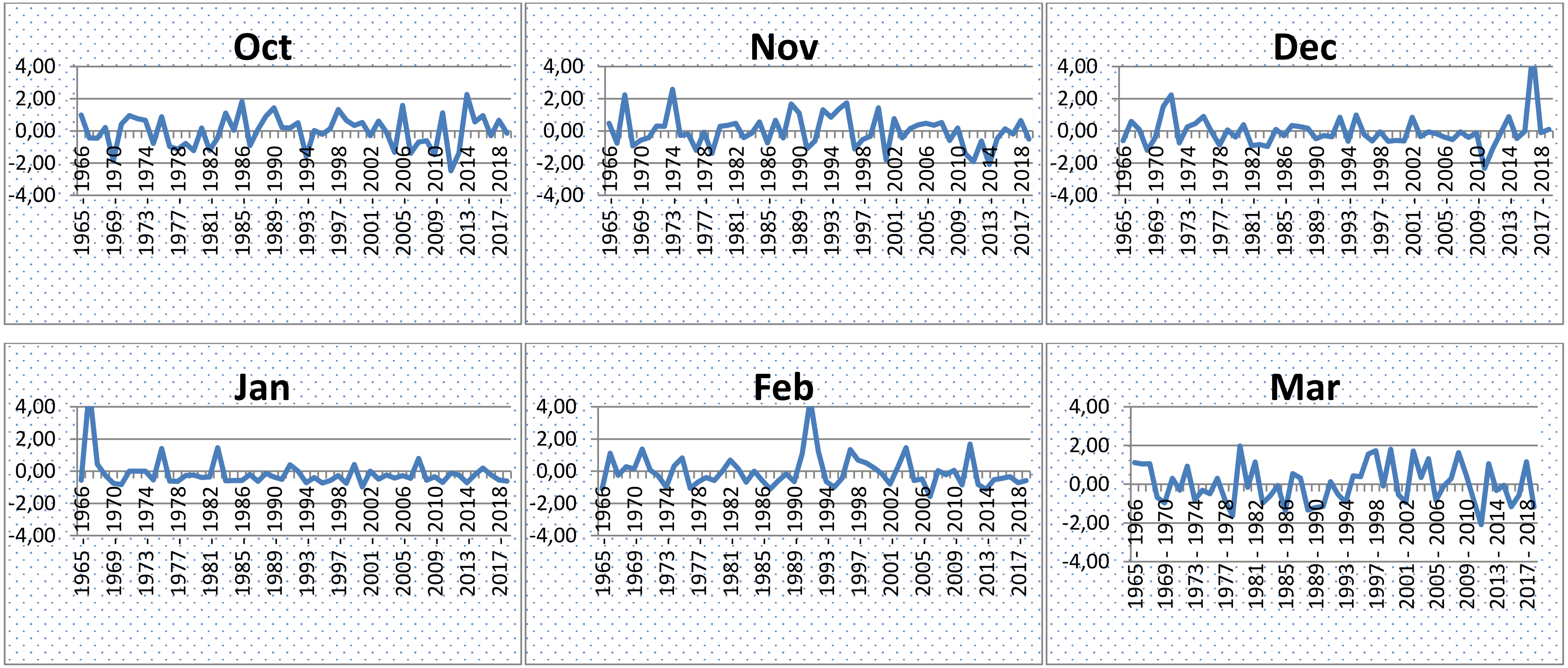


Figure 4.85. Dry - moist period distributions according to the monthly RDI values for the Ulus Station from 1965 to 2019.

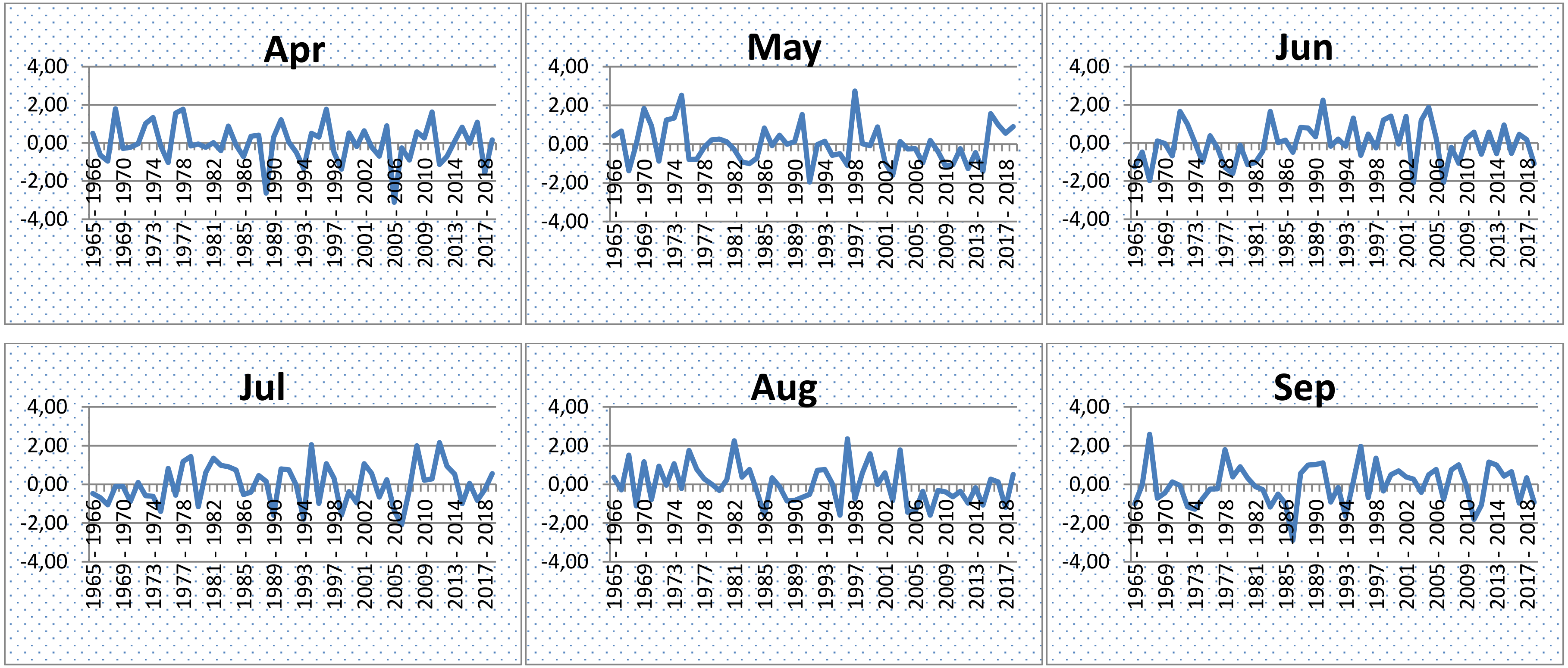
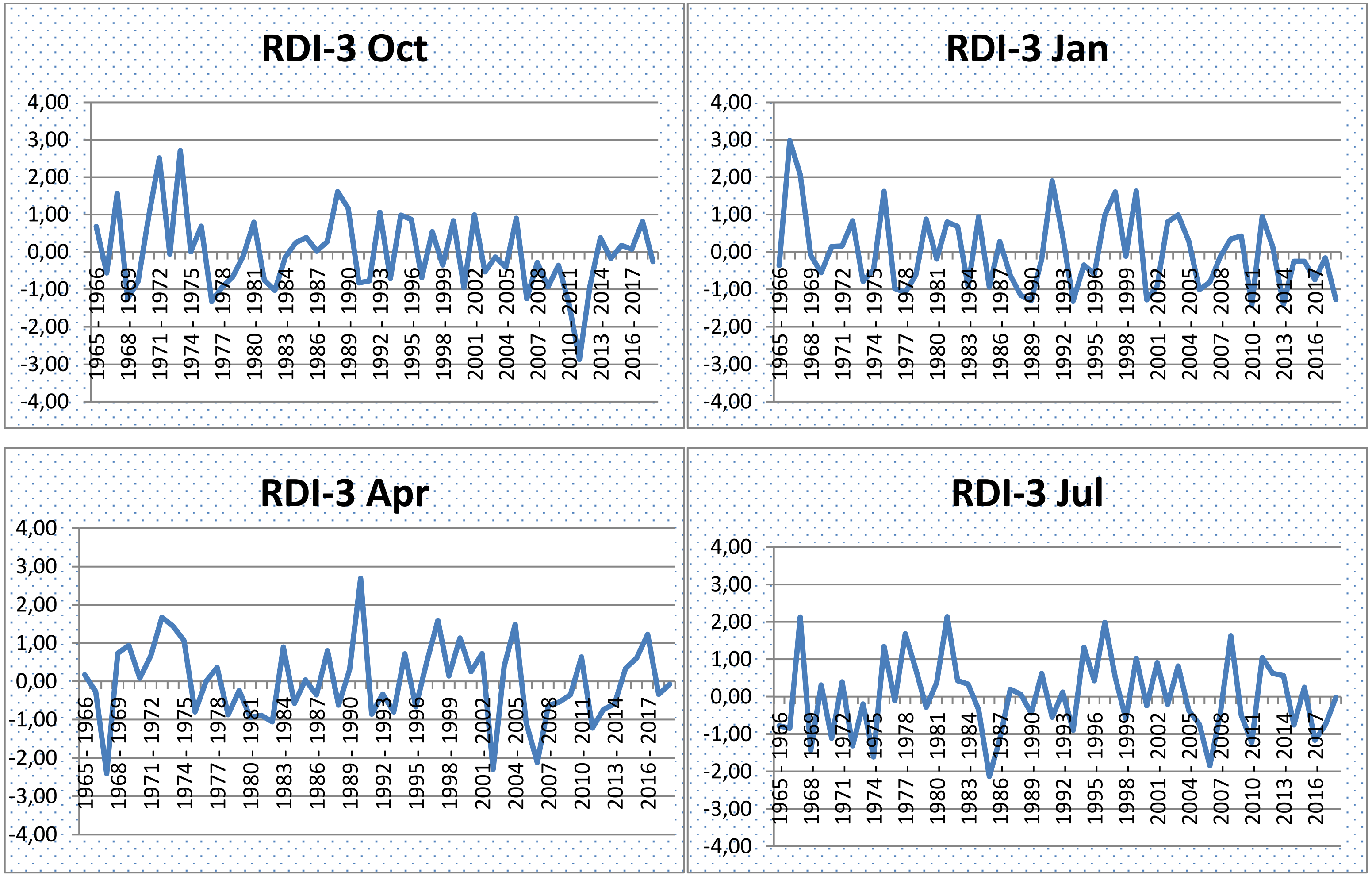


Figure 4.86. (Continued).


RDI-3 Oct

RDI-3 Jan

RDI-3 Apr

RDI-3 Jul

Figure 4.87. Dry - moist period distributions according to the 3-,6-,12 months RDI values for the Ulus Station from 1965 to 2019.

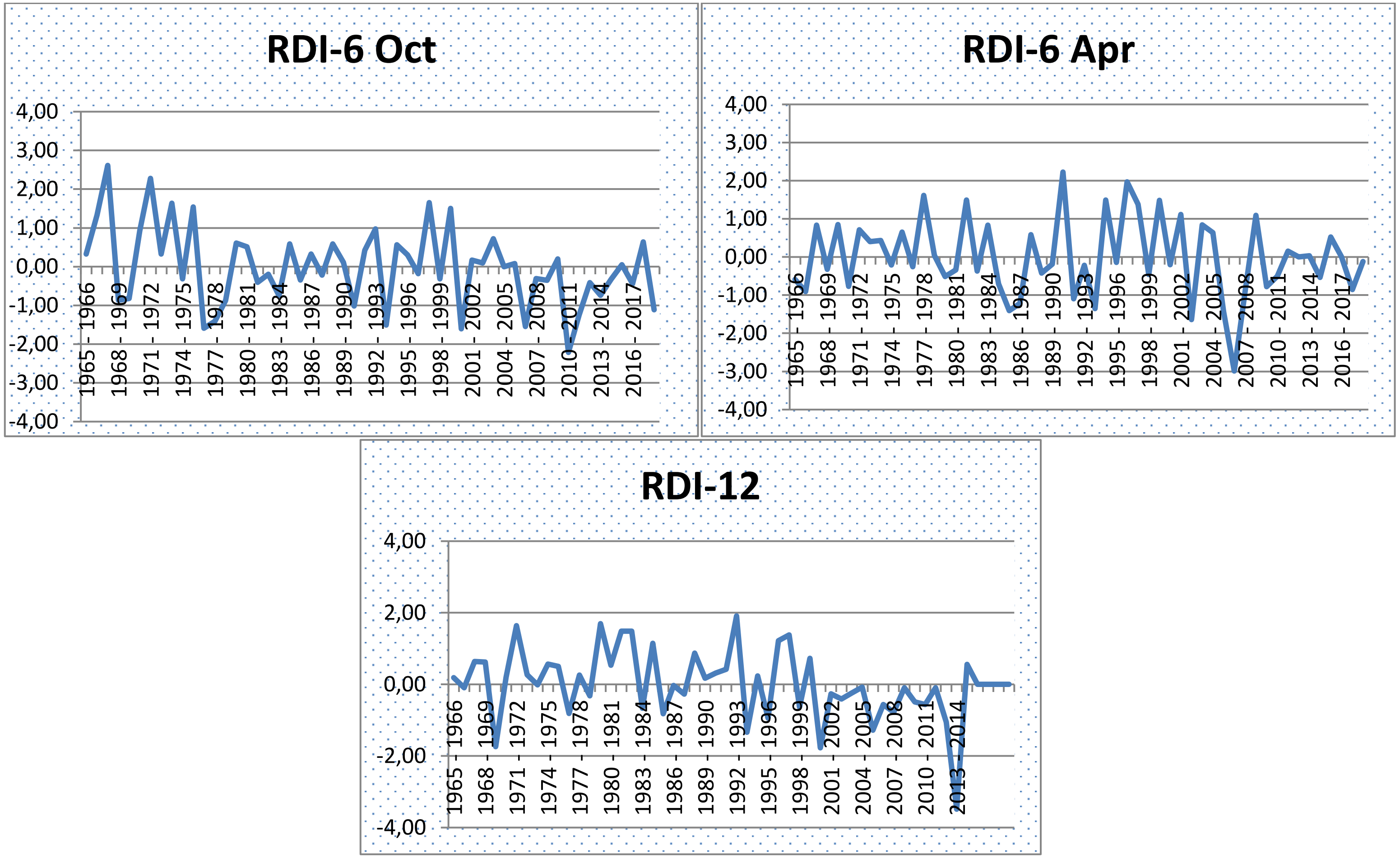


Figure 4.88. (Continued).

4.2.17. Kocaırmak/Bartın Flow Monitoring Station (D13A031) Hydrological Drought Analysis (SDI)

SDI values were examined during periods 1, 3, 6, and 12 months using monthly mean flow data measured between 1965-2015 of the Kocaırmak/Bartın Station. According to Figure 4.49 and Table 4.4, the highest dry month was at April in 1993-1994 period, and the highest moist month was in May 1997-1998 period.

Figure 4.50 time distributions of SDI values for 3, 6, and 12 months, while the highest dry periods were at SDI-3 in October in the year 2013-2014 and January 2012-2013 and April 1993-1994, the highest moist period was at SDI-3 in April in the year 1999-2000. The highest dry period at SDI-6 was in October 2012-2013, the highest moist period at SDI-6 was in October in the year 1990-1991, the highest moist period was in the year 1999-2000.

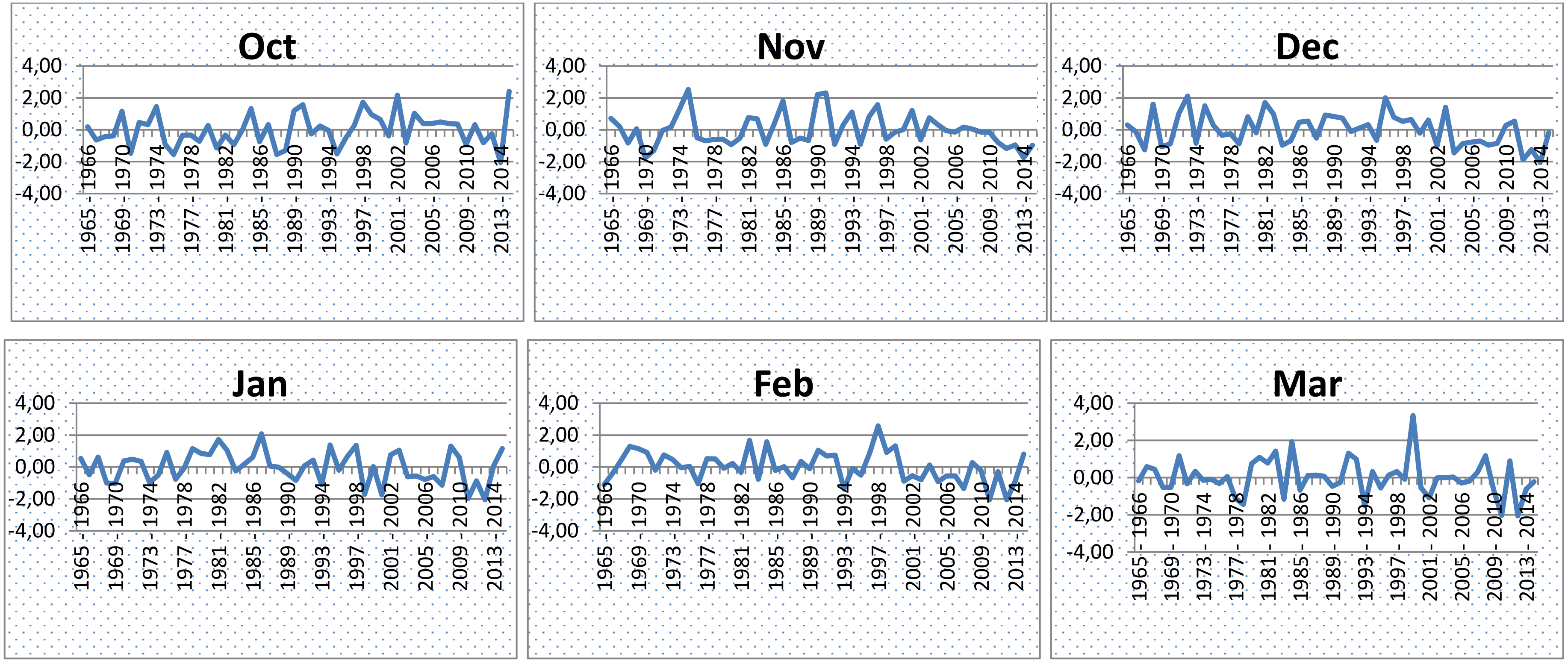


Figure 4.49. Dry - moist period distributions according to the monthly SDI values for the Kocaırmak/Bartın Station from 1965 to 2015.

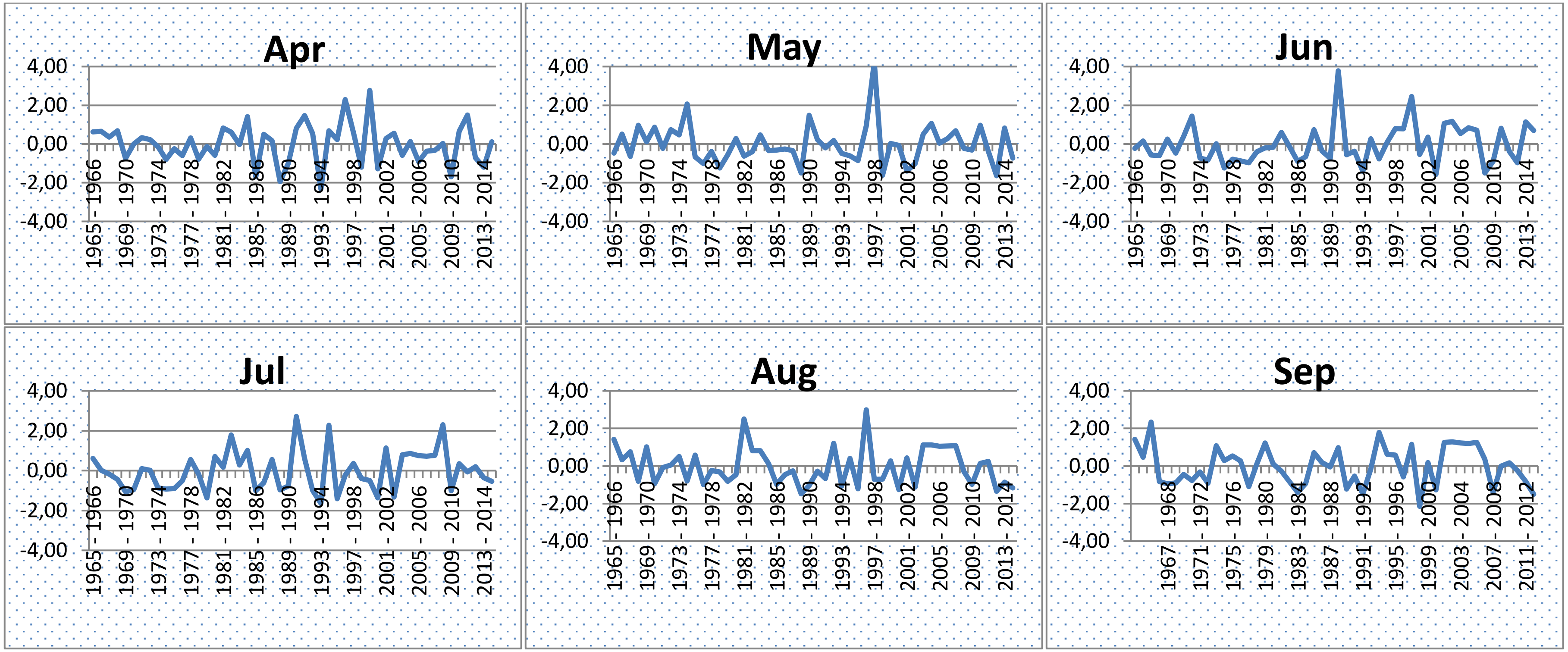


Figure 4.49. (Continued).

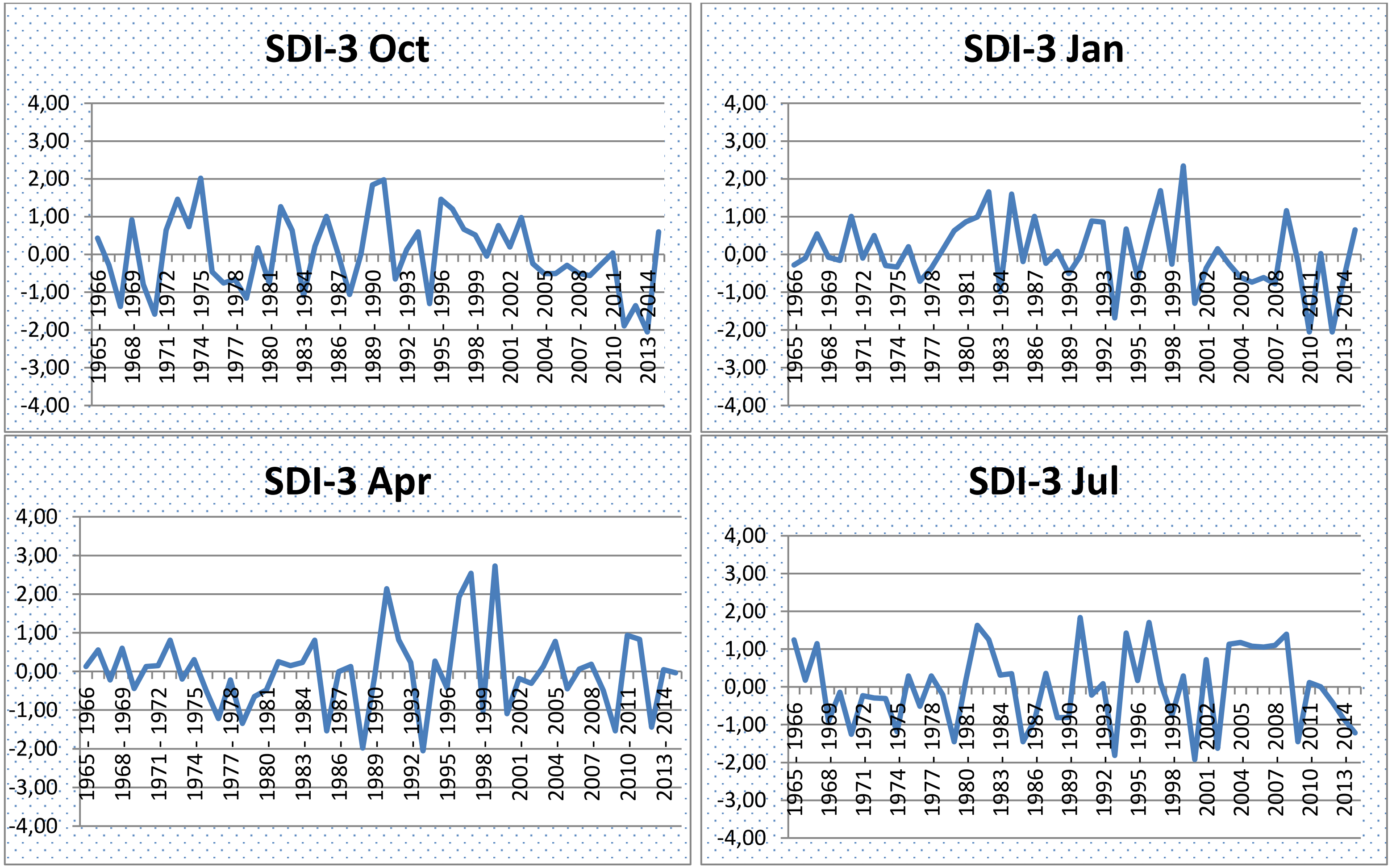


Figure 4.50. Dry - moist period distributions according to the 3-,6-,12 months SDI values for the Kocaırmak/Bartın Station from 1965 to 2015.

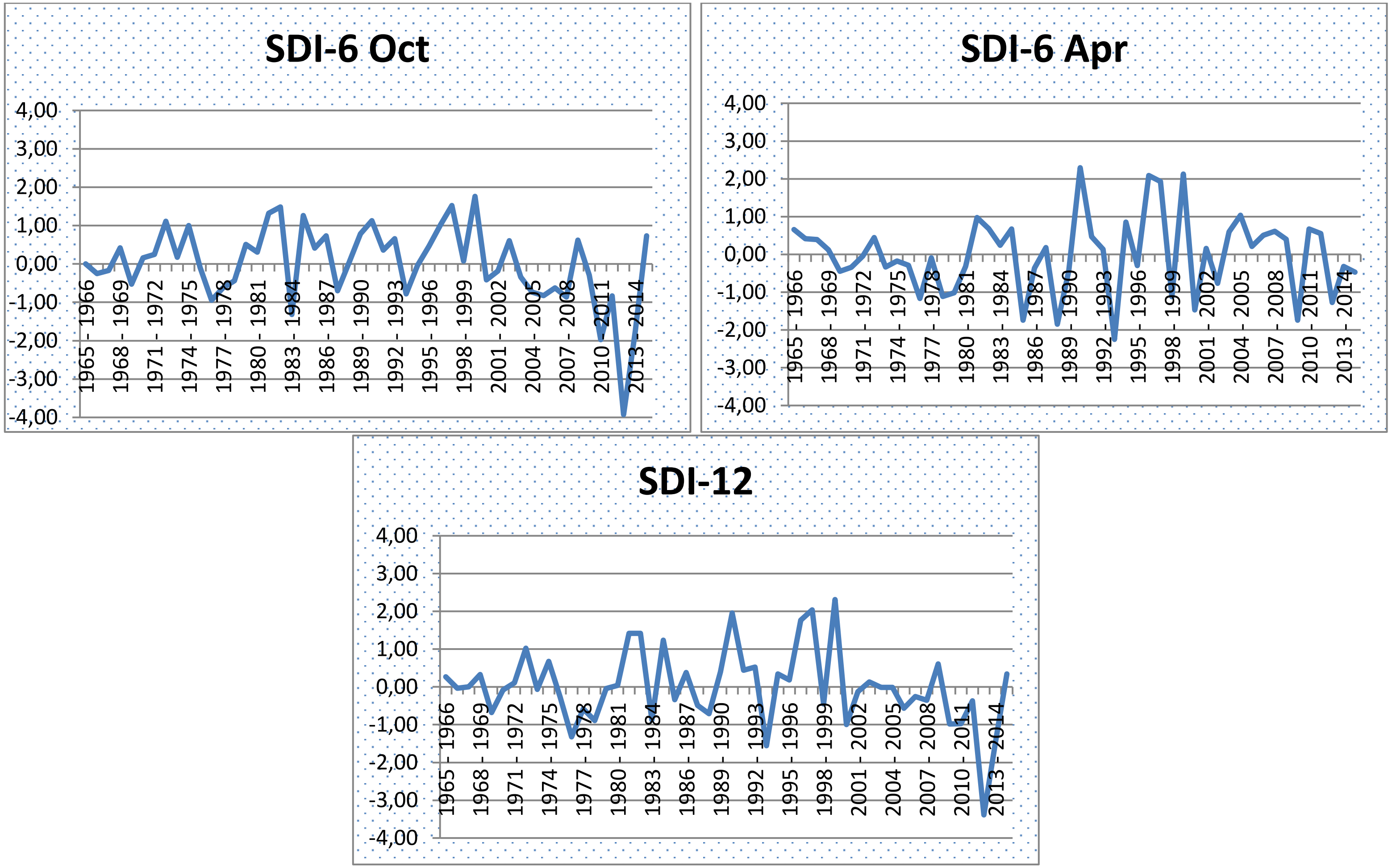


Figure 4.89. (Continued).

4.2.18. Karasu/Sinop Flow Monitoring Station (D13A032) Hydrological Drought Analysis (SDI)

SDI values were examined during periods 1, 3, 6, and 12 months using monthly mean flow data measured between 1965-2015 of the Karasu/Sinop Station. According to Figure 4.51 and Table 4.4, the highest dry month was at February in 2013-2014 period, and the highest moist month was at August in 1983-1984 period.

Figure 4.52 time distributions of SDI values for 3, 6, and 12 months, while the highest dry period was at SDI-3 in January in the year 2013-2014, the highest moist period was at SDI-3 in July in the year 1983-1984. The highest dry period at SDI-6 was in October 2013-2014, and the highest dry period was at SDI-12 in the year 2013-2014 , the highest moist period was in the year 1984-1985.

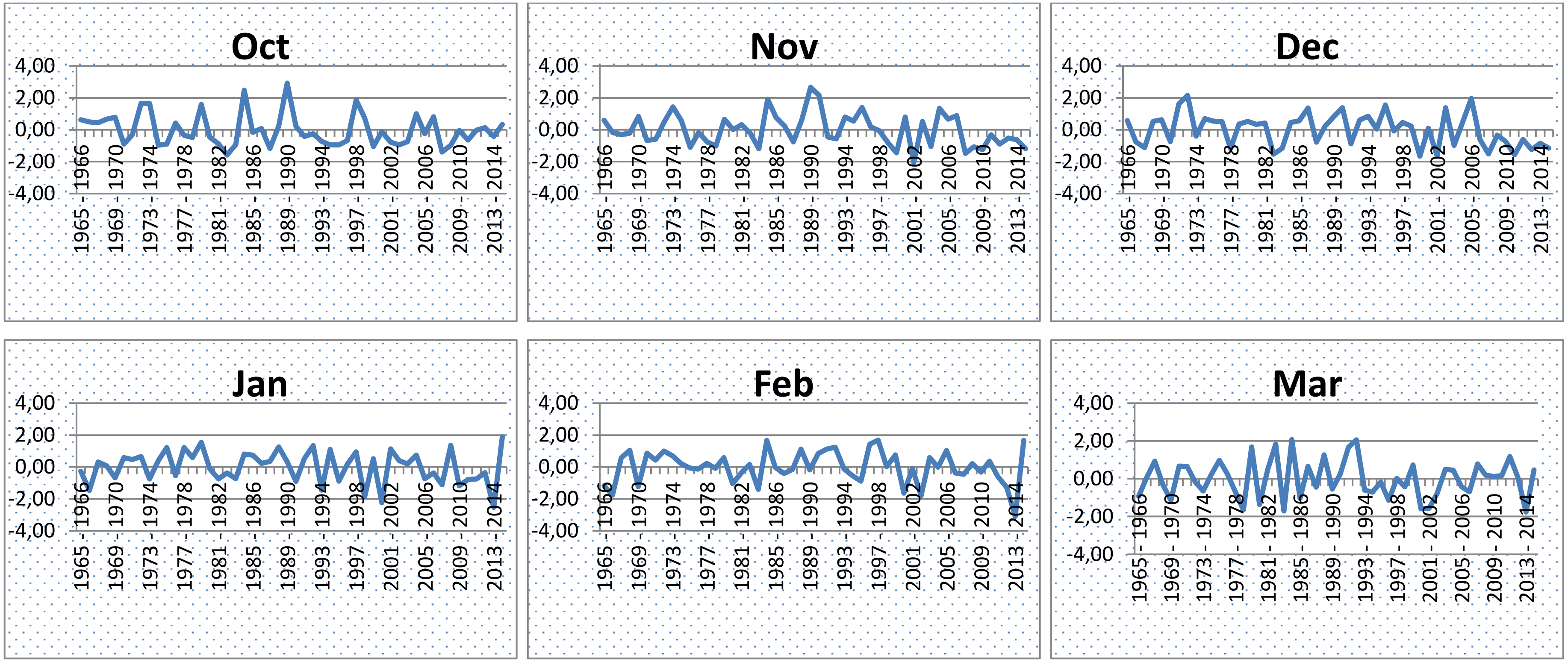


Figure 4.90. Dry - moist period distributions according to the monthly SDI values for the Karasu/Sinop Station from 1965 to 2015.

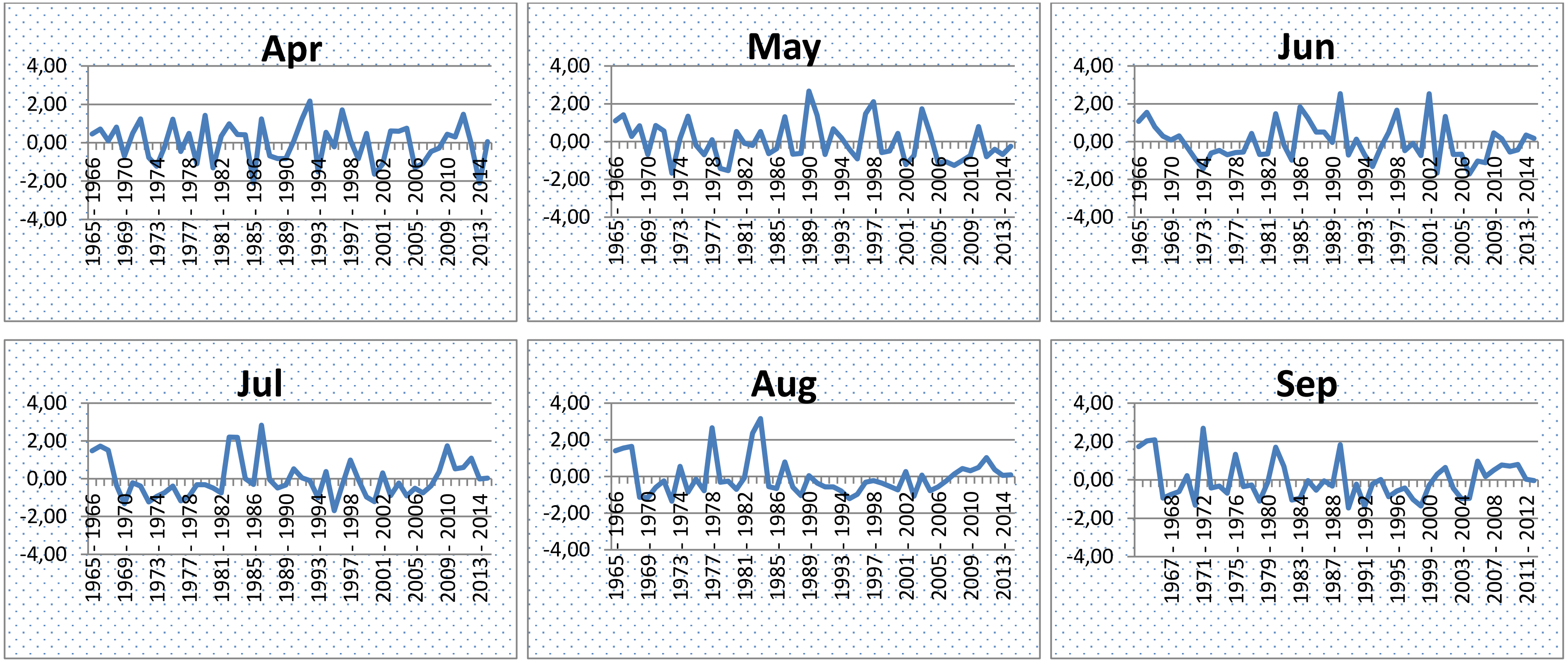


Figure 4.91. (Continued).

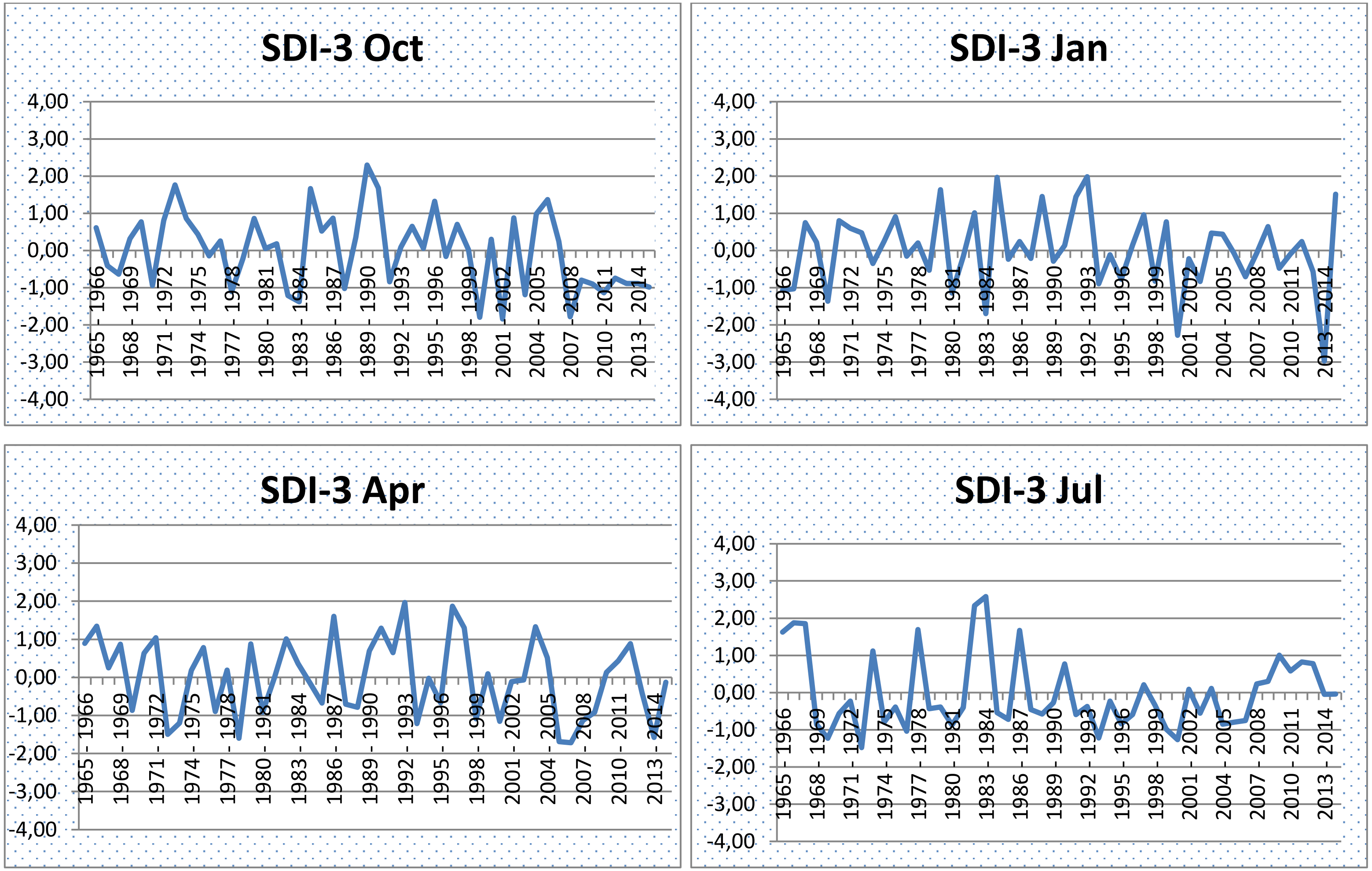
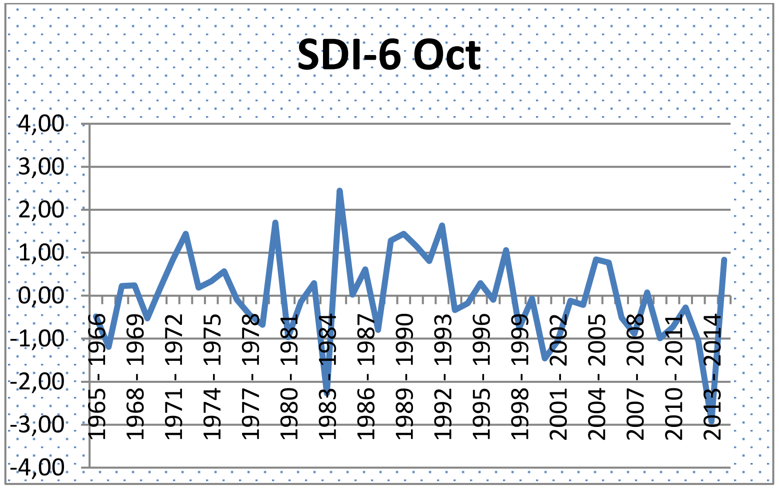
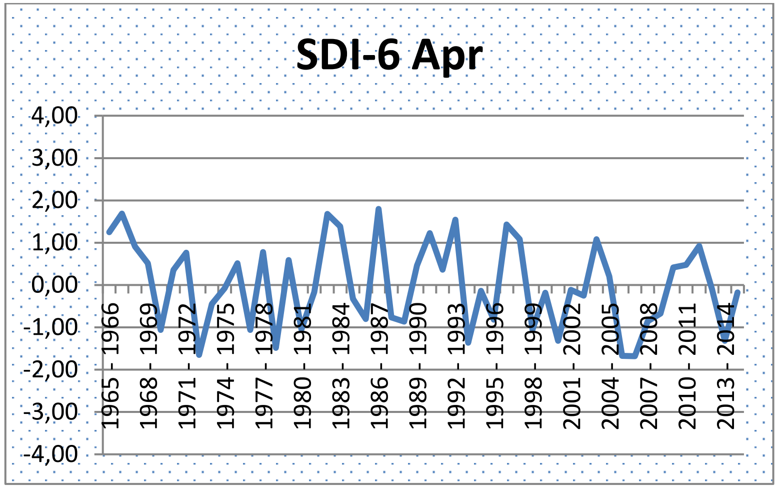


Figure 4.92. Dry - moist period distributions according to the 3-,6-,12 months SDI values for the Karasu/Sinop Station from 1965 to 2019.





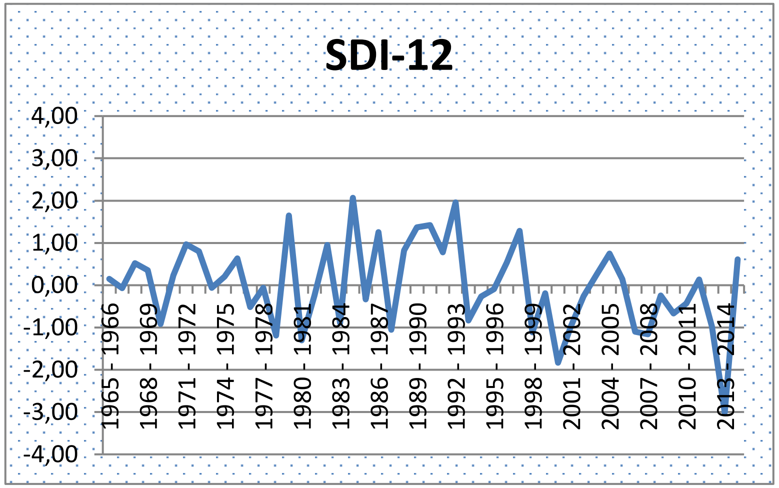


Figure 4.93. (Continued).

4.2.19. Devrekani /Kastamonu Flow Monitoring Station (E13A007) Hydrological Drought Analysis (SDI)

SDI values were examined during periods 1, 3, 6, and 12 months using monthly mean flow data measured between 1965-2015 of the Devrekani/Kastamonu Station. According to Figure 4.53 and Table 4.4, the highest dry month was at August 2005-2006 period, and the highest moist month was at October 1973-1974 period.

Figure 4.54 time distributions of SDI values for 3, 6, and 12 months, while the highest dry period was at SDI-3 in October in the year 2014-2015 and January and 2013-2014, the highest moist period was at SDI-3 in July in the year 1971-1972, The highest dry period at SDI-6 was in April 2013-2014, and the highest dry period was at SDI-12 in the year 2013-2014, the highest moist period was in the year 1992-1993.

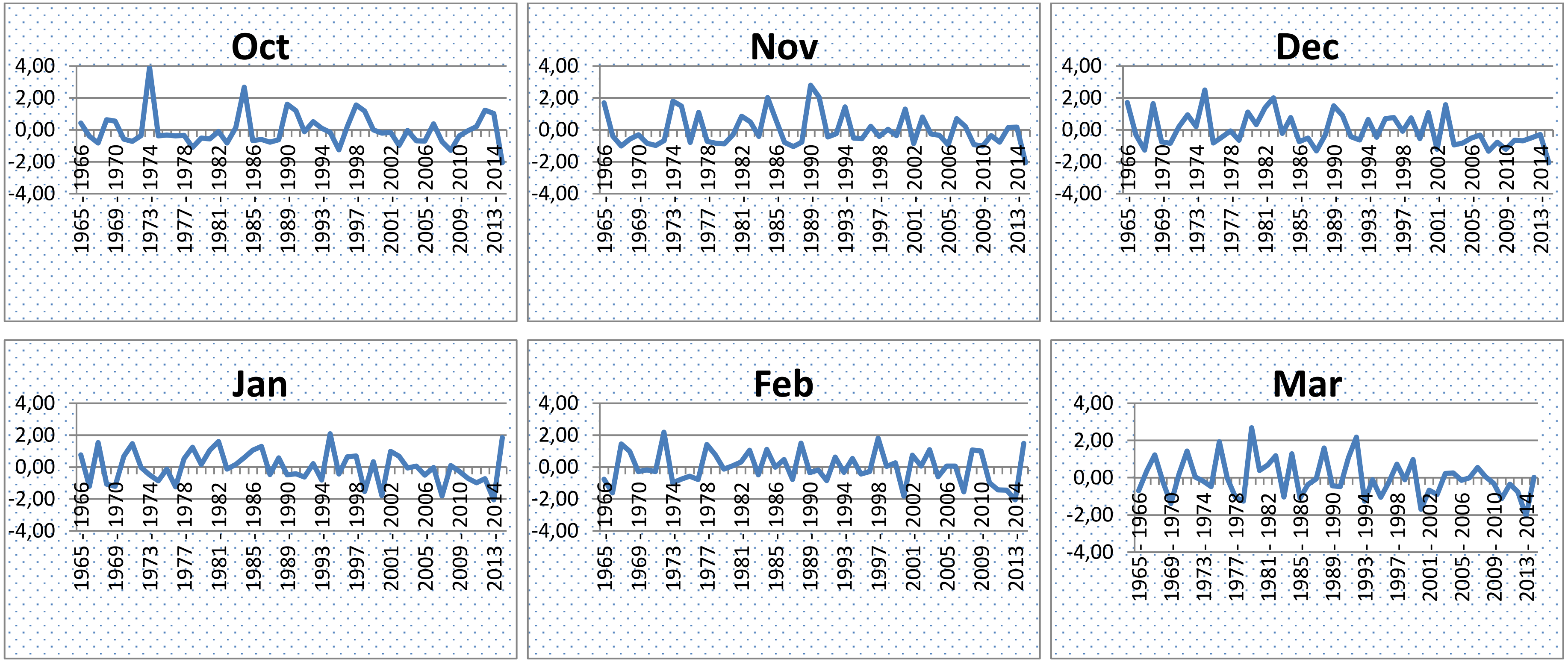


Figure 4.94. Dry - moist period distributions according to the monthly SDI values for the Devrekani/Kastamonu Station from 1965 to 2015.

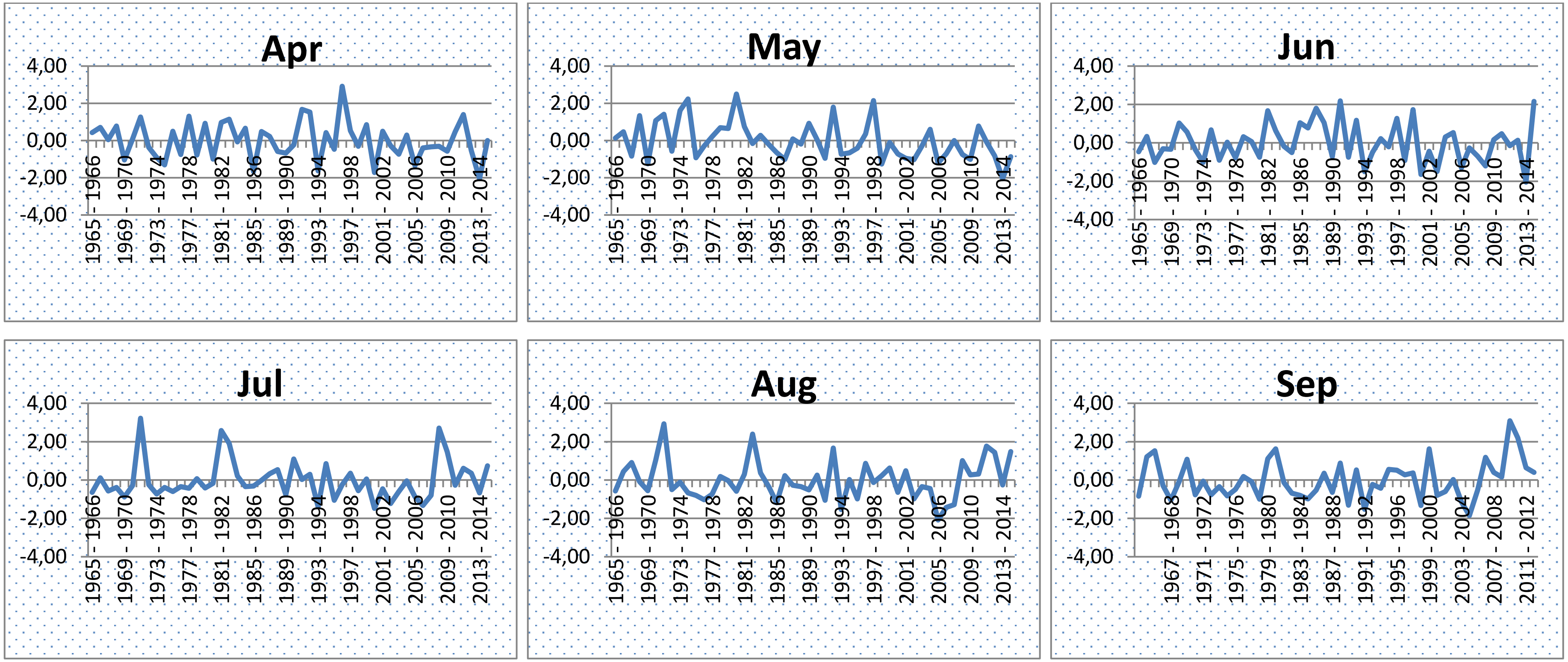


Figure 4.95. (Continued).

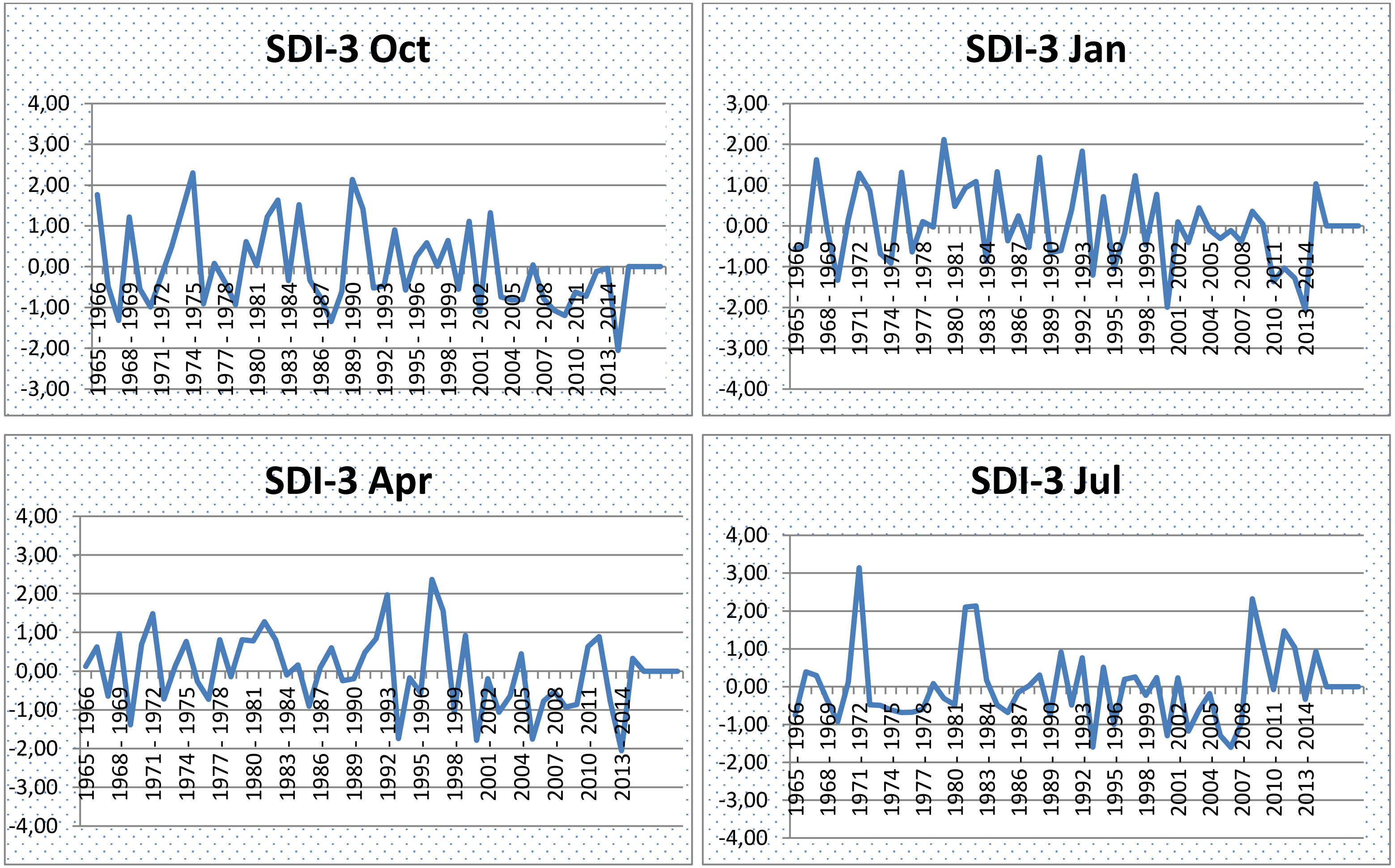


Figure 4.96. Dry - moist period distributions according to the 3-,6-,12 months SDI values for the Devrekani/Kastamonu Station.

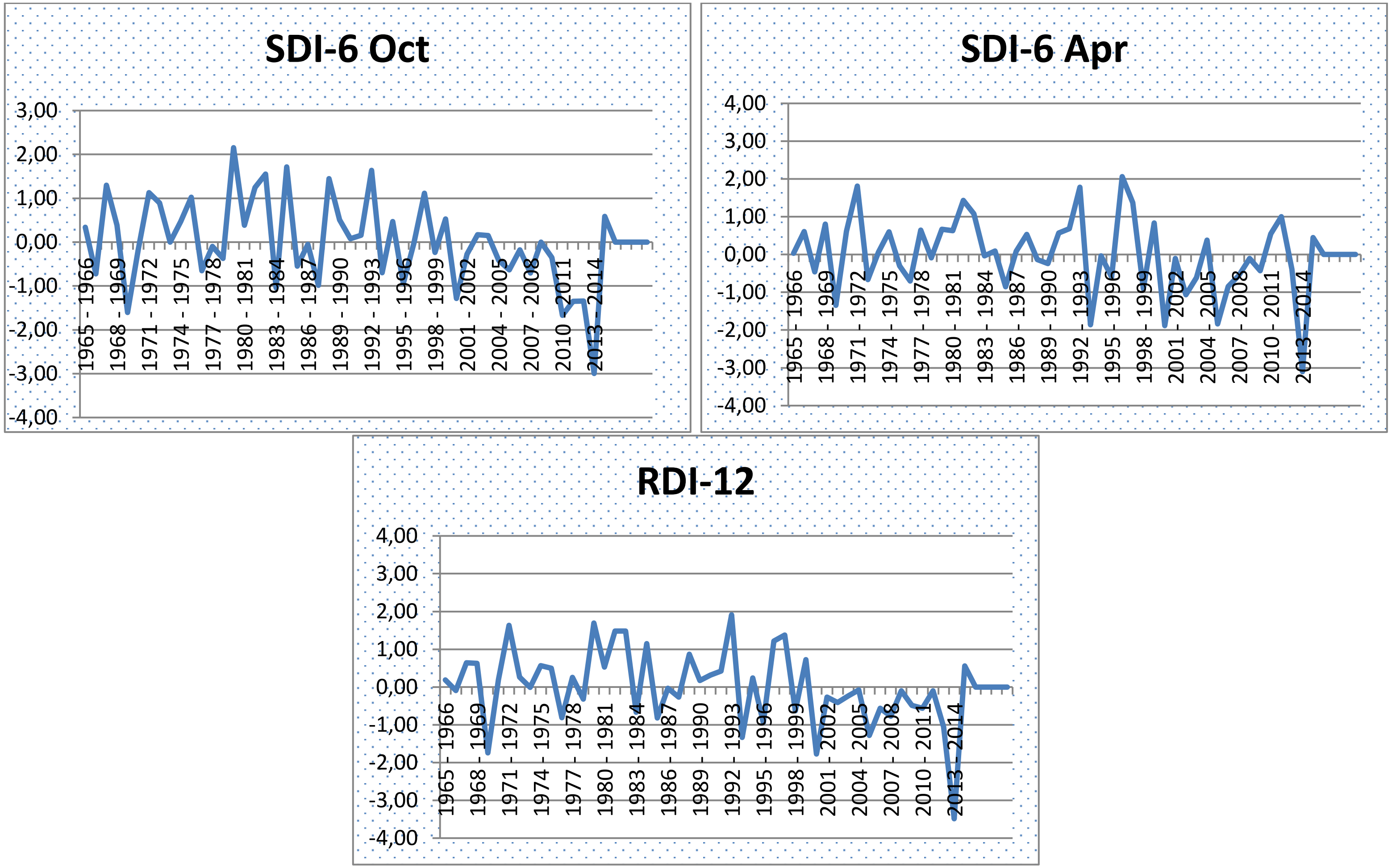


Figure 4.97. (Continued).

Table 4.5. Distributions of the dry-moist period according to the monthly SPI drought ratio for stations from 1965 to 2109.

		AMASRA	BARTIN	DEVREKANİ	İNEBOULU	KASTAMONU	SİNOP	BOZKURT	ULUS
Monthly	Range of Dry %	43% - 57%	41% - 54%	41% - 52%	35% - 56%	37% - 54%	41% - 54%	41% - 57%	43% -56%
	The highest Dry period	57% Jun	54% July	52% Sep, Aug	56% Oct, July	54% Oct, July	54% Mar	57% Aug	56% Feb, May
	The lowest Dry period	43% Dec	41% Apr	41% Jan, Apr	35% Sep	37% Aug	41% Jan, Sep	41% Jan, Apr, Jun	43% Oct
	The highest wet period	57% Dec	59% Apr	59% Jan, Apr	65% Sep	63% Aug	59% Jan, Sep	59% Jan, Apr, Jan	57% Oct
	The lowest wet period	43% Jun	46% July	48% Sep, Aug	44% Oct, July	46% Oct, July	46% Mar	43% Aug	44% Feb, May
3 Monthly	The highest Dry period	61% SPI3-Apr	54% SPI3-Jul	54% SPI 3-Jul	50% SPI 3-Jul	54% SPI 3-Oct	50% SPI 3-Jan, July	48% SPI 3-Oct	56% SPI3-Oct
	The lowest Dry period	44% SPI3-2 Jan	50% SPI3-1,2 Oct, Jan	44% SPI 3-1 Oct	41% SPI 3-3 Apr	43% SPI 3-3 Apr	46% SPI 3-1,3 Oct, Apr	43% SPI 3-2 Jan	46% SPI3-2 Jan
6 Monthly	The highest Dry period	54% SPI6-Apr	57% SPI6-Apr	56% SPI6-Oct	50% SPI6-Apr	50% SPI6-Apr	56% SPI6-Apr	52% SPI6-Oct	59% SPI6-Apr
	The lowest Dry period	48% SPI 6-Oct	54% SPI 6-Oct	50% SPI 6-Apr	46% SPI 6-Apr	46% SPI 6-Oct	46% SPI 6-Oct	48% SPI 6-Apr	48% SPI6-Oct
12 Month	Dryness	54%	56%	50%	48%	50%	44%	50%	46%

Table 4.6. The abstract of SPI results of all stations from 1965 to 2019.

		AMASRA	BARTIN	DEVREKANİ	İNEBOULU	KASTAMONU	SİNOP	BOZKURT	ULUS
Monthly	The highest Dry	Feb (2012-2013), Mar (1986-1987)	Apr (2005-2006), Jan, Nov (2000-2001)	Nov (2000-2001)	Nov (2000-2001)	Dec (1984-1985), Apr (1985-1986,) Nov (2000-2001)	Jan (1970-1971)	Mar (2016-2017)	Apr (2005-2006)
	The highest Moist	May (1998-1999)	May (1997-1998)	Jan (1967-1968)	Feb (1984-1985)	Sep (2013-2014), Jan (2009-2010)	Oct (1988-1989)	Feb (1984-1985)	Jan (1967-1968), May (1997-1998)
3 Monthly	The highest Dry	SPI3-Apr (2011-2012)	SPI3-Apr (2005-2006) (2002-2003)	SPI3-Oct (2000-2001), Apr (2002-2003)	SPI3-Oct (1966-1967)	SPI3-Oct (2013-2014)	SPI3-Oct (1982-1983)	SPI3-Jan (2016-2017)	SPI3-Oct (2011-2012)
	The highest Moist	SPI3-Oct (1973-1974)	SPI3-Apr (1990-1991)	SPI3-4 July (2001-2002)	SPI3-Jan (2011-2012)	SPI3-Oct (1988-1989)	SPI3-Oct (1988-1989)	SPI3-Apr (2003-2004)	SPI3-Apr (1990-1991)
6 Monthly	The highest Dry	SPI6-Oct (1976-1977)	SPI6-Oct. (1993-1994)	SPI6-2 Apr (1993-1994)	SPI6-Apr (1973-1974)	SPI6-Apr (1993-1994), Oct (2016-2017)	SPI6-Apr (2006-2007)	SPI6-Jan (2017-2018)	SPI6-Apr (2006-2007)
	The highest Moist	SPI6-Oct (1967-1968)	SPI6-Oct (1967-1968)	SPI6-1 Oct (1967-1968)	SPI6-Oct (2011-2012)	SPI6-Apr (2013-2014)	SPI6-Apr (1983-1984)	SPI6-Apr (1982-1983)	SPI6-Oct (1967-1968)
12 Month	The highest Dry	SPI -12 (1993-1994)	SPI-12 (1993-1994)	SPI-12 (2005-2006) (1993-1994)	SPI-12 (1974-1975, (2005-2006)	SPI-12 (1993-1994)	SPI-12 (1993-1994)	SPI-12 (2017-2018)	SPI-12 (2006-2007)
	The highest Moist	SPI-12 (1967-1968, 1999-2000)	SPI-12 (1967-1968) Moist	SPI-12 (1981-1982, 1967-1968)	SPI-12 (2015-2016)	SPI-12 (2009-2010)	SPI-12 (1967-1968)	SPI-12 (1999-2000)	SPI-12 (1967-1968)

Table 4.7. The abstract of RDI results of all stations from 1965 to 2019.

		AMASRA	BARTIN	DEVREKANİ	İNEBOULU	KASTAMONU	SİNOP	BOZKURT	ULUS
Monthly	The highest Dry	May (2012-2013)	Apr (2005-2006)	Apr (2011-2012), May (1991-1992)	Jun (2002-2003)	Apr (1985-1986)	Jan (1970-1971)	Mar (2016-2017)	Apr (2005-2006)
	The highest Moist	Feb (1984-1985)	Jan (1971-1972), Dec (2016-2017)	Mar (1966-1967)	Feb (1984-1985))	Dec (1974-1975)	Feb (1984-1985)	Feb (1984-1985)	Jan (1966-1967), Dec (2016-2017)
3 Monthly	The highest Dry	RDI3-Apr (2011-2012)	RDI3-Oct (1966-1967)	RDI3-Apr (2002-2003)	RDI3-Oct (1966-1967)	RDI3-Apr (1993-1994)	RDI3-Jul (1993-1994)	RDI3-Apr (2017-2018)	RDI3-Oct (2011-2012)
	The highest Moist	RDI3-Jan (1966-1967) RDI3-Oct (1973-1974)	RDI3-Jan (2011-2012)	RDI3-Jan (1966-1967)	RDI3-Jan (2011-2012)	RDI3-Jan (2011-2012)	RDI3-Jan (2011-2012) RDI3-Oct (1988-1989)	RDI3-Jan (1984-1985)	RDI3-Jan (1966-1967)
6 Monthly	The highest Dry	RDI6-Oct (1976-1977)	RDI6-Oct (1993-1994)	RDI6-Apr (1993-1994)	RDI6-Apr (1973-1974)	RDI6-Apr (1993-1994)	RDI6-Apr (2006-2007)	RDI6-Apr (2017-2018)	RDI6-Apr (2006-2007)
	The highest Moist	RDI6-Oct (1967-1968)	RDI6-Oct (2011-2012)	RDI6-Oct (1967-1968)	RDI6-Oct (2011-2012)	RDI6-Oct (2011-2012)	RDI6-Oct (1988-1989) Oct (2011-2012)	RDI6-Apr (1983-1984)	RDI6-Oct (1967-1968)
12 Month	The highest Dry	RDI-12 (1993-1994)	RDI-12 (1993-1994)	RDI-12 (2005-2006), (1993-1994)	RDI-12 (1974-1975)	RDI-12 (1993-1994)	RDI-12 (1993-1994)	RDI-12 (2017-2018)	RDI-12 (2006-2007)
	The highest Moist	RDI-12 (1967-1968)	RDI-12 (1967-1968)	RDI-12 (1981-1982)	RDI-12 (1999-2000)	RDI-12 (2008-2009)	RDI-12 (1967-1968)	RDI-12 (1992-1993)	RDI-12 (1967-1968)

Table 4.8 .The abstract of SDI results of all stations from 1965 to 2015.

		Kocaırmak/Bartın (D13A031)	Karasu/Sinop (D13A032)	Devrekani / Kastamonu (E13A007)
Monthly	The highest Dry	Apr (1993-1994)	Feb (2013-2014)	Aug (2005-2006)
	The highest Moist	May (1997-1998)	Aug (1983-1984)	Oct (1973-1974)
3 Monthly	The highest Dry	SDI3-Oct (2013-2014), Jan (2012-2013), Apr(1993-1994)	SDI3-Jan (2013-2014)	SDI3-Oct (2014-2015), Jan (2013-2014), Apr (2013-2014)
	The highest Moist	SDI3-Apr (1999-2000)	SDI3-Jul (1983-1984)	SDI3-Jul (1996-1997), (1971-1972)
6 Monthly	The highest Dry	SDI6-Oct (2012-2013)	SDI6-Oct(2013-2014)	SDI6-Apr (2013-2014) Oct (2013-2014)
	The highest Moist	SDI6-Oct (1990-1991)	SDI6-Oct (1984-1985)	SDI6-Oct (1979-1980) Oct (1996-1997)
12 Month	The highest Dry	SDI-12 (2012-2013)	SDI-12 (2013-2014)	SDI-12 (2013-2014)
	The highest Moist	SDI-12 (1999-2000)	SDI-12 (1984-1985)	SDI-12 (1992-1993)

PART 5

CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

The effects of the drought may be broken down into two categories: those that are directly felt by people and those that are felt by the socioeconomic and environmental system as a whole. A decline in food production owing to a reduction in crops and yields is the immediate result of the first batch of drought in agricultural cultures. Indirect and second-order consequences in these areas include a decrease in employment and income due to a decrease in land usage, a decrease in operations (irrigation and harvesting), and a decrease in harvesting. The price of food rises quickly when there is a decrease in food output due to drought. The prevalence of such issues, particularly for small farmers and landless laborers, is obvious. Declining food output leads unnaturally to increasing food costs, and lack of access to suitable occupations lowers rural people's access to food. When there is a severe drought, unpleasant and unconventional uses of water resources, as well as poor water distribution networks, worsen the situation.

One of the biggest impacts of global climate change occurs on precipitation. This event may appear as droughts and floods. While occuring drought due to lack of precipitation in some regions; some floods flow as a result of extreme rains in some regions manifest itself. In this study, the climate the effect of the change in the West Black Sea Basin is innovative. Within the scope of the thesis study, the values of SPI, SDI, RDI for 1, 3, 6, and 12 months were calculated using the monthly total precipitation, monthly average tempreraturе, monthly average flow, and values for 8 meteorological stations and 3 flow monitoring station in the West Black Sea region, and droughts were examined. In addition, temporal changes of drought indices were evaluated.

The percentages of dry and rainy months are generally similar in the region. in terms of rainy and dry periods, while Amasra with Bartın stations, and İnebolu with Kastamonu stations are more compatible (except for the last few years) with each other, Bozkurt and Sinop stations offer differences from other stations.

In general, while the wet/rainy rates of Bartın, İnebolu, Kastamonu and Sinop stations are higher after 2008, the drought rates of Amasra, Bozkurt and Ulus stations are higher. In fact, Bozkurt station has a completely dry period after 2011. Devrekani station, on the other hand, has a more balanced distribution.

Specialized results are summarized below:

- For the SPI index: In the SPI-1 analysis of all stations on a monthly basis, drought ratio of Amasra, Bartın, Devrekani İnebolu, Kastamonu, Sinop, Bozkurt, and Ulus stations range between 43%-57%, 41%-54%, 41%-52%, 35%-56%, 37%-54%, 41%-54%, 41%-57%, and 43%-56%, respectively. Also, in Amasra snd Bozkurt stations it is found that Jun and August are drier than other months with 57% ratio and İnebolu Station follows them with 56% in July and October. Sinop station has more drought ratio in March than other month with 54%. Therefore, the fact that the highest ration of wet/rainy, as monthly, September and August with 63% and 65% of İnebolu, and Kastamonu, respectively indicates that humidity can be observed in the summer period in the region.

- In calculating SPI-3 for all stations based on the 3 monthly precipitation data in Amasra station, the highest values of drought is observed in SPI3-April in 2011-2012 extreme drought. The fact that 3 monthly drought ratio of Amasra station is 61% in April indicates that drought can be observed in the spring period. In other stations, SPI-3 rates are observed with 48% and 56% in June and October.

- On a yearly basis, while Bartın Station has highest SPI-12 drought ratio with 56%, Sinop Station has lowest drought ratio with 44%.

- According to SPI-1 intensity description of all stations on a monthly basis, the extreme drought values at Amasra, Bartın, Devrekani, İnebolu, Kastamonu, Sinop, Bozkurt, and Ulus stations were determined in February (2012-2013), April (2005-2006), November (2000-2001), November (2000-2001), December (1984-1985 and November (2000-2001)), January (1970-1971), March (2016-2017), and April (2005-2006), respectively. These results show that there are more extreme droughts after the 2000s, and that extreme droughts were/may be experienced in winter/spring as well. In general, SPI-3 results show compatibility with SPI-1.

- According to the SPI-12 results, while the extreme drought values in stations were observed between 1993-1994 and 2005-2006 periods, in Bozkurt station was observed 2017-2018 years.

- For the RDI index: The SPI and RDI results present very similar data with each other and RDI-1 and RDI-3 results show that in general, there are more extreme droughts after the 2000s, and winter/spring droughts were/may be observed in the region.

- For the SDI index: While the SDI values of the D13A0031 (Kocaırmak/Bartın) and D13A0032 (Karasu/Sinop) stations were with some delay compatible with SPI and RDI in terms of long-term dry and rainy periods, no significant compatibility was found at the E13A007 (Devrekani/Kastamonu) station. It is observed that hydrologically dry periods are dominant after 2000. While the most extreme drought was observed between 2012-2013 at Bartın and Karasu stations, it was observed at Devrekani station in 2013-2014 hydrological year.

- Although there is no study in the literature that fully overlaps with the study area, study method and/or study duration, there are various drought and trend analyzes for the Black Sea Region, and results that generally overlap with other general meteorological results were obtained from this study. The percentages of dry and rainy months in the region are generally similar and an increase in meteorological, agricultural and hydrological droughts has been observed in recent years.

5.2. RECOMMENDATIONS

- This study investigated drought analysis in eight extreme precipitation indicators for the observed and forecast data at eight stations located in the Western Black Sea Basin, Turkey. They were evaluated separately for each indicator. These indicators, as indicators of climate change in the Western Black Sea area, determine the rainfall pattern of the study area, and any change compared to previous years in their values can be a useful criterion for future modeling. On the other hand, the results of climate change projections based on global circulation models can be useful to planners or policymakers in terms of flood risks or drought analyses. As indicated by the results of this study, there will be an increase in the total amount of precipitation and the number of dry days. This indicates that it will be more likely for a short time duration and extreme precipitation events that will occur in the future. This means there will be more dry days and more wet days with the potential to cause flooding. On the other hand, to deal with the challenges of changing the precipitation pattern and maintaining economic growth.

- Monitoring, assessment, and continuous awareness of drought and the effects of drought in order to prevent and reduce its negative effects in rural areas are the main factors in effective management. Undoubtedly, the development of standard tools and availability of reliable data and information accessible through can provide a solid foundation for efficient planning. Due to the importance of the subject, this study was conducted to compare and assesment the drought impact scale. Results, drought impact the scale/instrument developed for the assessment has sufficient validity and reliability. However, work to increase the number synoptic stations, and improvements to data completeness and standard completion of missing data with the most reliable methods is necessary to raise the efficiency and performance of West Black Sea meteorological stations.

- What is certain is that drought cannot be avoided at all. Cause the drought is probably random. It is an event and is unpredictable. However, in this context, the consequences of drought and impacts by formulating and implementing consistent programs and largely by adopting strategies appropriate to the local conditions and conditions of the region. It can be reduced. The results of this study are based on water resources management and water supply and demand. Managers, planners, and experts in optimizing planning can enable them to make the necessary arrangements and offer practical solutions.

- The severity of drought will increase dramatically with increasing temperature. The temperature of the weather on the Earth's surface has increased due to global warming, and the temperature is expected to rise by 3-5°C in the next 100 years. Aridity indicators that only precipitation cannot reflect the effects of global warming on drought. RDI methods is important due to contain temperature data. In future meteorological, agricultural and hydrological drought studies, it is recommended to compare different drought methods in the study area ant its vicinity with different climatic characteristics. Expecially, Standardized evapotranspiration index (SPEI) that consider temperature, solar radiation, humidity, wind speed, and precipitation data can use at in the future study for reflect the effects of global warming.

- This study investigated drought analysis in eight extreme precipitation indicators for the observed and forecast data at eight stations located in the Western Black Sea Basin, Turkey. They were evaluated separately for each indicator. These indicators, as indicators of climate change in the Western Black Sea area, determine the rainfall pattern of the study area, and any change compared to previous years in their values can be a useful criterion for future modeling. On the other hand, the results of climate change projections based on global circulation models can be useful to planners or policymakers in terms of flood risks or drought analyses. As indicated by the results of this study, there will be an increase in the total amount of precipitation and the number of dry days. This indicates that it will be more likely for a short time Duration and extreme precipitation events that will occur in the future. This means there will be more dry days and more wet days with the potential to cause flooding. On the other hand, to deal with the challenges of changing the precipitation pattern and maintaining economic growth.

Generally, there is a lag time correlation of a period of time between hydrological and meteorological droughts for the Western Black Sea Basins. Since a meteorological drought emerges in the following year as a hydrological drought, prudent executive decisions can be made regarding the adequate planning of water resources and hydroelectric and agricultural productions in a studied region. The streamflow drought index (SDI), together with their classifications, provides a reliable method in the analysis of meteorological and hydrological droughts.

- In this study, it has been revealed that hydrolic drought is remarkable especially in recent years. However, the number of current observation stations with especially high quality and long-term data in the region is low. In particular, these stations need to be replicated and improved.

- In general, it seems that monitoring of meteorological and hydrological droughts can be carried out by using several drought indices (e.g., SPI and SDI). The results suggest links between meteorological and hydrological droughts based on the use of the SPI and SDI. For example, the lag time between the SPI and SDI series can be helpful information for improving drought monitoring and early warning systems. However, hydrological droughts may not be fully explained just by the meteorological drought indices, there may be contain other geological, topografical and some physical variables.

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CURRICULUM VITAE

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