Abstract: The present research was carried out to study drought and its effects upon water resources using remote sensing data. To this end, the tropical rainfall measuring mission (TRMM) satellite precipitation, the synoptic stations, and fountain discharge data were employed. For monitoring of drought in the study area, in Kermanshah province, Iran, the monthly precipitation data of the synoptic stations along with TRMM satellite precipitation datasets were collected and processed in the geographic information system (GIS) environment. Statistical indicators were applied to evaluate the accuracy of TRMM precipitation against the meteorological stations’ data. Standardized precipitation index, SPI, and normalized fountain discharge were used in the monitoring of drought conditions, and fountains discharge, respectively. The fountains were selected so that in addition to enjoying the most discharge rates, they spread along the study area. The evaluation of precipitation data showed that the TRMM precipitation data were of high accuracy. Studies in temporal scale are indicative of the strike of drought in this region to the effect that for most months of the year, frequency and duration in dry periods are much more than in wet periods. As for seasonal scales, apart from winter, the frequency and duration of drought in spring and autumn have been longer than in wet years. Moreover, the duration of these periods was different. A comparison between the results of changes in fountain discharges and drought index in the region has verified that the drought has caused a remarkable decline in the fountain discharges.

Keywords: synoptic stations; water resources; SPI; precipitation; fountain

1. Introduction

Drought is reckoned to be one of the prevalent and economically injurious climatic phenomena. Wireless sensor networks are one of the most efficient techniques for real-time monitoring of areas that are prone to disasters [1]. Gerislioglu et al. [2] introduced a reconfigurable antenna board to control nearly the entire planar antenna design through a phase transition procedure with a combined independently addressable micro heater matrix. Valipour [3] studied the annual precipitation based on nonlinear input–output (NIO), a nonlinear autoregressive neural network (NARNN), and NARNN with exogenous input (NARNNX). They showed that the accuracy of the NARNNX was better than that of
the NARNN and NIO. Decreasing of drought aftermath requires management and nonstop monitoring of this incident [4,5]. Centers such as National Aeronautics and Space Agency, NASA and National Oceanic and Atmospheric Administration, NOAA, by means of various tools like Tropical Rainfall Measuring Mission, TRMM, have made a conspicuous bunch of climatic data with different spatial and temporal resolutions in global and regional scale available to users [6]. According to Flores et al. [7], drought indices are single values that determine the current situation of the region precipitation. Considering the negative effects of drought on water resources, Monea Lain [8] suggested alternative managerial solutions for drought seasons. Using TRMM and stations data, Naumann et al. [9] addressed the monitoring of the droughts happening in four river basins in Africa. Their results showed that TRMM data with high spatial resolutions are reliable for drought monitoring of those rivers. Jiang et al. [10] used TRMM images of an 11-year period, as well as data of the upstream and downstream meteorological stations, to study droughts. The comparison between the results obtained from standardized precipitation index (SPI), TRMM images, and meteorological stations in the one- and three-month scales was indicated by a more than 60% conformity. Ezzine et al. [11], using TRMM data and monthly precipitation data of meteorological stations in Morocco, concentrated on droughts in the one- and three-month scales with standardized precipitation index (SPI). Their results showed a good agreement among TRMM data and meteorological station data in the three-month scale. Cheng and Shuhe [12] studied the droughts of Huanghuai Hai plain through downscaling of TRMM data with the spatial resolution of 0.25 × 0.25 degrees to 0.05 degrees, and also by using SPI and stations’ data. Their results corresponded high accuracies to the downscaled data and showed that this approach could be used in drought monitoring. Levina et al. [13] compared the TRMM data with the APHRODITE database to investigate the droughts of Pemali-comal river basin. Their results were compared to the meteorological stations’ data to infer their apt procedure. The TRMM data were yet of higher performance in monitoring of hydrological droughts than APHRODITE data. Using TRMM monthly precipitation data, De Jesus et al. [14] studied the droughts in Mexico in the duration of 1998–2013. The results showed that the data, though not enjoying adequate time periods, could be well applied in the monitoring of droughts in the region. Ouatiki et al. [15] investigated the drought situation, along with water resources, of Oum-Er-Rbia basin in Morocco by means of TRMM precipitation data. They showed, through their results, that TRMM precipitation data can be employed in monthly and annual scale in monitoring and management of water resources in ungauged watersheds of semiarid regions. By surveying groundwater recharge rates in drought periods relating to Santa Catalina Island, S. California, Harlow and Hagedorn [16] got the conclusion that the recharges have conspicuously decreased in drought periods. Khameepea et al. [17] used drought indices to study drought monitoring in the south of Thailand. Their inspections confirmed that in this region the groundwater level declines noticeably as the precipitation lessens in dry seasons. Drought and water instability seem to be a major challenge facing many watersheds.

Kermanshah Province has, in recent years, encountered environmental hazards such as drought followed by reduction in water resources. Recognizing spatial and temporal changes in precipitation, along with monitoring of drought by the use of high spatial resolution data in this province, particularly in ungauged basins, will facilitate the optimal management of water resources. The aims of this study were twofold, firstly, analysis drought conditions using observed precipitation and remote sensing TRMM data and secondly, analysis relationship of drought to spring/fountain discharge for the Kermanshah province.

2. Research Method

2.1. Study Area

Kermanshah province, located in the west of Iran between latitudes 33° 36′ and 35° 15′ N, and longitudes 45° 24′ and 48° 30′ E, has an elevation of 1332 m, and average precipitation of 430 mm. The Zagros mountains influenced the study area and its hot, summer Mediterranean climate. The area
is located in Sanandaj Sirjan zone and comprises hilly land and plains with agricultural and forest areas. Zagros Mountains comprise shale, limestone, marls, and sandstone materials. Ravansar station, with an average of total rainfall of 530 mm, has the maximum, and Ghasr-e-Shirin station, with the average of 360 mm, has the minimum rate of annual precipitation [18]. Figure 1 depicts the study area and geographical locations of synoptic stations of Kermanshah province.

2.2. Satellite Images of TRMM

The TRMM is the meteorological satellite launched by National Aeronautics and Space Agency, NASA, and National Space Development Agency, NASDA, with the aim of quantitative measuring of precipitation in tropical and subtropical areas [6]. Being approximately 350 km above sea level, this satellite has five primary sensors, each measuring some kind of rainfall-dependent parameters. This satellite voyages several times each day around the globe to capture the required information. The repetition of data acquisition and transmission of the satellite varies from area to area and depends on the latitudes. According to the research, the information obtained from TRMM 3B42 and 3B43 are typically used to inspect the rainfall values of via TRMM satellite. The main difference between these two byproducts is their temporal scale. The TRMM 3B42 encompasses daily and hourly data and 3B43 includes monthly data of precipitation. The latter is a combination of satellite estimation data of TRMM 3B42 and observational data [6]. In this study, TRMM 3B43 monthly precipitation data was used.

2.3. Statistical Indicators

In the present research, evaluation of the two databases was performed with the help of statistical indices of correlation coefficient ($R^2$), efficiency coefficient (EF), agreement coefficient (IA), slope, normalized root mean square error (NRMSE), and BIAS in the MATLAB environment (MathWorks, MA, USA). The coefficient $R^2$ is calculated from Equation (1) [19]:

$$R^2 = \frac{\sum_{i=1}^{n} (P_i - \overline{P})(O_i - \overline{O})^2}{\sum_{i=1}^{n} (P_i - \overline{P})^2 (O_i - \overline{O})^2}$$

where $P_i$, $O_i$, $\overline{P}$, $\overline{O}$, are, respectively, TRMM precipitation rate, the observational precipitation rate, the average TRMM precipitation, the average observational precipitation.
EF is a statistical indicator, having the most application in the comparison between TRMM precipitation data and observed precipitation. When EF = 1, the efficiency of TRMM satellite in the estimation of the real precipitation sounds appropriate. This indicator is computed by Equation (2) [20]:

\[
EF = 1 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} (O_i - \bar{O})^2}.
\]  

(2)

The agreement coefficient (IA) designates the rate of conformity between the values of the two time series, and is obtained by Equation (3):

\[
IA = 1 - \frac{\sum_{i=1}^{n} (P_i - O_i)^2}{\sum_{i=1}^{n} (|P_i - \bar{P}| + |O_i - \bar{O}|)^2}.
\]  

(3)

In linear regression, the more the slope between TRMM and observational precipitation is close to 1, the more direct the relationship between the two variables would be. The slope is obtained from Equation (4):

\[\text{Slope} = R \frac{\sigma_P}{\sigma_O}\]  

(4)

where \(R\), \(\sigma_P\), and \(\sigma_O\) are, respectively, correlation coefficient between TRMM and observational precipitation, standard deviation of TRMM precipitation data, and standard deviation of observational precipitation data.

The NRMSE represents the mean square error dimensionless, and it is calculated by Equation (5) [21]:

\[
\text{NRMSE} = \frac{1}{O} \sqrt{\frac{1}{n} \sum_{i=1}^{n} (P_i - O_i)^2}
\]  

(5)

where \(n\) is the number of data. The BIAS coefficient, which determines the discrepancy between observational and TRMM data, is computed through Equation (6) [15]:

\[
\text{BIAS} = \frac{1}{n} \sum_{i=1}^{n} (P_i - O_i).
\]  

(6)

It is necessary to be able to identify bias in results, since BIAS is the tendency of a statistic to overestimate or underestimate the parameter, such as TRMM precipitation. The BIAS index indicates the average error of the model in the overestimation or underestimation of observed values. A value of zero for this index indicates that the model was able to predict the observed values well. Positive and negative values also indicate overestimation and underestimation, respectively [20].

2.4. Drought Indices

Drought indices signify the precipitation rate of a certain period relative to precedent periods. In this research, the Standardized Precipitation Index (SPI) was used in monitoring of drought. SPI is a dimensionless index whose negative values are a sign of drought and its positive values signify the wetness condition. The SPI values vary from less than or equal to −2 for extreme dry situations, toward +2 for more for wet conditions [22]. This index makes the observational precipitation into a drought index, and is calculated by Equation (7) [23]:

\[
\text{SPI} = \frac{P_i - \bar{P}}{\sigma}
\]  

(7)
where $\sigma$ is the standard deviation and $P_i$ and $\bar{P}$ are the precipitation in the $i$th season or year, and the average participation during the statistical data period, respectively. The normalized fountain discharge is calculated by Equation (8) [24]:

$$\text{Normalized Fountain Discharge} = \frac{Q_i - \bar{Q}}{\sigma}$$

where $\sigma$ is the standard deviation and $Q_i$ and $\bar{Q}$ are the discharge in the $i$th season or year and the average discharge during the statistical data period, respectively.

### 2.5. Data Analysis

#### 2.5.1. Drought

To the purpose of drought monitoring of the intended area, monthly precipitation data of the synoptic stations of Kermanshah Province were collected from the Iran Meteorological Organization. The gridded data pertaining to TRMM precipitation at 42 points with spatial resolution of 0.25 × 0.25 degrees were received from NOAA official site, and were processed via geographic information system, GIS. GIS is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. Considering the statistical duration of the monthly precipitation from the meteorological stations and the monthly precipitation of TRMM, a joint period from 2000 to 2014 was established. Using statistical tools, the precision of TRMM data against the observational data of the selected synoptic stations was scrutinized. Evaluations were conducted using MATLAB, SPSS (IBM Corporation, NY, USA), and MS-Excel software (Microsoft, WA, USA). After the evaluation of TRMM data and ensuring high spatial and temporal precision, the drought and wet periods of the study area were monitored by the SPI index using monthly, seasonal, and annual scales. Figure 2 shows the TRMM gridded points as well as the selected synoptic stations in the study area.

![Figure 2. Distribution of gridded points of the tropical rainfall measuring mission (TRMM) satellite and synoptic stations.](image)

#### 2.5.2. Water Resources

To study the effects of droughts on quantitative features of the water resources in the study area, the discharges pertaining to the fountains of the study area were gathered from Iran Water and
Power Resources Development Company and were processed. The fountains were selected so that they have proper distribution in the region, and also possess the most number of discharge data. Hence, four fountains were selected, including Hashilan, Biabr, Ravansar, and Niloofar. The data of these fountains required the least reformations, and covered the period of the droughts at study area. Since the scales of the two variables, TRMM precipitation data and fountains discharges, were not the same, to find the relationship between them necessitated the use of SPI and normalized fountain discharge. The influence of precipitation deficiency upon water resources, particularly underground waters, is revealed by delay, and lack of monthly precipitation does not show its effects clearly. Therefore, the 12-month scale of SPI leading up to December, along with normalized fountain discharge, was employed and the relationship between fountains’ discharge and precipitation was analyzed.

3. Results and Discussion

3.1. TRMM Data Verification

To assess the accuracy of the TRMM satellite precipitation data, they were compared with the meteorological data of the study area, using statistical indicators. The indicators’ values computed in different stations are shown in Table 1.

| Statistical Indicator | R²    | EF   | IA     | NRMSE   | Slope | BIAS |
|-----------------------|-------|------|--------|---------|-------|------|
| Values                | 0.7–0.8 | 0.6–0.8 | 0.91–0.95 | 0.6–0.85 | 0.7–1.1 | <8.38 |

The value of $R^2$ could imply the satisfactory precision of estimated precipitation in different locations of the study area. The results of EF attest that TRMM satellite is able to both predict the real precipitation of the province and estimate the extreme precipitations at an admissible precision. As stated by [20], the EF greater than 0.5 indicates that the performance of the model in predicting the data is land satisfying. The values of IA connote an agreement between monthly precipitation rates in the selected stations and TRMM precipitation data. The best agreements between time series of estimated and observed precipitations were discovered for Kangavar, Sonqor, Javanrud, Qasr-e-Shirin, and Islamabad-e-Gharb stations. It is to be also noted that the values of IA in the other stations exceeded the value of 0.9. The results regarding the spatial distribution of NRMSE have inferred an acceptable estimation of precipitation with not so much error of TRMM. The NRMSE values showed that there are few precipitation deviations in different stations. This issue was observed commonly in the southern and western halves of the study area. The slope values, which lie in the range of 0.7–1.1, confirmed that in most parts of the province, the estimated data were not so far away from the fit line. For instance, Figure 3 illustrates the comparison between the data of TRMM precipitation and those of the selected stations in the study area based on of BIAS indicator.

According to Figure 3, the model, apart from Sanqor and Gilan-e-Gharb stations, overestimates the precipitation at all stations. The maximum overestimation for Kermanshah station was 8.38 mm, which is about 2% relative to the total BIAS average monthly rainfall at 439 mm. Moriasi et al. [20] stated that the relative BIAS values were less than 10% of the model’s very good performance, between 10% and 15% of the model’s good performance, and between 15% and 25% of the model’s relatively good performance. Generally, the precision assessment of TRMM precipitation data based on various statistical models in Kermanshah province verified that this data set enjoys a suitable accuracy. The high precision of TRMM precipitation data is pointed out in the research of Levina et al. [13] and Ouatiki et al. [15].
Figure 3. TRMM precipitation versus synoptic stations based on BIAS as a statistical indicator.

3.2. Drought Trend

3.2.1. Monthly

For monthly assessment of drought, the SPI index was computed for the 17-year precipitation data of 42 points from the TRMM database, and the monthly conditions from October to June were considered. For example, Figure 4 shows the average SPI of January precipitation in the study area. Accordingly, in most years of study, 40% of the precipitation rate was normal in this month of the year. During the study, the wet periods occurred more often than dry periods, with frequencies of six and four months in the study period, respectively. The maximum value of SPI in this month was 1.36 and the minimum was −2.1.

Figure 4. Average standardized precipitation index (SPI) for Januarys in the study area.

Figure 4 shows that the most severe drought happened in January 2009. The zoning of drought severity during this month in the study area based on the meshed TRMM data is depicted in Figure 5. Although the least average SPI in January for the whole area was −2.1, the drought distribution in the region was not uniform. Based on Figure 5, the severity of drought in the south and west of the study area was very extreme, so that the value of the selected index reached less than −2. These various conditions were also observed in some central areas of the study area, such as Kermanshah city. In central and most eastern regions of the province, the drought was extreme, with SPI values
between −1.5 and −1.9. The most moderate drought in January belonged to the northern parts of Kangavar city, with an SPI value of −1.3, which is the manifestation of moderate drought in this area.

![Map of drought severity in January 2009.](image)

By considering SPI values for different months during the study period, it was revealed that in most months of the year, the frequency and duration of dry periods were more than wet periods. Meanwhile, the wet periods enjoyed more severity compared with droughts. In recent years, the number of dry periods, the downward trend of the precipitation, was increased across the study area. Despite the higher frequency and duration of wet relative to dry periods in some months such as November, December, and January, the severity of dry periods was more apparent. There is no specific trend for precipitation in March, and with reference to May, as compared to most months of the year, the precipitation shows a tendency to increase, with a few dry periods in recent years.

3.2.2. Seasonal Drought Analyses

The three-month values of SPI up to March (for winter), June (for spring), and December (for autumn) were employed in seasonal study of drought. Indeed, the three month SPI value up to March is the result of a cumulative precipitation calculation in January, February, and March. The average SPI of the total points of the TRMM network for winter, spring, and autumn is shown in Figure 6.
The wetness in winters of 1998 and 2005 had a good deal prevalence, respectively, with very severe probable droughts in different periods repeated intermittently. The duration of dry periods was more long-lasting than wetness. The longest duration of dry periods amounted to five. As for duration, the wet periods were more than that of droughts. The longest duration of dry periods was three years, and that of wet periods was two years.

Throughout autumn, the droughts happened irregularly and were distributed through the study period. The above-average conditions are easily discernible in the first decade of 2000. In this time of the year, the study area either got along in wet or normal-to-wet conditions. From 2007 on, the precipitation fluctuations became severe, and different periods repeated intermittently. The frequency of wet periods was more than dry periods, so that from 2001 to 2004 the SPI were always positive. Meanwhile, the maximum duration of negative SPI values amounted to five. As for duration, the droughts were more than wetness. The longest duration of dry periods was three years, and that of wet periods was two years.

In spring and at the beginning of the study period, the precipitation situation was less than average, while during the middle period of the study it exceeded the average. In the last period, the precipitation fluctuations were more serious, and the dry and wet periods were intermittently observable. During this season, the frequency of dry periods totaled six, and that of wet periods amounted to five. As for duration, the droughts were more long-lasting than wetness. The longest duration of dry periods was three years, and that of wet periods was two years.

Figure 6 shows that in winter, precipitation fluctuations in the study area were divided into two general sections. From 1998 to 2006, the precipitation exceeded the average, and in the year interval of 2008–2014, it was recurrently below the long-term average. Considering the values of 0.5 to −0.5 as the normal limits of SPI, the number of wet and dry periods of winter was, respectively, five and four. From the view point of severity, the wet periods are more intense than dry ones so that the frequency percentage of severe and very severe wet years is more than that of severe and very severe droughts.

The wetness in winters of 1998 and 2005 had a good deal prevalence, respectively, with very severe and severe intensity in most areas of the study area.

In spring and at the beginning of the study period, the precipitation situation was less than average, while during the middle period of the study it exceeded the average. In the last period, the precipitation fluctuations were more serious, and the dry and wet periods were intermittently observable. During this season, the frequency of dry periods totaled six, and that of wet periods amounted to five. As for duration, the droughts were more long-lasting than wetness. The longest duration of dry periods was three years, and that of wet periods was two years.

Throughout autumn, the droughts happened irregularly and were distributed through the study period. The above-average conditions are easily discernible in the first decade of 2000. In this time of the year, the study area either got along in wet or normal-to-wet conditions. From 2007 on, the precipitation fluctuations became severe, and different periods repeated intermittently. The duration of wet periods was more than dry periods, so that from 2001 to 2004 the SPI were always positive. Meanwhile, the maximum duration of negative SPI values was two consecutive years. In autumn, despite the remarkable number of normal periods, the frequency of droughts was more than that of wet years. During this season, wet periods were longer and more intense. So that, the frequency of severe and moderate droughts was more than that of severe and moderate wetness. In fact, the severity of probable droughts in different zones of the study area was more than that of wetness notwithstanding the fact that their frequency was fewer.

The mappings of SPI values were produced during the investigation, with the purpose of examining drought situation in winter, spring, and autumn all over the study area. Figure 7 illustrates the SPI mapping, for example, in winter of 2009, spring of 2008, and autumn of 2014.
The precipitation fluctuations became severe, and different periods repeated intermittently. The duration of wet periods was more than dry periods, so that from 2001 to 2004 the SPI were always positive. Meanwhile, the maximum duration of negative SPI values was two consecutive years.

In autumn, despite the remarkable number of normal periods, the frequency of droughts was more than that of wet years. During this season, wet periods were longer and more intense. So that, the frequency of severe and moderate droughts was more than severe and moderate wetness. In fact, the severity of probable droughts in different zones of the study area was more than that of wetness notwithstanding the fact that their frequency was fewer.

The mappings of SPI values were produced during the investigation, with the purpose of examining drought situation in winter, spring, and autumn all over the study area. Figure 7 illustrates the SPI mapping, for example, in winter of 2009, spring of 2008, and autumn of 2014.

Figure 6. Cont.
were inclusive of widespread drought, and two were with prevalent wet years. The frequencies of
intensities of the droughts, except for Javanrud, were mild and generally medium. A greater extent of severe droughts corresponded to south-western,
compared to south-eastern, areas of the study area. Figure 7b shows that spring of 2008 had the most severe drought during the study period with average SPI of −1.9, 47% severe drought, and 47% very severe drought. According to this figure, the severity of drought in the spring of 2008 was decreased in the direction of the west to the east. In the west part of the study area, exclusive of the northernmost area of Paveh, and the south of Gilan-e-Gharb and Somar, the drought was extremely severe, and the SPI index fell below −2. The eastern half of the study area along with the north of Paveh, the south of Gilan-e-Gharb, and the south of Somar underwent severe drought and the SPI values for these regions ran between −1.5 and −1.9. The most widespread drought occurred in autumn with the same severity throughout the points of the network belonging to the year of 2014. In autumn of 2014, no rainfall occurred, whence the three month SPI value up to December reached −1.6, and a severe drought struck the whole study area (Figure 7c).

To investigate the prevalence of drought in winter, spring, and autumn during the period of study, the frequency percentage of different categorizations of SPI were analyzed. The study of very prevalent droughts frequencies in the winter showed that this type of drought in the study area occurred in the years 2009, 2012, and 2013. In 2012 and 2013, the major zones of the study area were subject to mild or medium droughts. This was the case, while in 2009 the most frequencies were allocated to medium and very severe droughts striking 53% and 27% of the study area, respectively. Therefore, the total severity of the province’s drought was evaluated as extreme. In spring, the frequency of very severe wetness was far less than that of very severe droughts, to the extent that in 2002, enjoying the wettest spring, the SPI of 13% of the region was above +2. In the dry spring of 2008, however, 47% of the study area lay in the very severe drought category. Nevertheless, the wet periods have experienced more severity relative to the dry ones.

In autumn, no very severe drought or wetness was noticed in any of the stations during 1998 to 2014. In most years, the maximum frequency corresponded to the normal category. All the same, no station experienced the normal conditions for the duration of five years. Of these five years, three were inclusive of widespread drought, and two were with prevalent wet years. The frequencies of severe and medium droughts were more than those of respective wet years. To put it another way, the intensity of drought in different parts of the province was more than that of wetness, though its
frequency may be lesser. The reason is that the wet years are frequently of mild severity in most periods and region.

3.2.3. Annual Time Series

The 12-month SPI index up to December was used to study annual droughts. The annual average SPI of all study stations is given in Figure 8.

Considering the values of 0.5 to −0.5 as the normal limits of SPI, the numbers of annual wet and dry periods were the same, and during 17 years of study, six dry periods and six wet periods were observed. The temporal distribution of these periods is at variance, so that there were high fluctuations of annual precipitation in the first few years with alternating repetition of positive and negative periods. From 2002 to 2006, wet conditions prevailed in most parts of study area. As of 2008, however, drought periods ensued in most areas of the study area and were prolonged seven years until reaching its utmost severity in 2014.

Reviewing the frequency percentage of various SPI categories on an annual scale acknowledged that the wetness severity was contained by mild to medium states in most stations, and more than half of the frequencies were devoted to these two categories. The same trend was held for the drought periods. In the severest wet year in 2002, 60% of the study area experienced extreme wetness and 40% underwent medium wetness. As to the severest drought occurred in 2014, more than 80% of the study area was stricken by very extreme drought. The mapping of drought in 2014 is shown in Figure 9. On the basis of this figure, the lowest level of drought was observed in the south of Ghasr-e-Shirin, with the SPI value of −1.4. In the other parts of the study area, the SPI lay below −2, which points to a very severe drought.
Annual monitoring of drought showed that the severity of wet periods was much more than that of drought periods. Due to the fact that the majority of wet years fall in the medium category, and most of the droughts belong to the mild category.

Moradi et al. [25] and Rajabi [26], using SPI, showed that in the last decade, most cities of Kermanshah experienced severe and extreme droughts. Roodposhti et al. [27], using support vector machine algorithm, enhanced vegetation index (EVI), and SPI showed that in the duration of 1978–2008, the most severe drought was in 2008 in the study area, which is consistent with the results presented in Figure 8. Bazrafshan [28] and Emadodin et al. [29] showed that, in recent years, at most stations in Iran, including stations in the Kermanshah, the severity of the drought has become more severe with time, which is consistent with the results of this study.

3.3. Water Resource Instability

To study the effects of drought on water resources instability, the relationship of the discharge data of four main fountains, including Hashilan, Biabr, Ravansar, and Niloofar, and TRMM precipitation data were investigated. To correspond precipitation with discharge, the information of the nearest point of the TRMM precipitation network to the selected fountains was employed. The results are shown in Figure 10.
Figure 9. Cont.
Figure 10 demonstrates the fact that in most years, there was a direct relation between precipitation and discharge of the fountains in the region under study. So that there was consistency between the negative SPI values and the negative normalized fountain discharges, and correspondingly, between the positive SPI values and the positive normalized fountain discharges. Figure 10a shows that in fountain of Hashilan, the drought incidence affected the fountain discharge annually and almost without delay. The SPI values turned negative from 2007 onward, while the negativity of normalized fountain discharges began two years ahead from 2005, contemporaneous with precipitation decrease. Hence, this fountain has a great deal of sensitivity to reduced precipitation. Incidentally, the fountain discharge plummeted as of 2005, which would follow the rate of drought in the next years. Figure 10b guarantees that the discharge sensitivity of Biabr fountain to the low intensity wetness and droughts (close to normal) was high, which may be related to nonrecharging of the fountain from permanent aquifers. Figure 10c,d shows the direct relationship between Ravansar and Niloofar discharges and annual drought. From 2010 onwards, the changes of normalized fountain discharge were reduced in Ravansar fountain. As for Niloofar fountain, drought duration tremendously influenced...
the discharge. Field observations confirm this upon drying of this permanent fountain in recent years. This result agrees with the findings of Shakiba et al. [30] and those of Masoompour Samakosh et al. [31].

In the selected fountains, the highest value of discharge growth was recorded in 1998, 2002, and 2003. In these years, the medium-to-severe wetness governed the fountains’ area, and the annual SPI took on its greatest values. The continual discharge decline from 2008 to 2013 is well noticeable in all the four selected fountains, which is in agreement with the 12-month precipitation SPI. During the study period, the most prevailing drought happened in 2008 and 2009. In these two years, the discharge of the fountains went through a significant decrease. For some of the fountains, such as Nilooofar in the center of the study area, the most extreme droughts took place in the years of 2012 and 2013. Shakiba et al. [30] and Masoompour Samakosh et al. [31] alluded to the strike of drought during the years of 2007 to 2013, with reference to its negative effects on fountains as well as water resource instability, having much agreement with the results of the current research.

4. Conclusions

The present research was conducted to study drought effects on water resources using remote sensing data. The data that were employed in this regard included the meshed precipitation data of TRMM with spatial resolution of 0.25° × 0.25 degrees, precipitation data of synoptic stations, and fountains’ discharge data. The SPI was used in monitoring of drought conditions, and normalized fountain discharges were applied in comparison between precipitation and discharge data. The most important results taken in this investigation are as follows:

- The precision assessment of TRMM precipitation data based on various statistical tools verified that this dataset enjoys a suitable accuracy.
- Monthly scale study of drought showed that in most months of the study period, the frequency and duration of dry periods were more than those of wet periods.
- In regards to seasonal scale, it was revealed that exclusive of winter, the frequency and duration of the droughts was longer than those of wet years. It should be noted that the duration of these periods were different.
- A remarkable direct relationship between drought and fountain discharges was observed in the study area. Depending on geological properties, the effects of droughts was immediate or with delay.

Author Contributions: A.A., A.A.K., N.A.-A. and M.K.M., editing, data interpretation, and contributed reagents, materials, analysis data; A.A., writing—review and editing the paper and research method; A.A.K., editing the paper and consulting research method; N.A.-A. and T.M., provided critical comments in planning this paper and edited the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References
1. Ramesh, M.V. Design, development, and deployment of a wireless sensor network for detection of landslides. *Ad Hoc Netw.* **2014**, *13*, 2–18. [CrossRef]
2. Gerislioglu, B.; Ahmadiavand, A.; Karabiyik, M.; Sinha, R.; Pala, N. VO2-based reconfigurable antenna platform with addressable microheater matrix. *Adv. Electron. Mater.* **2017**, *3*, 1700170. [CrossRef]
3. Valipour, M. Optimization of neural networks for precipitation analysis in a humid region to detect drought and wet year alarms. *Meteorol. Appl.* **2016**, *23*, 91–100. [CrossRef]
4. Amini, A.; Mohamad, T.A.; Halim, G.; Bujang, H.; Azlan, A.; Akib, S. Impacts of land use change on streamflow generation in Damansara watershed, Malaysia. *Arab. J. Sci. Eng.* **2011**, *36*, 713–720. [CrossRef]
5. Hesami, A.; Amini, A. Changes in irrigated land and agricultural water use in the Lake Urmia Basin. *Lake Reserv. Manag.* **2016**, *32*, 288–296. [CrossRef]
6. Yu, H.; Li, L.; Liu, Y.; Li, J. Construction of Comprehensive Drought Monitoring Model in Jing-Jin-Ji Region Based on Multisource Remote Sensing Data. *Water* **2019**, *11*, 77. [CrossRef]

7. Flores, F.; Garrote, L.M.; Martín Carrasco, F.J. The hydrologic regime of the Tagus basin in the last 60 years. In *Proceedings of the World Water Congress*, Madrid, Spain, 5–9 October 2003.

8. Monea Lain, M. Drought and Climate Change Impacts on Water Resources: Management Alternatives. Ph.D. Thesis, Departamento de Economía y Ciencias Sociales Agrarias Escuela Técnica Superior de Ingenieros Agrónomos Universidad Politécnica de Madrid, Madrid, Spain, 2008.

9. Naumann, G.; Barbosa, P.; Carroa, H.; Singleton, A.; Vogt, J. Monitoring drought conditions and their uncertainties in Africa using TRMM data. *J. Appl. Meteorol. Climatol.* **2012**, *51*, 1867–1874. [CrossRef]

10. Jiang, S.; Ren, L.; Hong, Y.; Yong, B.; Yang, X.; Yuan, F.; Ma, M. Comprehensive evaluation of multi-satellite precipitation products with a dense rain gauge network and optimally merging their simulated hydrological flows using the Bayesian Model Averaging Method. *J. Hydrol.* **2012**, *452*, 213–225. [CrossRef]

11. Ezzine, H.; Bouziane, A.; Ouazar, D. Seasonal comparisons of meteorological and agricultural drought indices in Morocco using open short time-series data. *Int. J. Appl. Earth Obs. Geoinf.* **2014**, *26*, 36–48. [CrossRef]

12. Cheng, C.H.E.N.; Shuhe, Z.H.A.O. Drought monitoring and analysis of Huanghuai Hai plain based on TRMM precipitation data. *Remote Sens. Land Resour.* **2015**, *28*, 122–129. [CrossRef]

13. Levina; Hatmoko, W.; Seizarwati, W.; Vernimmen, R. Comparison of TRMM satellite rainfall and APHRODITE for drought analysis in the Pemali-comal River Basin. *Proc. Environ. Sci.* **2016**, *33*, 187–195. [CrossRef]

14. De Jesus, A.; Breña-Naranjo, J.; Pedrozo-Acuña, A.; Alcocer Yamanaka, V. The use of TRMM 3B42 product for drought monitoring in Mexico. *Water* **2016**, *8*, 325. [CrossRef]

15. Ouatiti, H.; Boudharr, A.; Tramblay, Y.; Jarlan, L.; Benabdellouhab, T.; Hanich, L.; El Meslouhi, M.R.; Chehbouni, A. Evaluation of TRMM 3B42 v7 rainfall product over the Oum Er Rbia watershed in Morocco. *Climate* **2017**, *5*, 1. [CrossRef]

16. Harlow, J.; Hagedorn, B. SWB Modeling of Groundwater Recharge on Catalina Island, California, during a Period of Severe Drought. *Water* **2018**, *11*, 58. [CrossRef]

17. Khampeera, A.; Yongchalermchai, C.; Techato, K. Drought Monitoring using Drought Indices and GIS Techniques in Kuan Kren Peat Swamp, Southern Thailand. *Walailak J. Sci. Technol.* **2018**, *15*, 357–370.

18. Modarres, R.; Sarhadi, A. Rainfall trends analysis of Iran in the last half of the twentieth century. *J. Geophys. Res.* **2009**, *114*, 1–9. [CrossRef]

19. Yan, N.; Wu, B.; Chang, S.; Bao, X. Evaluation of TRMM Precipitation Product for Meteorological Drought Monitoring in Hai Basin. *IOP Conf. Ser. Earth Environ. Sci.* **2014**, *17*, 012093. [CrossRef]

20. Moriasi, D.N.; Arnold, J.G.; Van Liew, M.W.; Bingner, R.L.; Harmel, R.D.; Veith, T.L. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Trans. Am. Soc. Agric. Biol. Eng.* **2007**, *50*, 885–900.

21. Haekyung, P.; Kyungmin, K.; Dong kyun, L. Prediction of Severe Drought Area Based on Random Forest. *Appl. Sci.* **2019**, *9*, 5377.

22. Amini, A.; Gharibreza, M.; Shahmoradi, B.; Zareie, S. Land aptitude for horticultural crops and water requirement determination under unsustainability of water resources condition. *Environ. Monit. Assess.* **2019**, *191*, 1–13. [CrossRef]

23. Fetemi, M.; Narangifard, M. Study of spatial and temporal rain and drought patterns in the south of Iran using TRMM. *Desert* **2018**, *23*, 243–253.

24. Nalbantis, N.; Tsakiris, G. Assessment of hydrological drought revisited. *Water Resour. Manag.* **2009**, *23*, 881–897. [CrossRef]

25. Moradi, M.; Yahya Safari, S.; Biglari, H.; Ghayebzadeh, M.; Darvishmotevalli, M. Multi-year assessment of drought changes in the Kermanshah city by standardized precipitation index. *Int. J. Power* **2016**, *8*, 17975–17987. [CrossRef]

26. Rajabi, A. Analysis of SPI drought class transitions due to climate change. Case study: Kermanshah (Iran). *Water Resour. Manag.* **2017**, *31*, 4683–4698. [CrossRef]

27. Roodposhti, M.S.; Safarrad, T.; Shahabi, H. Drought sensitivity mapping using two one-class support vector machine algorithms. *Atmos. Res.* **2017**, *193*, 73–82. [CrossRef]

28. Bazzafshan, J. Effect of air temperature on historical trend of long-term droughts in different climates of Iran. *Water Resour. Manag.* **2017**, *31*, 66. [CrossRef]

29. Emadodin, I.; Reinsch, T.; Taube, F. Drought and Desertification in Iran. *Hydrolog. Water Resour. Sci. Technol.* *2019*, 6, 66. [CrossRef]
30. Shakiba, A.; Mirbagheri, B.; Kheyri, A. Drought and its Effect on Underground Water Resources in East of Kermanshah Province Using SPI Index. *Geography* **2010**, *8*, 104–124. (in Persian)
31. Masoompour Samakosh, J.; Miri, M.; Bagheri, S. The Effect of Climate Change on the Discharge and Characteristics of Karst Springs in Kermanshah Province. *Gov. Spons. Enterp.* **2017**, *6*, 51–66.

© 2019 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).