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Area Change Monitoring of Dokan & Darbandikhan Iraqi Lakes Using Satellite Data

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ABSTRACT

Iraq is one of the richest countries, especially in the Middle East and generally in the world, in natural resources such as water due to existing of Tigris and Euphrates rivers, tributaries branches, marshlands and lakes which are already affected by climate change. Thus, Dokan and Darbandikhan lakes (in the northern of Iraq) have been monitored and studied throughout the past eighteen years (1999-2016) in term of area and average monthly rainfall (AMR) of feeding basin to Figure out the effect of historical climate change. Landsat images satellite (5, 7, and 8) types were used to collect 36 satellite images for the study area (18 images for each lake), ArcGIS 10.2 program was used as well to create a map of the water drainage networks. The results showed that the average variation in AMR of feeding basins of the two lakes was about 1.12. Also, overall average area of Darbandikhan and Dokan lakes was about 71.52 km^2 and 168.86 km^2 respectively. In addition, overall average AMR of Darbandikhan and Dokan lakes was 1.02 km^3 and 0.92 km^3 consecutively. In addition, the correlation coefficient between area and AMR of feeding basin for Darbandikhan and Dokan Lakes was 75% and 90% respectively. Coefficient of variance (COV) has been found as well to be the lowest for Dokan Lake area, which was about 23% in comparison with Darbandikhan which was about 39%.

Keywords: Dokan; Darbandikhan; Landsat; Area Lake; Average monthly rainfall.

1. INTRODUCTION

Iraq is located in the eastern part of the MENA (Middle East and North African) section .It is surrounded by Iran in the east, Turkey to the north, Syria and Jordan to the west, Saudi Arabia and Kuwait to the south and the Gulf to the southeast as shown in Figure 1.The total area of Iraq is 438,320 km^2 of which 924 km^2 of inland water. Middle East and North MENA area are considered to be arid or semi-arid as the average annual rainfall does not exceed 166 mm (Al-Ansari, 2013).

Geographically, Iraq is located in the driest belt in the world, which means that Iraqi agriculture depends on the surface and groundwater resources to provide the irrigation water needed for the stability of agriculture. These resources are limited and most of them are shared with other countries neighboring Iraq. In addition, water is one of the most important components of life (Toma, 2013), and its continuation on the surface of the earth. It also plays an important role in the formation of soils and determines the various types of chemical and biological activity in it. Water, soil, seeds and climate are the most important

elements of agricultural development (Hayami, 1971, Saysel et al., 2002). There is no agriculture if none of them exist. Water is the decisive factor in the expansion of agriculture as well as the cornerstone of economic and social development in all its aspects, especially in Iraq (Ra'ad Rahim Hamoud, 2015).

Many researcher have been studied Darbandikhan and Dokan lakes in term of physico-chemical characteristics, poisoning event, earthquake effect, infection and etc. (ABDULLAH, 2005, Abdullah and Abdullah, 2013, Toma, 2013). Taking into account the limited studies on the evaluation of Dokan and Darbandikhan lakes (ABDULLAH, 2005), in term of climate changes. It is significant and essential to evaluate how climate has changed and varied in the past regarding these lakes. In addition, the historical average monthly rainfall data can be plotted to show the baseline climate and seasonality by month, for particular years. Therefore, the purpose of current study is to calculate the average monthly rainfall (AMR) for feeding basin of Dokan and Darbandikhan lakes through climate data for consecutive periods (1999-2016). Also to study the variations of water area extent for the mentioned lakes through satellite images using remote sensing technology.

Figure 1: Iraq location map

2. STUDY AREA

The study area is located in Sulaymaniyah province in the northeastern part of Iraq. The general character of the governorate's surface is mountainous, interspersed with valleys and some small plains. The city is located on the western slopes of Azmur Mountains and at 850 m elevation above sea level and between latitudes 44 and 46 east and latitudes 35 and 36 north as shown in Figure 2. The city is surrounded by several mountain ranges from north-west to south-west, and it is placed on hilly land with a slope of about 3.5%.The northern end of the city rises by 885 meters, while the southern end rises by 800 meters above sea level.

There are several plateaus on the southern and western sides of the city, which are usually not noticed on the topographic map. It can be seen from Figure 3 that there is a similarity in the topography of the surrounding areas of the city.

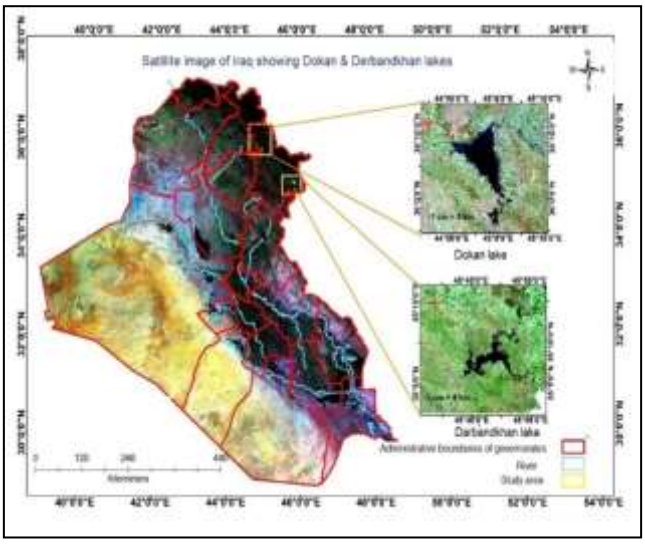


Figure 2: Satellite image showing Dokan & Darbandikhan lakes

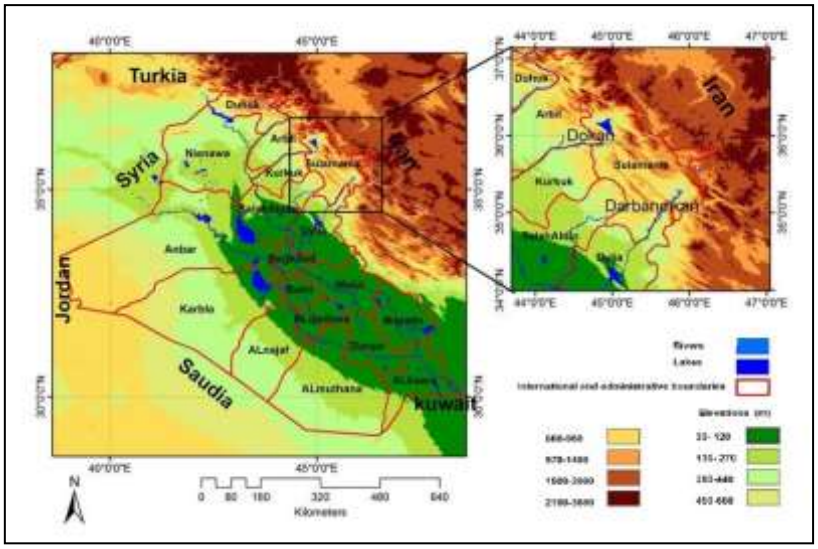


Figure 3: Topography of Iraq and study area

1.1 Dokan Lake

The lake is located in the northern part of Iraq (Sulaymaniyah Governorate/Kurdistan region). It is a relatively considered the largest lake within the region (Toma, 2013). It is created by the construction of Dokan Dam, in 1959 which located about 70 km away from city center of Sulaymaniyah, to generate electricity and flood protection. It can be seen from Figure 4a that it is located on Al Zab Al Sageer River, one of the tributaries of the Tigris River, and stems from the Qandil mountain range from western Iran. It runs southward from Darazhur, Walton, Kiri and Dibs, 10 km away from Tigris River.

The nature of this lake, in term of mountains multitude, is mountainous including Sultan and Sara mountains, in addition to the abundant forests, made it distinguished by the views of the steals, so it is considered a large tourist complex and an

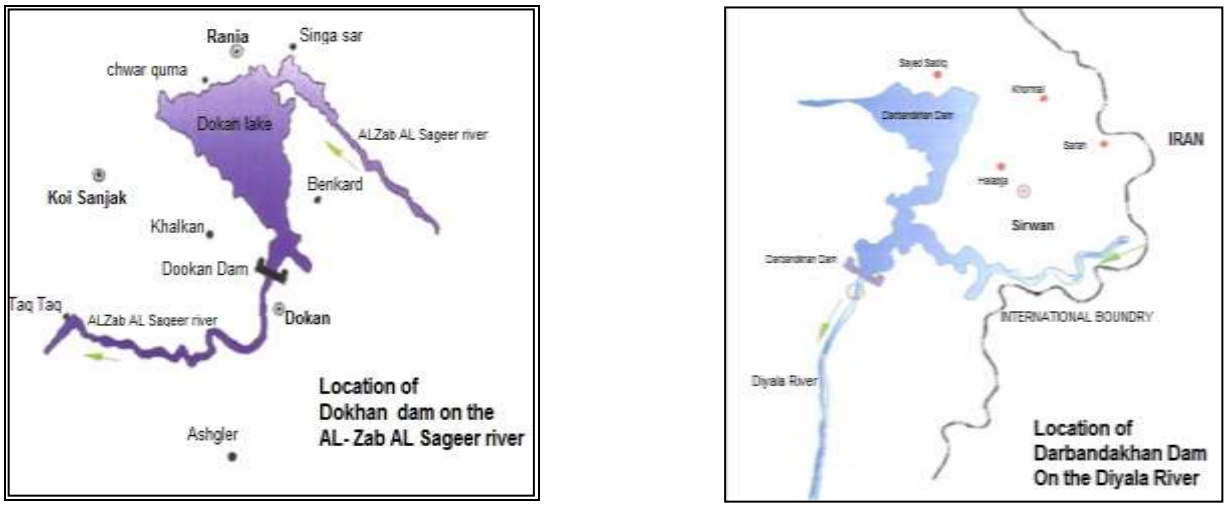
important resort in the region. The average area of the Dokan Lake for the years (1999 - 2016) was 168.86 km^2. Overall AMR of the lake feeding basin for the same time period was 0.92 km^3.

1.2 Darbandikhan Lake

Darbandikhan Lake is one of the three largest lakes in Kurdistan, northern Iraq. It is 230 km northeast of Baghdad (at about 60 km southeast of Sulaymaniyah city, Kurdistan region, situated between 35°N and 45°E) and it as completely constructed in 1961. It is also located on Diyala River, one of the tributaries of Tigris River. This and the surrounded area is a biological diverse area for wildlife and listed as an Important Bird Area in Iraq by Bird Life International. Many people benefit from this lake and its waters as it is used as a source for drinking and irrigation water, as an important fisheries, and as a beautiful site used by many for recreation. It is also an important source of electricity generated by the Darbandikhan Dam (Abdullah and Abdullah, 2013, Ararat et al., 2008, Toma, 2013).

Overall average area of this lake for the years (1999 - 2016) was 71.52 km^2. Overall AMR of the feeding basin for the same period was 1.02 km^3.

It is fed by two main tributaries: Tanjero River, which flows in from the north/northwest, and the Sirwan River, which flows in from the east (from Iran). It is worth mentioning that Iran has built a number of dams on the Sirwan River, which is connected to Darbandikhan Lake by Julula hill, on the left side of the Alwand River passing through Khanaqin city as shown in Figure 4b.



a. Dokan Lake b. Darbandikhan Lake

Figure 4: Details of a- Dokan and b- Darbandikhan lakes with their own dams and ramps

3. MATERIALS AND METHODS

3.1 Digital Elevation Model (DEM)

Digital Elevation Model was obtained from Shuttle Radar Topographic Mission (SRTM) with 90 m digital elevation data for the study area (Sulaymaniyah governorate) and nearby. DEM data was corrected and modified through eliminating negative and missing values.

For hydrological analysis, Arc Hydro function which it is one of ArcGIS 10.2 program, was used to create a map of the water drainage networks that represent the paths and levels of the natural water drainage networks in the study area.

These levels represent group gradient of drainage networks from the first level, which accumulates in the second level and second levels accumulates in the third and so on. Paths for gathering water has been drawn from which it is possible to identify the potential places of rainwater harvesting and rainfall water discharge [8].After that, two largest basins combining rainfall water have been identified, first one is Dokan Lake and second is Darbandikhan lake as shown in Figure 5.

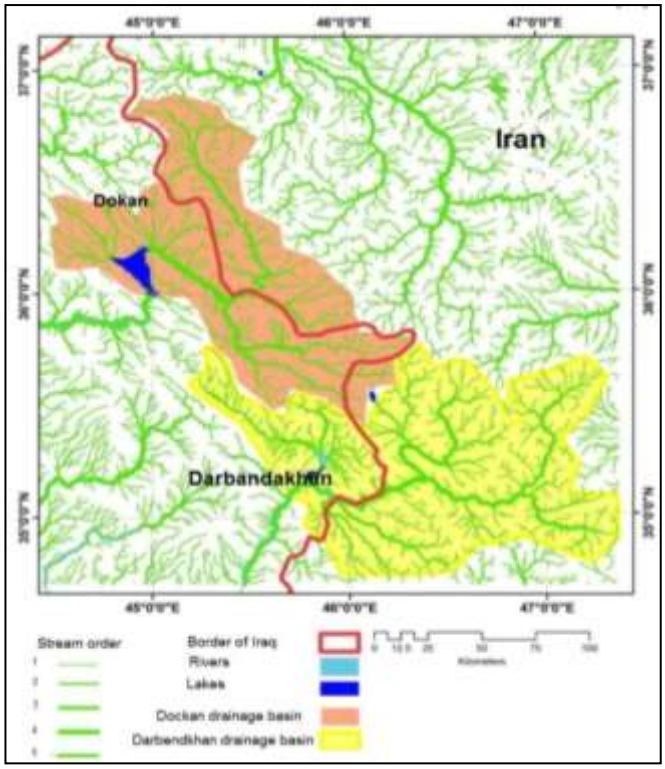


Figure 5: Water drainage networks levels and feeding basins for Dokan and Darbandikhan lakes

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3.2 Collecting Satellite Images

The satellite images were collected for 18 years from 1999 to 2016. 36 images were collected, 18 for Dokan Lake (Figures 5) and 18 for Darbandikhan Lake (Figures 6). For the same time period. Landsat (5, 7, and 8) types were used. Satellite images of Landsat 7 were processed by filling the gabs using ENVI 5.1 program.

After that, classification of Dokan and Darbandikhan lakes was carried out using ArcGIS 10.2 program. Extracting and calculating the area of both lakes in km^2 were done eventually as shown in Figures 6 and 7.

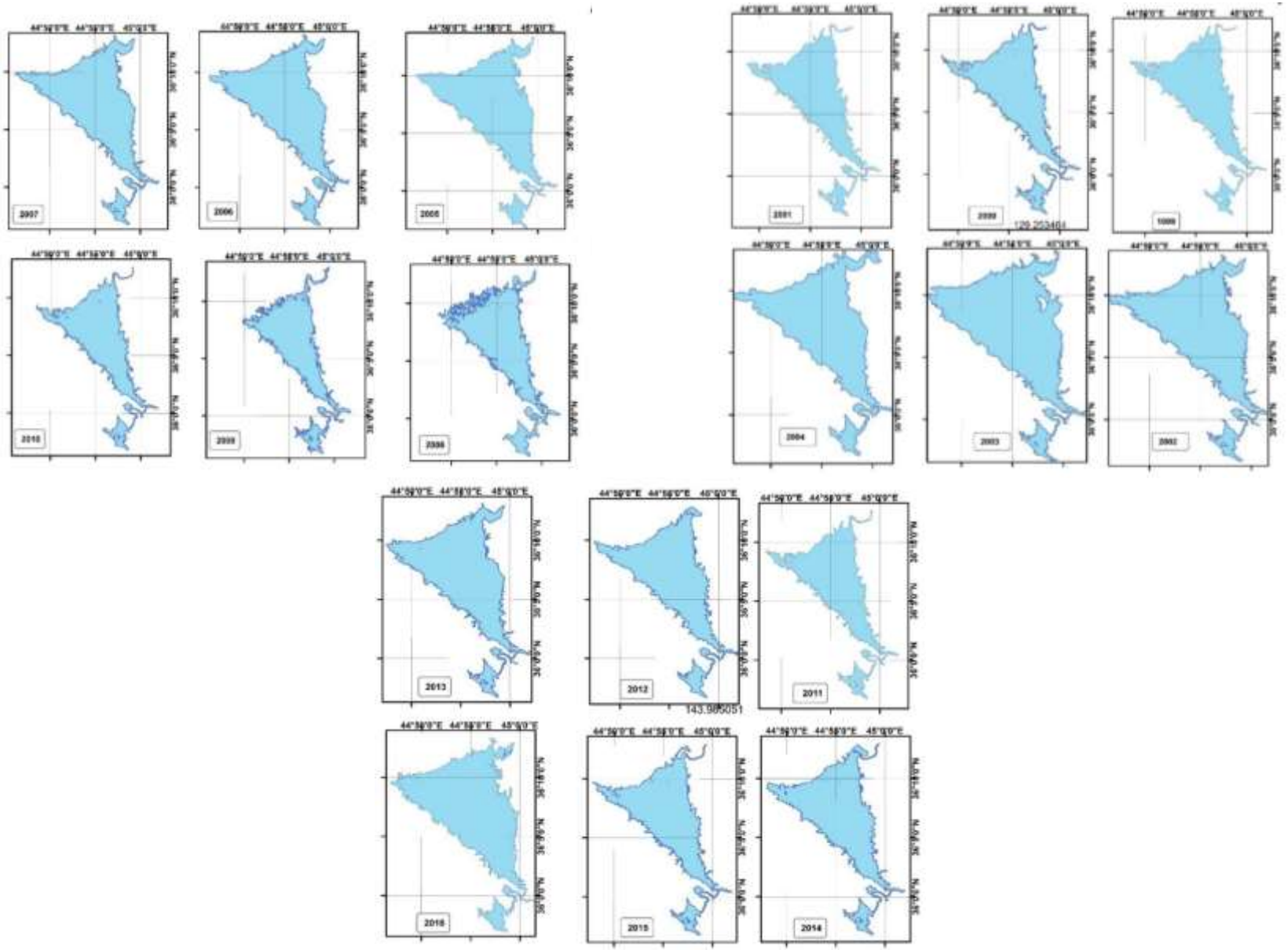


Figure 6: Dokan lake area images (1999-2016)

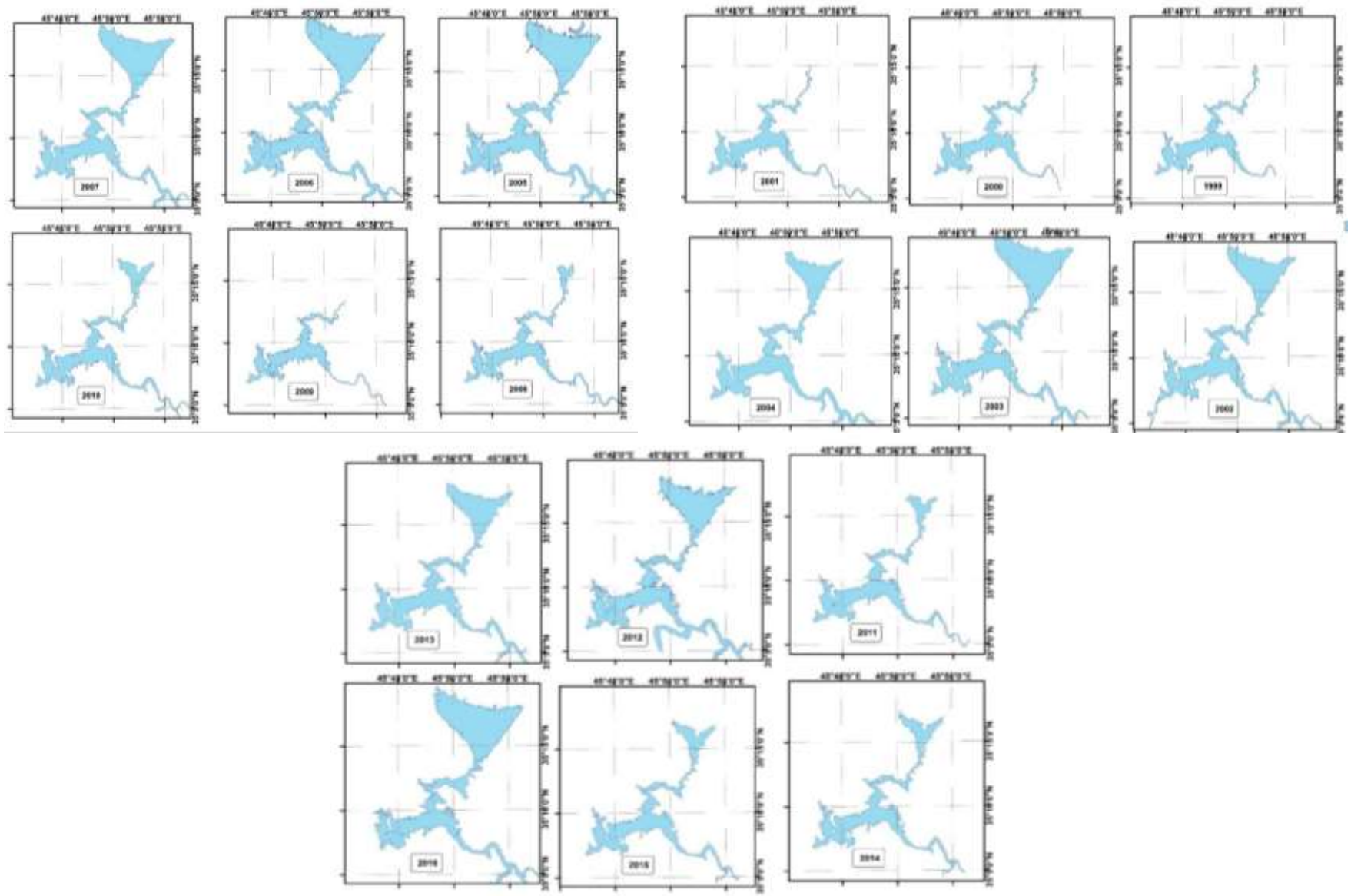
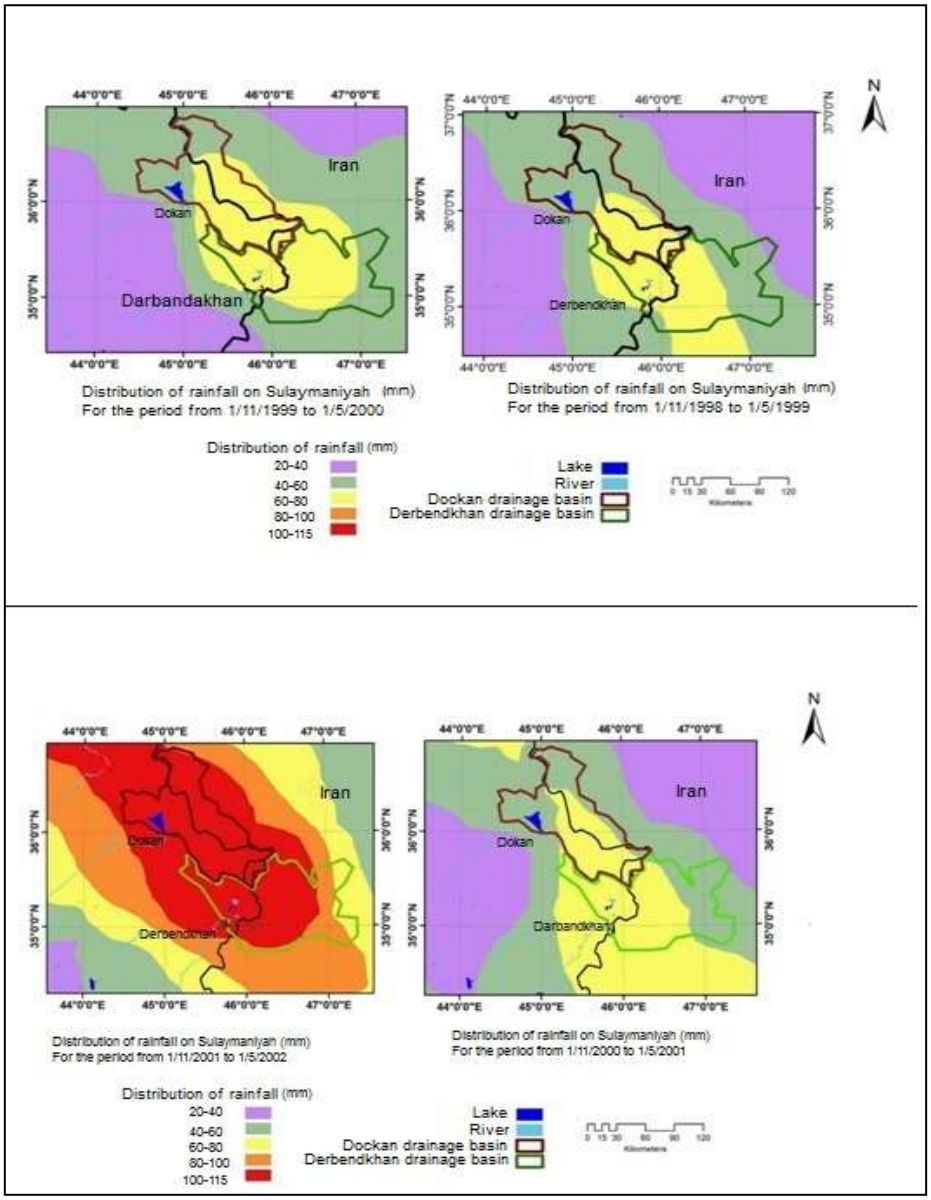


Figure 7: Darbandikhan Lake area images (1999-2016)

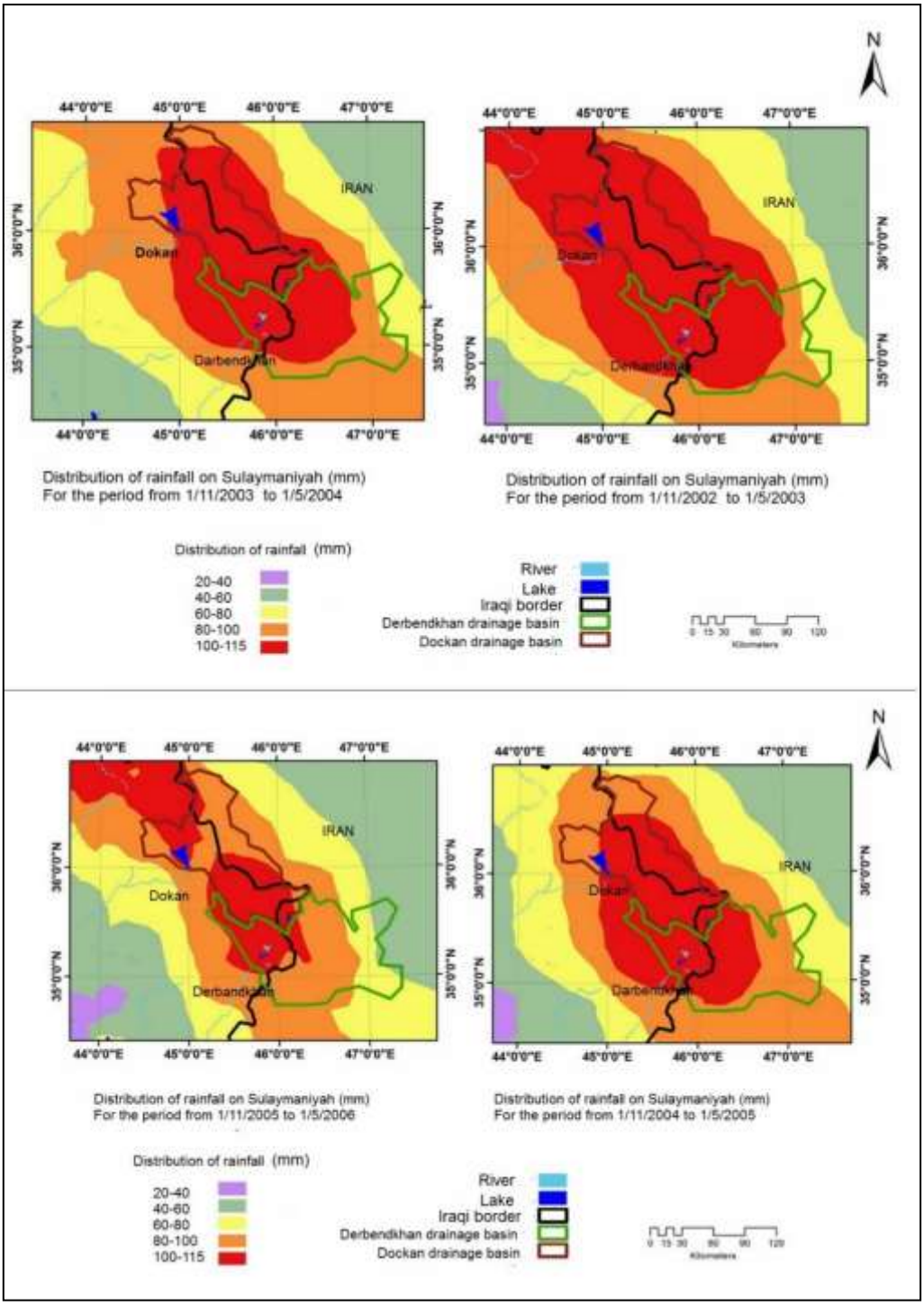
3.3 Calculation of Average Monthly Rainfall (AMR)

After determining the drainage basins of Dokan and Darbandikhan lakes, climate data was used to calculate the AMR precipitation of the region in km^3 for eighteen years from 1999 to 2016 (Acker and Leptoukh, 2007). These data were taken from TRMM satellite (Tropical Rainfall Measuring Mission), which was released to measure various types of rainfall, whose data are significant because it provides comprehensive spatial data coverage (tropical rainfall is observed between latitudes 50 ° N and 50 ° S with accurate about (0.25 ° x 0.25) and its time coverage range is monthly, as it can be used to provide data for large-scale studies and regional studies.

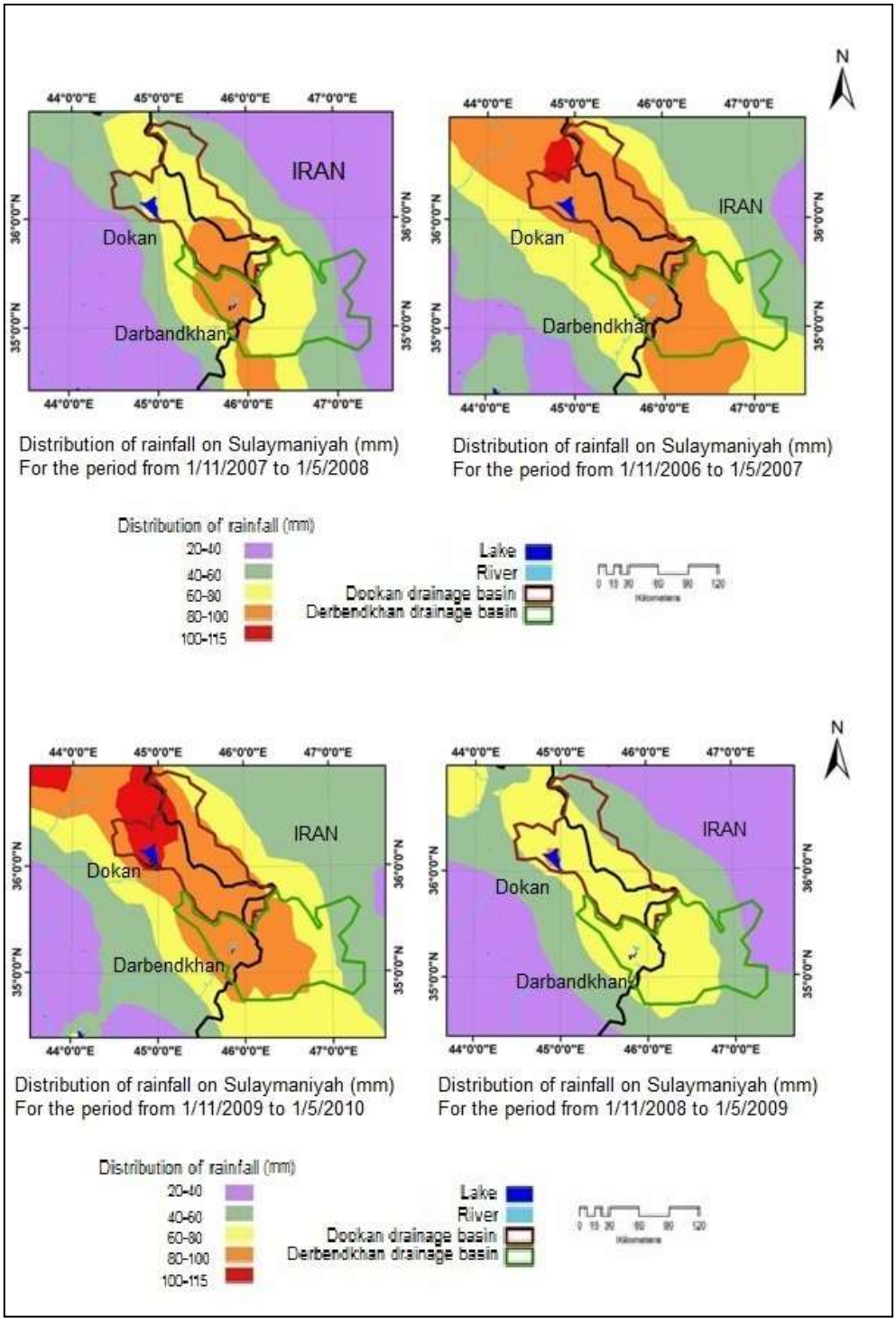
These data was imported to ArcGIS program to obtain bitmap maps that were subsequently converted to spatial maps with dimensions of 0.25 °x 0.25 ° to represent each point a grid position for the measurement. After that, stored in the geographic information system and conducted the spatial analysis process to become spatial maps suitable for a geographical analysis to calculate the amount of rainfall in the feeding basins of Dokan and Darbandikhan lakes (Figure 8).



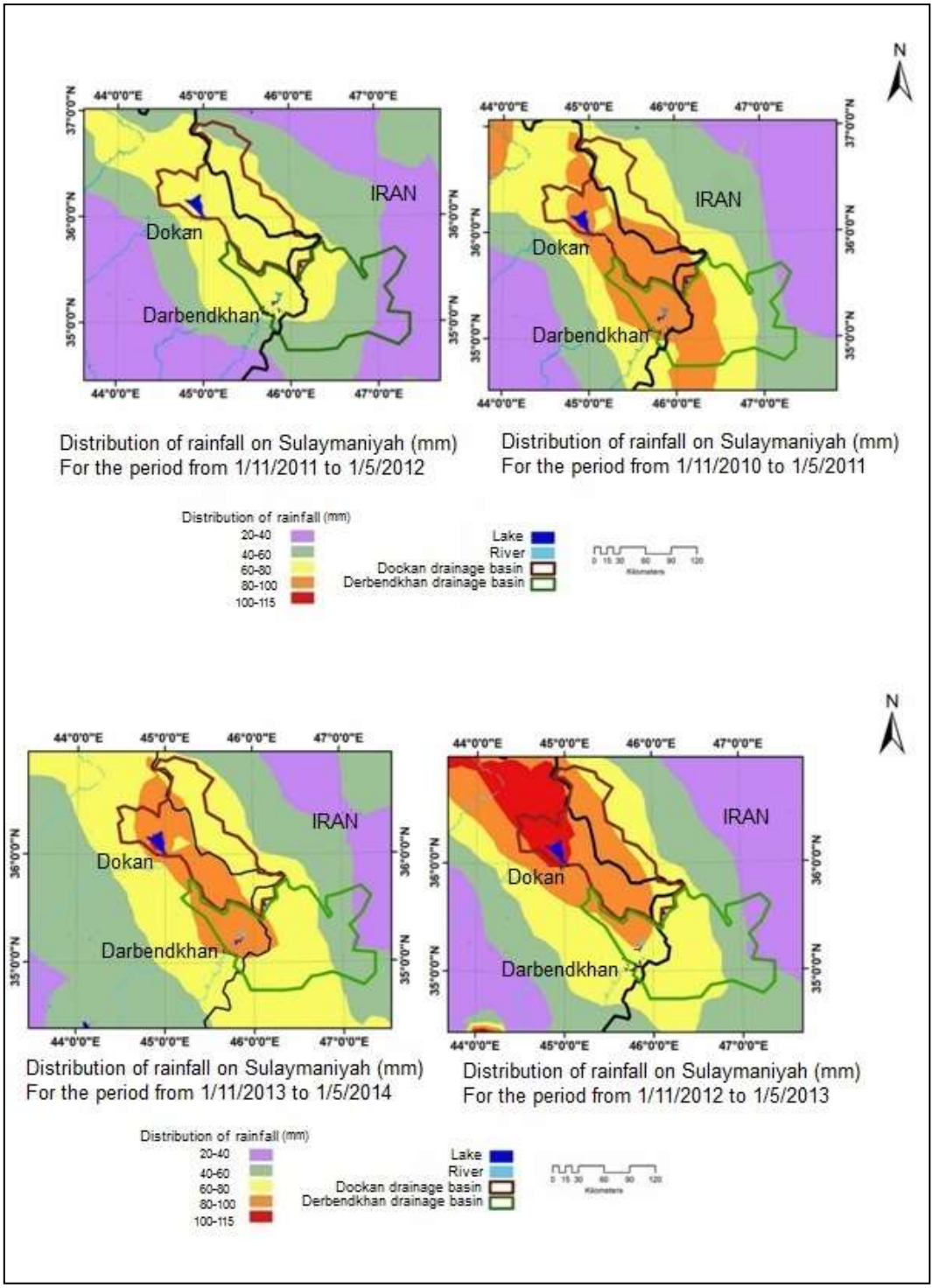
a- Years (1999-2002)



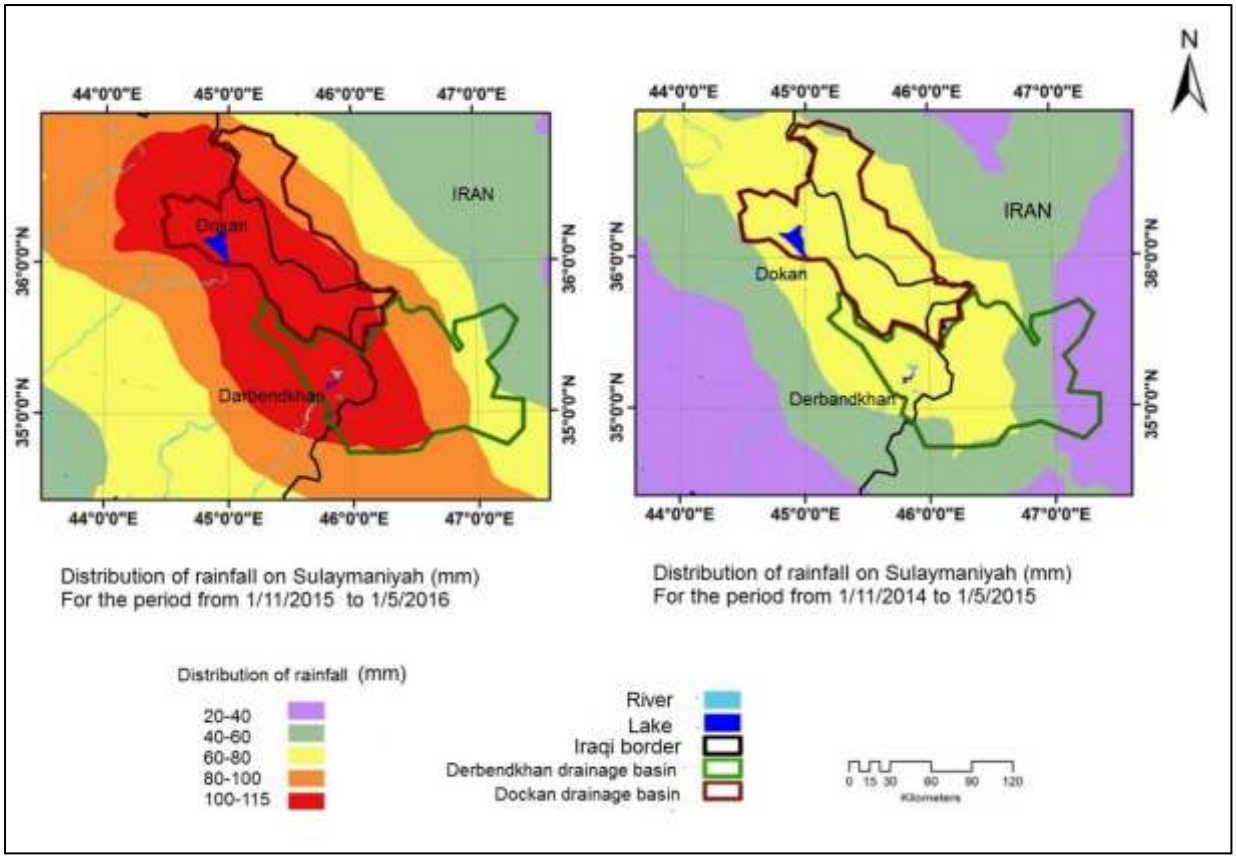
b- Years (2003-2006)



c- Years (2007-2010)



d- years (2011-2014)



e- Years (2015-2016)

Figure 8: Rain quantities distribution (mm/month) of study basin area for the years a- (1999-2002), b- - (2003-2006), c- (2007-2010), d- (2011-2014), and e- (2015-2016)

4. RESULTS AND DISCUSSION

Average monthly rainfall (AMR) and areas of Dokan and Darbandikhan lakes has been monitored by using image satellite and climate throughout the period accrued during 18 years (1999-2016).

4.1 Area of the Lakes

According to Figure 9, during the first three years (1999-20010), no significant rising or reducing in the area. After that, area amounts for both lakes were increased gradually and fluctuated almost similarly during the next years reaching the maximum value of about 112.50 km^2 in 2005 for Darbandikhan and about 237.40 km^2 for Dokan Lake in 2003 and fluctuated almost similarly during the next years. On the other hand, the lowest area values were recorded in 2009 of about 35.38 km^2 and about 121.23 km^2 for Darbandikhan and Dokan Lakes respectively. In addition, the average differences between the two lakes was approximately about 97 km^2 throughout the studied years.

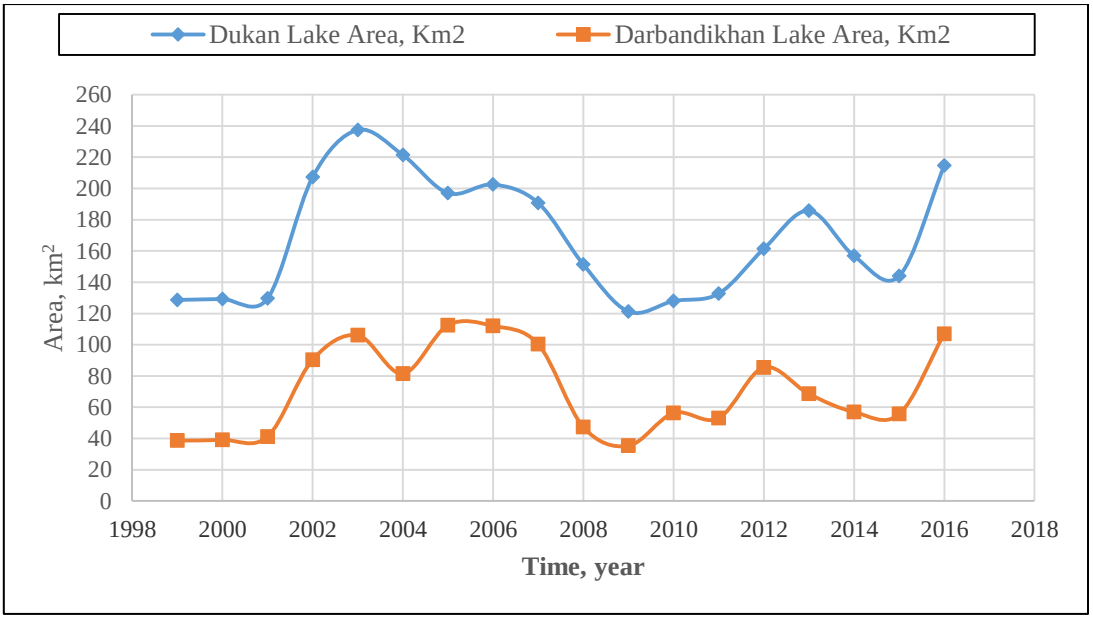


Figure 9: Dokan and Darbandikhan area changes throughout (1999 - 2016) years

4.2 AMR of Feeding Basins

Concerning AMR, eighteen yearly rainfall variations has been studied and analyzed. It can be clearly seen from Figure 10 (amount of AMR was multiplied by 100 for plotting purpose) that the maximum amount reached 1.46 km^3 and 1.37 km^3 for Darbandikhan and Dokan feeding basin consecutively in 2003. On the contrary, the lowest AMRs were about 0.75 km^3 in 2015 and about 0.62 km^3 in 1999 for Darbandikhan and Dokan feeding basin respectively. Furthermore, 0.1 km^3 was approximately the average differences between the two lakes throughout the studied years. It is worth mentioned that there was a single increment of Dokan AMR above Darbandikhan in 2013 and 2015.

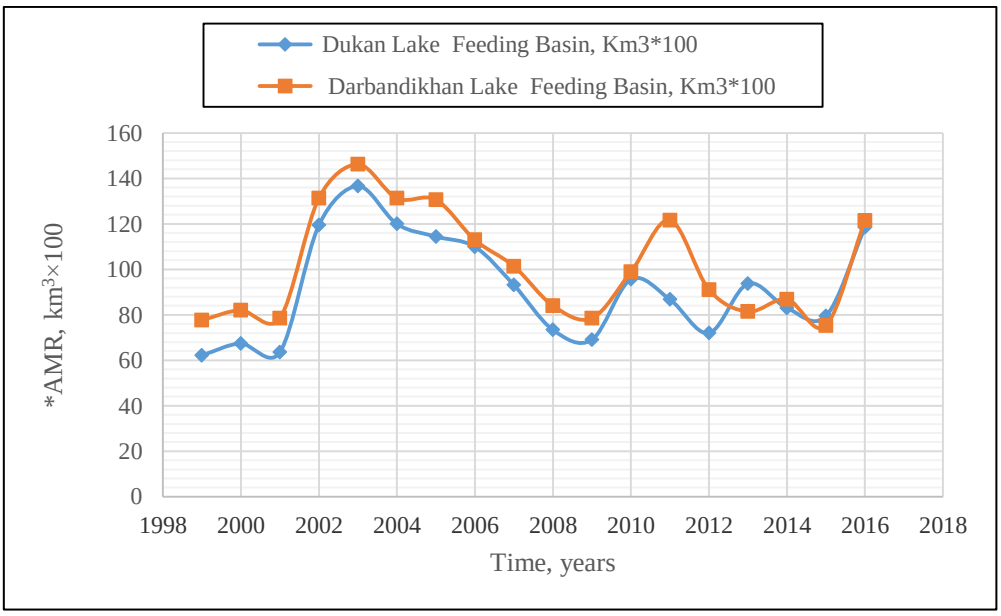


Figure 10: AMR changes for Dokan and Darbandikhan Lakes throughout (1999 - 2016) years
*Amount of AMR was multiplied by 100 for plotting purpose

4.3 Statistical Analysis

In order to identify the variation in AMR of feeding basins and water policy regardless standard ratio, AMR amounts of feeding basin of Darbandikhan Lake were divided by the AMR amounts of Dokan Lake feeding basin. It was observed that AMR of Darbandikhan recharge basin was greater than AMR of Dokan lake recharge for all years of about 1.12 except for the years 2013 and 2015 as shown in Table 1.

Correlation coefficient has been calculated between area and AMR of feeding basin for Darbandikhan and Dokan Lakes and it was about 75% and 90% respectively as indicated in Table 1. Since it positive that means that the two variables move in the same direction. However, decreasing in Darbandikhan correlation coefficient was probably due to local and global consequences of water policy issues.

Standard deviation (SD) measures the variation in the data, consistent data would have low values of SD. In other words, higher the SD, higher would be the variation and vice versa. However, since SD alone is not sufficient, coefficient of variance (COV) has been determined since it is a true measure of relative variance. Accordingly, it can be seen from Table 1 that Dokan Lake area has the lowest COV, which is about 23% in comparison with Darbandikhan of about 39%.

Table I: AMR and area details of Dokan and Darbandikhan Lakes for years (1999-2016)

Time, Year	**Darbandikhan**		**Dokan**		**AMR of Darbandikhan Feeding Basin/AMR of Dokan Feeding Basin**
	Lake Area, km^2	**AMR of Feeding Basin, km^3×100**	**Lake Area, km^2**	**AMR of Feeding Basin, km^3*100**	
1999	38.68	77.67	128.66	62.21	1.25
2000	39.13	82.00	129.25	67.40	1.22
2001	41.22	78.48	129.54	63.55	1.23
2002	90.35	131.32	207.19	119.43	1.10
2003	106.03	146.18	237.40	136.61	1.07
2004	81.47	131.24	221.40	119.95	1.09
2005	112.50	130.62	197.00	114.40	1.14
2006	112.09	112.94	202.50	109.88	1.03
2007	100.33	101.34	190.74	93.08	1.09
2008	47.38	84.03	151.36	73.37	1.15
2009	35.38	78.51	121.23	69.05	1.14
2010	56.32	98.88	127.96	95.62	1.03
2011	52.99	121.63	132.70	86.76	1.40
2012	85.47	91.09	161.37	71.98	1.27
2013	68.50	81.42	185.79	93.69	0.87
2014	56.98	86.83	156.85	83.02	1.05
2015	55.63	75.29	143.99	79.50	0.95
2016	107.00	121.46	214.60	118.44	1.03
SD	27.90	23.37	38.21	22.88	0.13
Mean	71.52	101.72	168.86	92.11	1.12
COV	39%	23%	23%	25%	11%
Correl. Coeff.	75%		90%		

4.4 Relationship between AMR and Area

Regressions and correlations were analyzed and joined together to predict a relationship (equation) between the amount of AMR and area for Dokan and Darbandikhan feeding basins of each lake by knowing the area of any of the two lakes for a given year as shown in Figure 11. The coefficient of determination R2 is an indispensable part of any serious research report and its sheer magnitude is often regarded as the most important indicator of the quality of a study (Moksony, 1999).

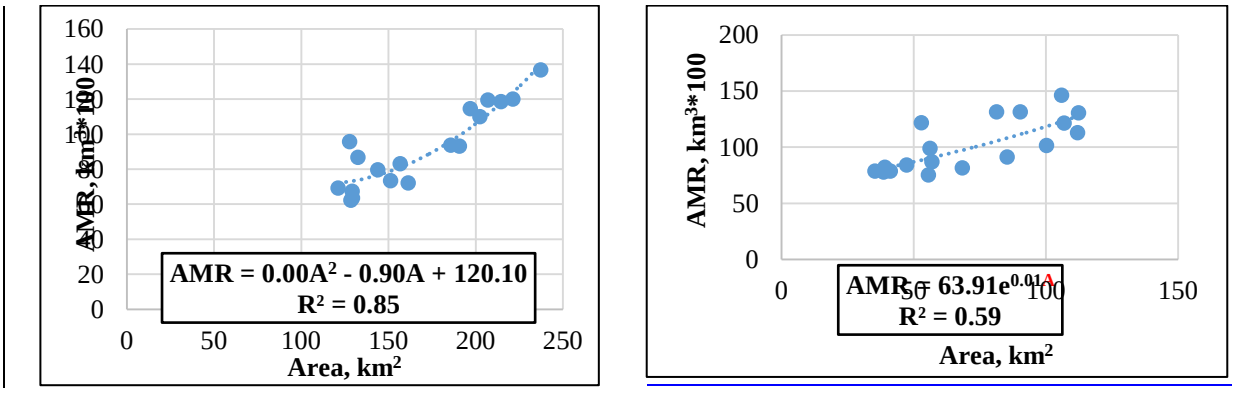
Regarding Dokan Lake (Figure 11a), determination coefficient value of R2 was found to be of about 0.85, this value considered as substantial value (Henseler et al., 2009). The best following model between the amount of average monthly rainfall and area of the lake was polynomial and it is found to be:

$$AMR = 0.00A^2 - 0.90A + 120.10 \qquad Eq.\ (1)$$

Where AMR and A represent the amount of average monthly rainfall in km3 (multiplied by 100) and the area of the lake in km^2 respectively. It can say that 85% of the variation in the values of AMR are accounted for by the exponential relationship with area.

Similarly, Figure 11b demonstrates the proposed equation for the relationship between AMR and area, the best fit model (with maximum determination coefficient R2 = 0.59, which considered as moderate indication (Henseler et al., 2009)) was exponential and it is assumed to be:

$$AMR = 63.91e^{0.01A} \qquad Eq.\ (2)$$



a- Dokan lake

b- Darbandikhan lake

Figure 11: Relationship between AMR of feeding tank verses study lakes areas

5. CONCLUSION

The study indicated the minimum area of Darbandikhan and Dokan lakes was recorded in 2009 of about 35.38 km^2 and 121.23 km^2 respectively, whereas, the maximum area of Darbandikhan and Dokan lakes was found to be 112.50 km^2 in 2005 and 237.4 km^2 in 2003 consecutively. AMR for feeding basin of Dokan and Darbandikhan lakes reached the maximum amount in 2003 of about 1.37 km^3 and 1.46 km^3 respectively. On the

other hand, the lowest AMR was observed for Dokan and Darbandikhan feeding basin of about 0.62 Km^3 in 1999 and about 0.75 km^3. In 2015 consecutively. Correlation coefficient analysis has been between area and AMR of feeding basin for Darbandikhan and Dokan Lakes and it was found to be 75% and 90% respectively. Declination in Darbandikhan correlation coefficient probably due to the neighboring countries controlling the water imports as well as the territorial policy. Overall average ratio of Darbandikhan AMR of feeding basin over Dokan AMR of feeding basin was about 1.12 km^3 throughout the 18 years during the period (1999-2016). While, overall average area of Darbandikhan and Dokan lakes was about 71.52 km^2 and 168.86 km^2 respectively. In addition, overall average AMR of Darbandikhan and Dokan lakes was 1.02 km^3 and 0.92 km^3 consecutively. Predictive correlation equation addressed by this study can be conducted to calculate the amount of AMR for the feeding basin of each lake by knowing the area of any of the two lakes for a given year.

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