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SURFACE AREA EVALUATION OF MOSUL DAM LAKE USING SATELLITE IMAGERY TECHNIQUE

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Abstract

Due to water resources such as Tigris and Euphrates rivers, tributaries branches, marshlands and lakes, Iraq is considered, generally in the world and especially in Middle East, as one of the richest countries. These resources are already affected by the consequences of climate change increasingly. One of the most vital projects in Iraq is Mosul Dam (in the northern of Iraq), thus, Mosul Dam lake (MDL), in term of surface area, was observed and studied during the prior 35 years (1984-2019) to detect the effects of historical climate changes on surface area. Satellite data of Landsat has been used in this study based on route 170 and line 35. Best and cloud-free satellite images were downloaded from US Geological Survey. Eventually, ArcGIS technique was used to process and analyze the satellite images. The result displayed that average surface area and parameter of study area was about 242 km^2 and 432 km consecutively. Relationship between surface area (A) and parameter (P) of study area has been generated and formulated. Furthermore, the correlation coefficient between surface area and parameter was about 71%. Coefficient of variance (COV) was found also to be about

0.271. Minimum surface area and parameter of study area were recorded in Sep. 2018 of about 171 km^2 and 350 km respectively regardless the dates before the operating Mosul Dam, whereas, maximum A and P lake was found to be 337 km^2 and 664 km in April,1994 respectively. The analysis showed that the exponential curve representing the best relationship between P and A.

Keywords

Mosul Dam Lake, Landsat, GIS, Water Resources Monitoring

1. Introduction

In the second half of the last century,water resource in Iraq such as Mosul Dam Lake (MDL) suffered from a lot of damage and threats that drove to a incline in water supplies (Al-Mossawi, 2020). The main source for drinking water for Iraqi provinces like Mosul, Baghdad and other cities is supplied by MDL, which is located on the Tigris river.Climate change and global warming contributed to the drought aspect in the Middle East in general and Iraq in particular, resulting in a significant decrease in rainfall amounts leading to decreasing in water resources in Iraqi rivers and tributaries (Adamo et al., 2020; Al-Khalidi et al., 2020; Khayyat et al., 2020; Othman et al., 2020). Most of Iraqi's areas suffer from lack of rainfall to less than 50% except for very small areas (Boryan et al., 2011).

Negative impact on MDL and rivers in Iraq resulting as well from construction of many dams and irrigation projects in the neighboring countries which represent the sources of Tigris and Euphrates rivers such as Iran, Turkey and Syria (Husain, 2016). Accordingly, MDL has shrunk 60% in surface area from the late of 1990s to 2018 based on a report from World Resources institute (WRI). Many researches have been done to study Mosul Dam and its reservoir in term of water quality, risk assessment, sedimentation and other characters but rare or no studies have been conducted in term of evaluating the surface area and parameter of MDL.

Remote sensing and satellite data have been widely used in the field of monitoring and classification of natural, flood control and water resources. Landsat provides reliable and accurate spectral data for identifying changes in surface area of water bodies. Landsat 5, 7 and 8 offer a good calibrated continuous data set of moderate spatial resolution (30 m). satellite images are significant for the researches of natural resources(M. F. Khattab & Merkel, 2014; Moran et al., 2001; Mustafa & Bayat, 2019; Rogan & Chen, 2004; Wu et al., 2009; Yaseen et al., 2018).

The targetfor current study is to show the temporal comparison of area changes in water surface of MDL throughout the chosen period of years (1985-2019) to give a clear idea of the deterioration of study area. Accordingly, highlighting risks and challenges facing Iraq in the near future. By combining the techniques of spatial image analysis and geographic information system

(GIS), it was possible to obtain a realistic, scientific and significant results for surface area changes of the lake generated by Mosul Dam over the period specified in this research.

2. Remote Sensing Application

The use of remotely sensed data in Earth observation and all natural resources applications is a modern and advanced approach that helps to monitor all the environmental phenomena involved in the agricultural development process, water bodies and reservoirs.Eventually, it helps in reaching the results that give a predictive view of resources status and possibility of building and adopting appropriate policies (Aljoborey & Abdulhay, 2019; Allawai & Ahmed, 2019; Lillesand et al., 2015).

Remote sensing and GIS technique are powerful tools to detect changes in natural resources in comparison with conventional methods(Al-Quraishi & Negm, 2020; Kaoje & Ishiaku, 2017; Mohamad et al., 2016; Mustafa & Bayat, 2019; Sameen et al., 2014).

Many studies have been conducted for the purpose of surveying water bodies and monitoring rivers periodically. These studies used different programs and multiple software technologies to classify the multi-spectral images, using monitoring techniques by isolating the components of earth cover from each other to get the components of the earth cover area (Robertson, 2009; Shehab et al., 2010). In this study, different Landsat satellite was used as shown in Table 1

Table 1: *Landsat Images Characteristics used in the Study*

Satellite	Sensor	Spectral Resolution (Wave length in um)	Spatial Resolution	Temporal Resolution
Landsat 1-5	Multispectral Scanner (MSS)	1:0.5 – 0.6 (B) 2:0.6 – 0.7 (G) 3:0.7 – 0.8 (R) 4:0.8 – 1. 1 (NIR)	60 m; 185 km Swaths width	16 days
Landsat 4-5	Thematic Mapper (TM)	1: 0.45 – 0.515 (B) 2: 0.52 – 0.60 (G) 3: 0.63 – 0.69 (R) 4: 0.75 – 0.90 (NIR) 5: 1.55 – 1.75 (Mid-IR) 6: (thermal): 10.40 – 12.5 7: 2.09 – 2.35 (Mid-IR)	30m (visible, near and mid-IR): 120 m (thermal IR); 185 km Swaths width	16 days
Landsat 8	Operational	1: 0.43-0.45 (CA)	30m	16 days

	Land Imager (OLI) and Thermal Infrared Sensor (TIRS)	2: 0.45 – 0.51 (B) 3: 0.53 – 0.59 (G) 4: 0.64 – 0.67 (R) 5: 0.85 – 0.88 (NIR) 6: 1.57 – 1.55 (SWIR 1) 7: 2.11 – 2.29 (SWIR 2) 8: 10.40 – 12.5 (Panchromatic) 9: 1.36-1.38 (Cirrus) 10: 10.6-11.19 (TIRS) 1 11: 11.50-12.51 (TIRS) 2	(visible, near and mid-IR): 120 m (thermal IR); 185 km Swaths width	

3. Study Area

Mosul Dam Lake (MDL) was constructed in 1985 at Tigris River approximately 60 km north of Mosul city and 80 km from Syria and Turkey borders at latitude 36˚37'44"N and longitude 42˚49'23"E (Issa et al., 2015; M. Khattab & Merkel, 2012; M. F. Khattab & Merkel, 2014), as shown in Figure 1. Mosul Dam was operating officially on 24 July 1986 (Issa, Al-Ansari, & Knutsson, 2013). It is the second largest dam in the Middle East (Adamo & Al-Ansari, 2016). Accordingly, MDL is considered as one of the biggest artificial reservoir in Iraq (M. Khattab & Merkel, 2012). The total storage volume of the lake is about 13.13 billionm^3 with maximum operation level of 330m above sea level and maximum water depth of 80m leading to drainage basin of about 4,200 km^2 inside Iraq (Al-Taiee & Sulaiman, 1990; Kelley et al., 2007; M. F. Khattab & Merkel, 2014). MDL received of about (60-5000) m3/sec of discharge from Tigris River. Outflow amount varies from 100 to 1000 m3 since the manufacture of Mosul Dam in 1985 (M. Khattab & Merkel, 2012).According to (Issa, Al-Ansari, Sherwany, et al., 2013), the useful life of Mosul dam reservoir, by using bathymetric survey and algebraic formula, is approximately 125 years.

Arid to semi-arid is the ambient climate in the study area with temperature reaches to more than 55°C in July and drops to 12°C in winter, while average amount of rainfall is about 300mm/yr. Surface area of the lake is about 385 $km^2$and total storage volume 11.13×109m3 at max. operation level (M. Khattab & Merkel, 2012).

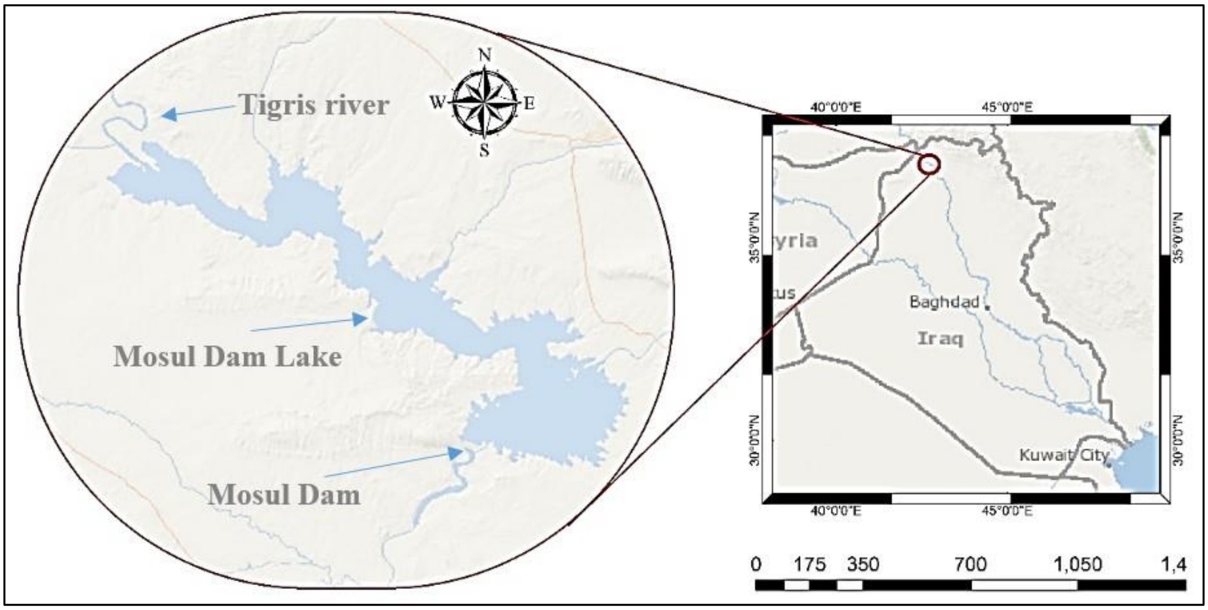

Figure 1: *Location of Mosul Dam Lake (Study Area)*

4. Data Description

According to (Bureau, 2010; Issa, Al-Ansari, & Knutsson, 2013), the highest and driest mean monthly discharge occurs usually during April and September respectively (Figure 2). The max. and min. monthly discharge of Tigris, observed since 1931, was 3514 m^3/s and 87.7 m^3/s during April 1954 and September 1986 consecutively.

Satellite data of Landsat have been used in this study based on route 170 and line 35 to determine and analyze the coverage area of each classified class, as shown in Table 2. Number of satellite images was 33, which covered the study area for the period from 1984 to 2019. Most of acquisition Dates were selected in April and September since the peak mean monthly discharge happensin April and the driest month is in September (Issa, Al-Ansari, & Knutsson, 2013).Data was downloaded from US Geological Survey's website (earthexplorer.usgs.gov) as can be seen in Table 2. Eventually, ArcGIS technique was used to process and analyze satellite images.

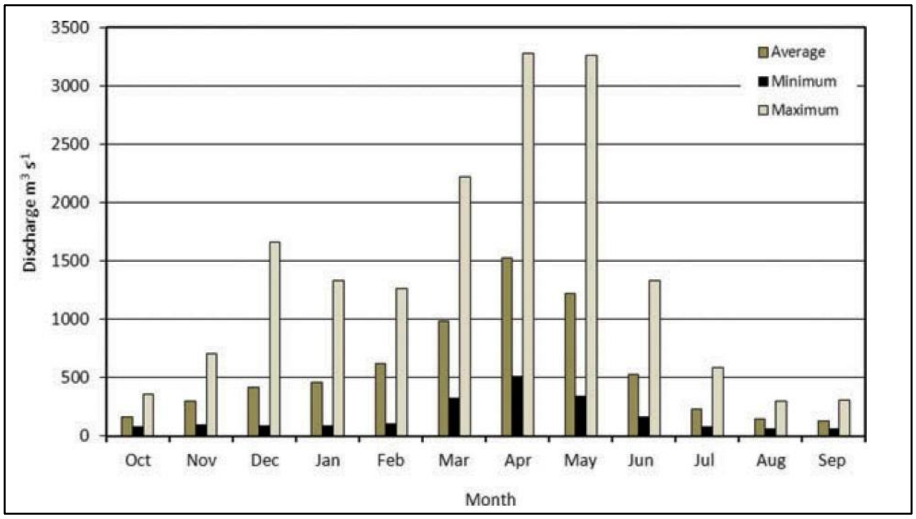

Figure 2: *Monthly Inflows Received by Reservoir from Tigris River throughout the Years 1931–2011*

Table 2: *Description of the Satellite Imagery with Patch/Row 170/35, (earthexplorer.usgs.gov)*

Landsat Type	Acquisition Date		Landsat Type	Acquisition Date	
Landsat 5	1984	June 6, 1984	Landsat 8	2013	September 10, 2013
		September 26, 1984		2014	April 22, 2014
	1985	July 27, 1985			September 13, 2014
	1986	April 25, 1986		2015	April 25, 2015
		August 15, 1986			October 2, 2015
	1987	September 3, 1987		2016	May 13, 2016
	1989	April 1, 1989			September 18, 2016
	1991	September 30, 1991		2017	March 29, 2017
	1994	April 15, 1994			September 21, 2017
	1996	September 27, 1996		2018	April 17, 2018
	1998	April 10, 1998			September 24, 2018
	2000	April 22, 2000		2019	May 22, 2019
	2004	April 26, 2004			September 11, 2019
	2006	September 23, 2006			
	2008	April 23, 2008			
	2009	September 15, 2009			
	2010	May 29, 2010			
		October 20, 2010			
	2011	April 14, 2011			
		September 21, 2011			

5. Methodology

Best and cloud-free satellite images, which covered the entire study area, were collected, bad images or containing some defects in their composition were excluded. Eventually, the total number of images included in this study was 33 satellite images.

The classification technique was used to categorize all images to obtain the distribution of land cover varieties, classified into three main categories: soil, plant and water as displayed in Figure 3. In this research, only water category has been studied and classified and it was the location of water surface (study area) for all selected years that were introduced in this study. GIS was used to perform all previous steps. In addition, water surface area and general direction of change in surface water area were calculated and analyzed to draw the various graphs related to the results.

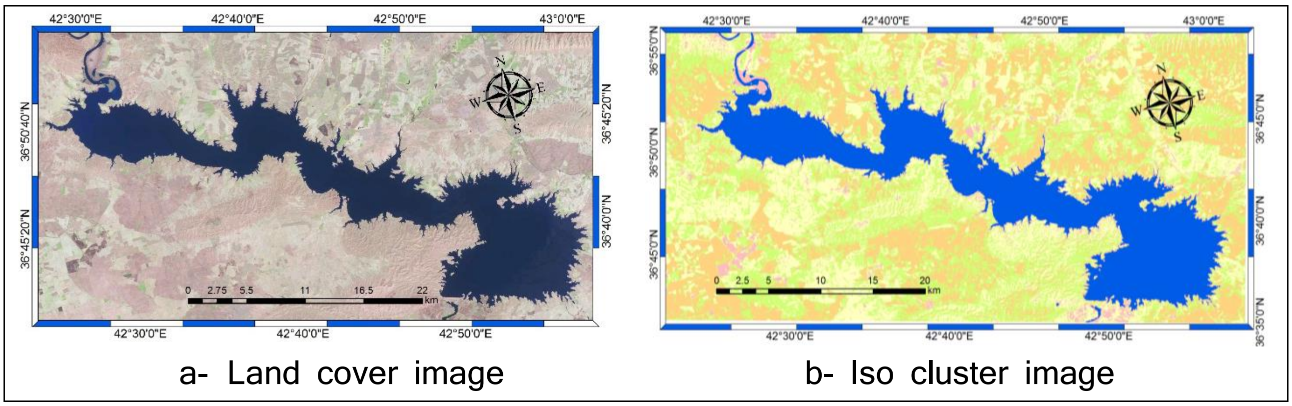

Figure 3: *Land Cover Classification Model for Study Area, Sep. 2019*

6. Results and Discussion

The remote sensing method offers a suitable technique in integrating water quality information composed from conventional measurements. Satellite images are also being commonly utilized for observing numerous quintessences in water bodies. Thirty-three satellite images, which covered the whole study area, were selected for detecting the variations in water surface of MDL throughout years (1984-2019). Landsat 5 and Landsat 8 have been used to collect the needed data. In addition, ArcGIS used to process and categorize the geometry analysis.

6.1 Water Surface Area of Study Area

The classification maps have been conducted for the study area according to the chosen years (1984-2019). The results indicated that the water layer suffered a pattern of changes concerning the water of surface area. Most of image dates were chosen in April and September since the peak average monthly discharge happens throughout April and the driest month is mostly during Sept. (Issa, Al-Ansari, & Knutsson, 2013). Impounding of MDL began in June (1984), with incipient basin fill throughout spring (1985), whereas the actual operating of the dam began in 1986 (Issa, Al-Ansari, & Knutsson, 2013), as shown in Figures4 and 5.

It can be clearly seen, from Table 3 and Figure 5, that A and P are about 242 km^2 and 43 km respectively. As expected, the maximum A and P were calculated to be about 337 km^2 and 664 km in

April 15, 1994. While the minimum A and P were about 171 km^2 and 350 km consecutively in September 24, 2018.

The bar chart in Figure 5 illustrates the amount of A and P during 35 years along the period 1984-2019. For the first three years, it was recorded very low average value for A and P of about 37 km^2 and 252 km respectively in comparison with average value 242 km^2 and 432 km respectively of the later 32 years (1987-2019), see Figure 7. Overall, the values of A and P fluctuated over the period given. increasing and decreasing in water surface probably due to the monthly inflows received by Mosul reservoir from Tigris River and because of the controlling of water imports by neighboring countriesand in addition the territorial policy.

Table 3: *Surface Area and Parameter Amount Details of MDL, 1984-2019*

Landsat Type	Acquisition Date		Area (A), km^2	Parameter (P), km	A/P
Landsat 5	1984	June 6, 1984	30	285	0.11
		September 26, 1984	34	249	0.14
	1985	July 27, 1985	46	222	0.21
	1986	April 25, 1986	244	327	0.75
		August 15, 1986	221	299	0.74
	1987	September 3, 1987	239	384	0.62
	1989	April 1, 1989	201	363	0.55
	1991	September 30, 1991	252	420	0.60
	1994	April 15, 1994	337	529	0.64
	1996	September 27, 1996	242	432	0.56
	1998	April 10, 1998	260	464	0.56
	2000	April 22, 2000	264	503	0.52
	2004	April 26, 2004	311	664	0.47
	2006	September 23, 2006	250	415	0.60
	2008	April 23, 2008	274	441	0.62
	2009	September 15, 2009	223	368	0.61
	2010	May 29, 2010	280	361	0.78
		October 20, 2010	200	360	0.56
	2011	April 14, 2011	229	389	0.59
		September 21, 2011	223	354	0.63
Landsat 8	2013	September 10, 2013	249	531	0.47
	2014	April 22, 2014	235	486	0.48
		September 13, 2014	194	365	0.53
	2015	April 25, 2015	294	524	0.56
		October 2, 2015	190	362	0.52
	2016	May 13, 2016	258	501	0.51
		September 18, 2016	201	399	0.50

	2017	March 29, 2017	207	350	0.59
		September 21, 2017	215	473	0.45
	2018	April 17, 2018	183	358	0.51
		September 24, 2018	171	352	0.49
	2019	May 22, 2019	323	553	0.58
		September 11, 2019	265	420	0.63
Mean			242	432	0.56
SD					0.10
COV					0.183

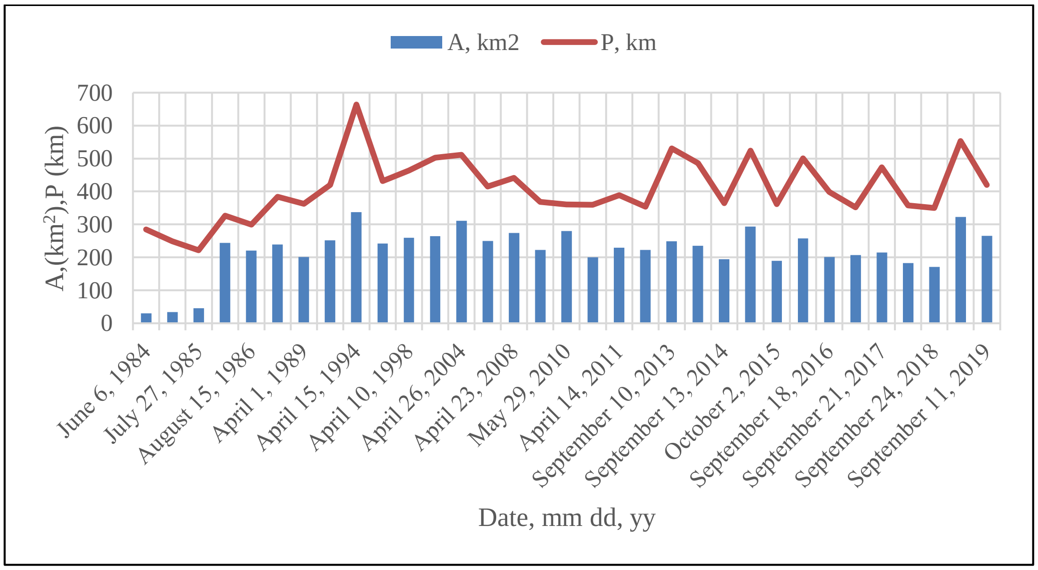

Figure 4: *Variations in Surface Area and Parameter of Study Area, 1987-019*

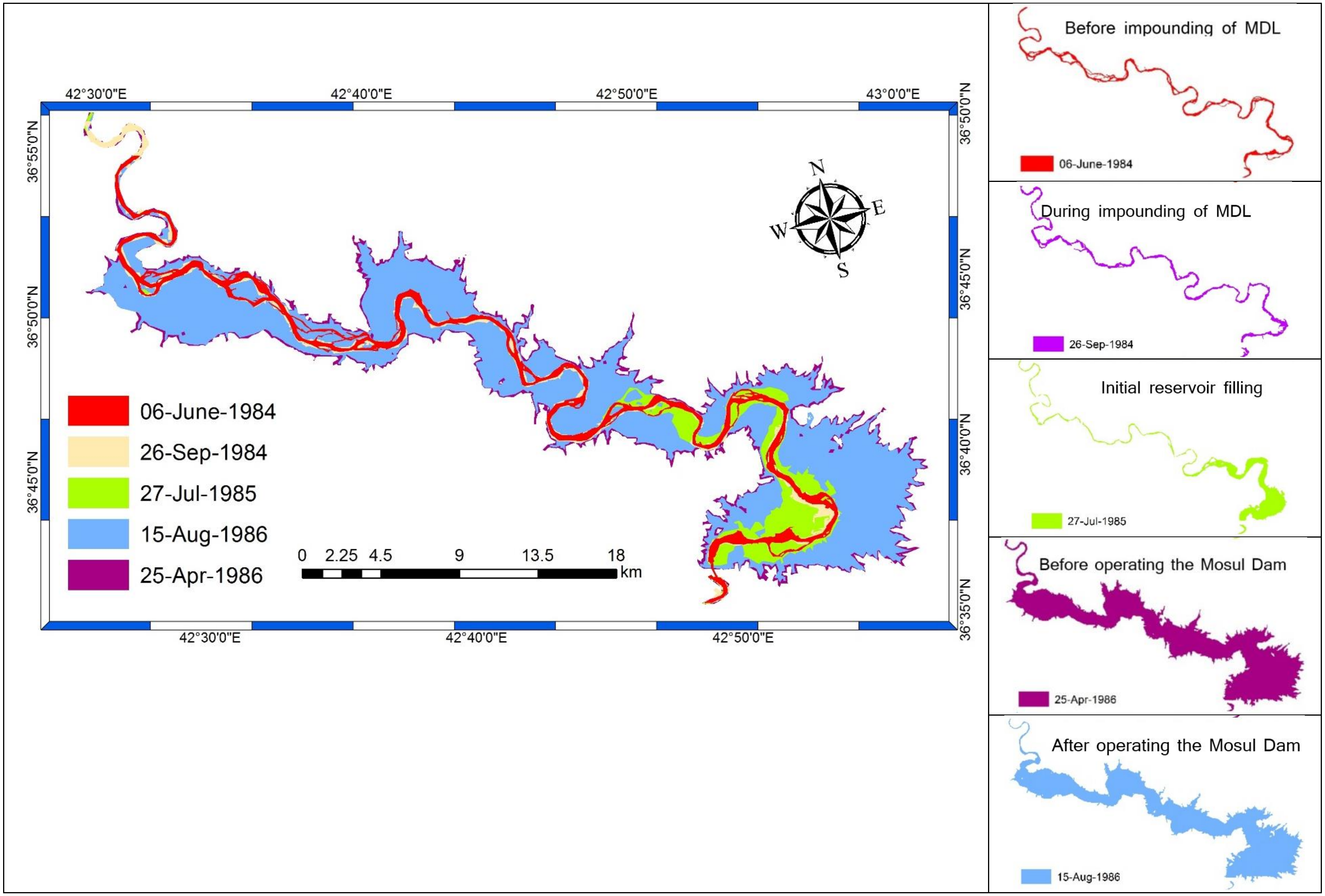

Figure 5: *Water Surface Area Variations of Mosul Reservoir during the Years during 1984-1986*

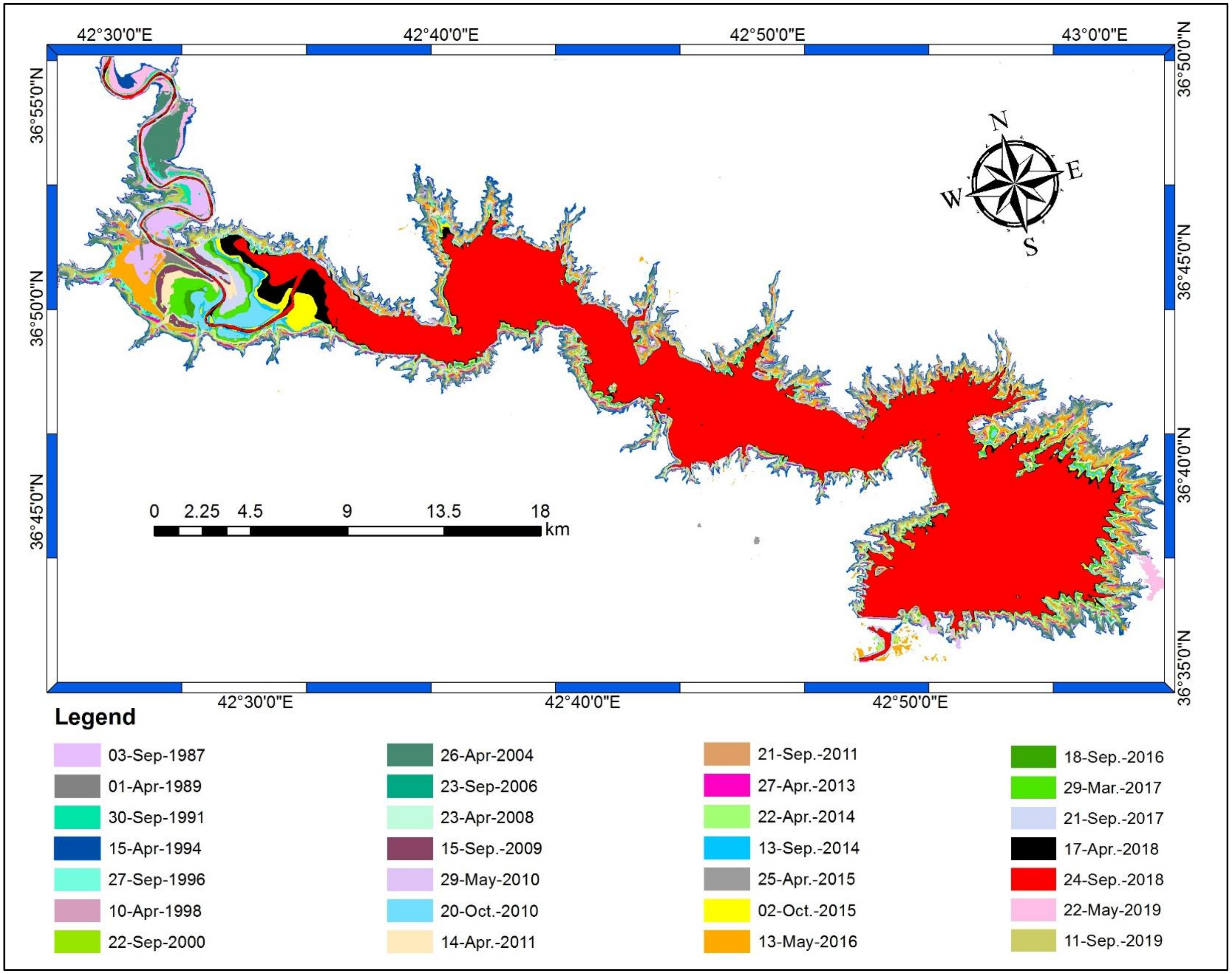

Figure 6: *Water Surface Area Variations of Mosul Reservoir during the years 1987-2019*

6.2 Statistical Analysis

Standard deviation (SD) has been found since it calculates the variation in the data. Lower the SD leads to lower variation in data and vice versa. In addition, coefficient of variation (COV) measures the true value of relative variance (Moksony, 1990). Table 3 expresses the statistical analysis of the surface area and parameter predicted by the proposed study. The mean value of the prediction is 0.54 with a standard deviation of 0.15 and coefficient of variation of 0.271. COV displayed good accuracy and consistency for the values obtained. This was enough to consider the suggested Equation model proper for evaluation the relation between surface area and parameter.

6.3 Regression Analysis

Regression and correlation were joined together to determine the relationship between A and P of MDL (Figure 7) to calculate out the magnitude of determination variable (R^2) since it represents the mostlysignificantindicators of quality of a study (Moksony, 1990). R^2 of maximum 0.71 shows a good exponential relationship with positive sign, which means that the relationship is proportional and the two variables move in the same direction.. In other words, it can be said that 71% of the variation of P are accounted for by the relationship with A.

The analysis show that the exponential curve representing the best relationship between P and A as observed in Figure 4 and the best equation assumed to be:

$$P = 217.1335e^{0.0027A} \quad (1)$$

where P and A are parameter and surface area respectively of MDL.

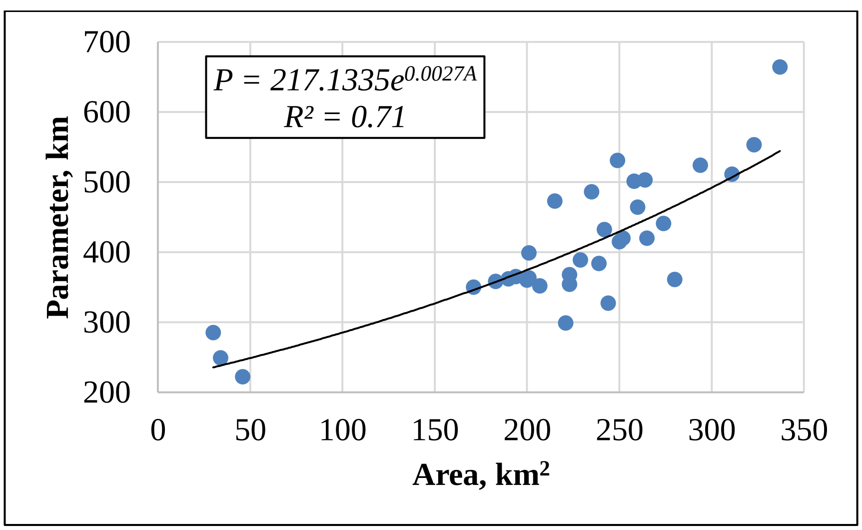

Figure 7: *Relationship between Surface Area and Parameter of Study Area*

7. Conclusion

This research is limited to the collected data from the resources and software mentioned previouslyfor the determination of surface area andparameter. Some data is impossible to perform because not all images captured in a GIS system can be available completely in the required date. However, the factors performance to be investigated in this study includes surface area, parameter and correlation equation of Mosul lake using Landsat satellite images to detect the changes occurred since 1984. Extensive future studies should be provided on all characteristics of Mosul dam Lake.

Thirty-three maps were created and compound for MDL using ArcGIS 10.2 technique. First stage was in 1984 (before and after impounding the reservoir), The second stage represented the initial filling of the reservoir in 1985 while the third was before and after operating Mosul Dam in 1986. Eventually, the period of 1987-2019 was studied to compare the overall changes in the surface area and parameter of MDL. It was found that the minimum surface area and parameter of study area was recorded in Sep. 2018 of about 171 km^2 and 350 km respectively, whereas, the maximum A and P of the studied lake were found to be 337 km^2 and 664 km in April, 1994 respectively. Correlation coefficient analysis has been formulated between A and P and it was found to be 71%. Iclination in correlation coefficient possiblybecause of the controlling of water imports by neighboring countriesand in addition the territorial policy. The exponential curve representing the best relationship between P and A displayed by the regression analysis. COV displayed a good accuracy and consistency for the values obtained.

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