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INVESTIGATION OF CHLOROPHYLL PIGMENT CONCENTRATION AND SEA SURFACE TEMPERATURE OF THE LAKE VAN

VAN GÖLÜ'NÜN KLOROFİL PİGMENT KONSANTRASYONU VE SU YÜZEY SICAKLIĞININ İNCELENMESİ

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ARTICLE INFO	ABSTRACT
Keywords: Chlorophyll-a Sea Surface Temperature Landsat OLI Coccolithophore Remote Sensing	Current study is investigated chlorophyll-a (Chl-a) pigment concentration and its relationship with Sea Surface Temperature (SST) using cloud-free high resolution 59 Landsat-The Operational Land Imager (OLI) images from May 2013 to September 2018 covering Lake Van of Turkey. In addition, the concentrations of coccolithophore which is a kind of phytoplankton was also studied using the same method. The fact that Van Lake is extremely rich in terms of aquatic life has led to the investigation of the factors affecting the marine habitat. Therefore, SST, Chl-a concentrations, as well as the relationship between them and coccolithophore concentrations were investigated to evaluate marine life and ecosystem in the Lake. Satellite-generated data can provide information about the marine life in a particular area worldwide. Coccolithophore, SST and Chl-a were obtained from high resolution 59 Landsat OLI using SeaDAS software. Aforementioned parameters were extracted from images using SeaDAS's OCSSW L2GEN module and then output processed by QGIS (Open Source Geographic Information System) to conduct statistical calculation. Negative correlation coefficients of 74% and 73.7% were found for 2014 and 2017, respectively, and these were not statistically significant. Although the information does not give meaningful results, it may be useful in future studies about the effects of global temperature changes and the marine life for particular region.

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MAKALE BİLGİSİ	ÖZET
Anahtar Kelimeler: Klorofil-a Su Yüzeyi Sıcaklığı Landsat-OLI Uzaktan Algılama kokolit	Bu çalışmada, Van Gölü'nü Mayıs 2013ve Eylül 2018 tarihleri arasını kapsayan bulutsuz 59 Landsat-The Operational Land Imager (OLI) görüntüleri kullanılarak klorofil-a (Chl-a) pigment konsantrasyonu,ve Su Yüzey Sıcaklığı (SST) ile ilişkisi araştırılmıştır ayrınca fitoplankton türü olan kokolit miktarı incelenmiştir. Türkiye'nin en büyük gölü olarak kabul edilen ve dünyanın en büyük soda gölü olan Van Gölü'nün tuzlu ve soda suları biyoçeşitliliği artıran faktörler arasındadır. Van Gölü'nün su canlılığı açısından son derece zengin olması, deniz yaşam alanını etkileyen faktörlerin araştırılmasına yol açmıştır. Bu nedenle Van Gölü'nde deniz yaşamı ve ekosistemi değerlendirmek için SST ve Chl-a konsantrasyonları ve ayrıca aralarındaki ilişki araştırılmıştır. Uydudan üretilen veriler, dünya çapında belirli bir alanda bulunan akuatik yaşam hakkında bilgi sağlayabilir. Van Gölü'nün klorofil-a pigment konsantrasyonlarını incelemek için yüksek çözünürlüklü 59 Landsat-OLI imager görüntüleri kullanıldı. SST ve Chl-a, SeaDAS yazılımı kullanılarak Landsat OLI'den elde edildi. SST, Chl-a ve Kokolit SeaDAS'ın OCSSW L2GEN modülü kullanılarak görüntülerden elde edildi ve daha sonra istatistiksel hesaplama yapmak için QGIS'de ((QGIS), 2009) (Open Source Geographic Information System) işlendi. 2014 ve 2017 yılları için istatistiksel olarak anlamlı olmayan %74 % 73,7 gibi korelasyon katsayıları bulundu. Bilgiler anlamlı sonuçlar vermese de, gelecekteki çalışmalarda küresel ısınma değişikliklerinin etkileri ve belirli bir bölge için akuatik yaşam hakkında faydalı olabilir.

INTRODUCTION

Lake Van is the largest lake in Turkey, located in the far east of the country. It is a saline soda lake, receiving water from numerous small streams that descend from the surrounding mountains. Lake Van is also one of the world's largest endorheic lakes (having no outlet). The original outlet from the basin was blocked by an ancient volcanic eruption. Although Lake Van is situated at an altitude of 1,640m with harsh winters, it does not freeze due to its high salinity except occasionally the shallow northern section, (Britannica, 2019).

Lake Van is 119 meters across at its widest point, averaging a depth of 171 meter with a maximum recorded depth of 451 meter. The lake surface lies 1,640 meter above sea level and the shore length is 430 kilometers. Lake Van has an area of 3,755km2 and a volume of 607 cubic kilometer (E. Degens, Wong, Kempe, & Kurtman, 1984).

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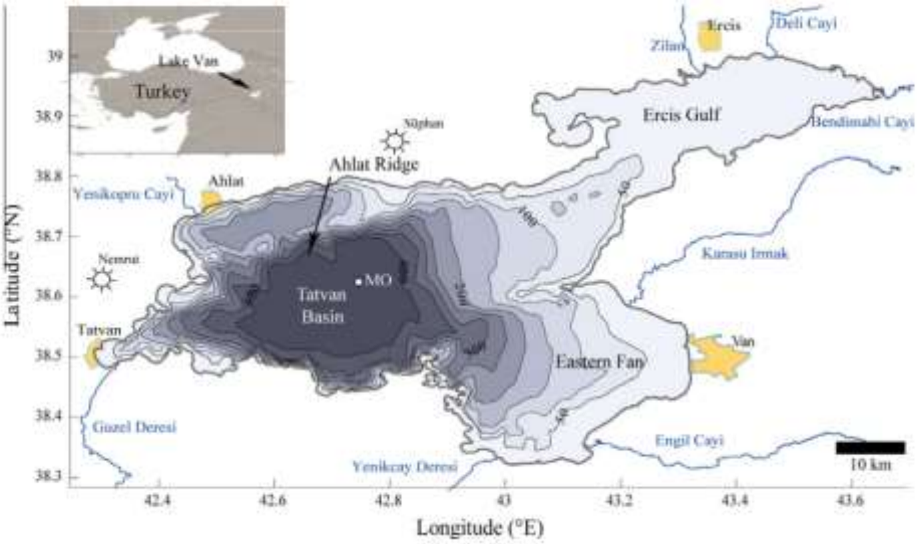

Figure 1. Geographic setting and bathymetry of Lake Van

The western portion of the lake is deepest, with a large basin deeper than 400 m lying northeast of Tatvan and south of Ahlat. The eastern arms of the lake are shallower. The Van-Ahtamar portion shelves gradually, with a maximum depth of about 250 m on its northwest side where it joins the rest of the lake. The Erciş arm is much shallower, mostly less than 50 m, with a maximum depth of about 150 m (Wong & Degens, 1978) (Tomonaga, Brennwald, & Kipfer, 2011).

The upwelling radiance and the derived Chlorophyll-a are identified as essential climate variables by Global Climate Observation System3 and their accuracy (and stability) are specified as 5% (0.5%) and 30% (3%) respectively. (GCOS-154, 2011).

Climate change is considered to be one of the most severe threats to ecosystems around the globe (Adrian et al., 2009) (Hassol et al., 2004) (Rosenzweig et al., 2007). Monitoring and understanding the effects of climate change pose challenges because of the multitude of responses within an ecosystem and the spatial variation within the landscape. A substantial body of research demonstrates the sensitivity of lakes to climate and shows that physical, chemical, and biological lake properties respond rapidly to climate-related changes (Hassol et al., 2004) (Rosenzweig et al., 2007). Previous studies have suggested that lakes are good sentinels of global climate change because they are sensitive to environmental changes and can integrate changes in the surrounding landscape and atmosphere (Carpenter et al., 2007) (Pham, Leavitt, McGowan, Peres-Neto, & Oceanography, 2008; Williamson, Dodds, Kratz, Palmer, & Environment, 2008). One parameter, SST, which is important indicator of global warming first, was studied for Lake Van by (Sari, Polat, & Saydam, 2000) from February 1998 to January 1999 to map SST with bathymetry and current using remote sensing techniques and by long-term SST by (Kavak & Karadogan, 2012). Level change studied by (Yıldız & Deniz, 2005). Environmental Geology of Lake Van Basin studied by (Çiftçi, Isık, Alkevli, & Yesilova, 2008).

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Affect by climate change studied by (Kadioğlu, Şen, & Batur, 1997). Geologically studied by E. T. Degens and Kurtman (1978).

Coccolithophores are a phytoplankton group inhabiting a wide range of variety of marine environments and these organisms synthetically generate each coccolith plate from calcium carbonate and play an important role in ocean-based calcium and carbonate cycling. Coccolithophores is a particular parameter to study global climate change and determine its effects on aquatic habitat. Coccolithophore blooms may occur on extraordinarily large spatial scales at sometimes under favorable conditions. These blooms can be seen in ocean color satellite imagery as a consequence of light scattering in near-surface waters suspended by the coccolith plates detached from cells released by cell death and coccolith overproduction (Moore, Dowell, & Franz, 2012).

Present work concentrated on two parameters SST and Chlorophyll-a and their relation using high resolution Landsat-OLI (Landsat-OLI, 2019) data for 6 years which might be useful for scientists to study Lake Van with other parameters such as level change, eco system, dissolved organic carbon (DOC), Harmful algal blooms, or HABs, regional air temperature etc., for today and after.

The aforementioned parameters, available from remote sensing observations, are commonly used to detect the presence of algal blooms: – Chlorophyll-a Concentration (Chl-a) – Chlorophyll-a Concentration Anomalies – Sea Surface Temperature (SST) – Optical Characteristics (absorption, backscattering).

Remote sensing is used for HAB detection using reflected solar radiation in various visible to near-infrared (NIR) bands are used to derive the properties of optically active water constituents, including Chl-a.

MATERIAL AND METHOD

To study Chlorophyll pigment concentrations of Lake Van 59 (Table 1) Landsat OLI images were used. SST, CHL and coccolithophore extracted from Landsat OLI using SeaDAS software which was developed by NASA staff (Moore et al., 2012) and runs on Linux, Windows and Mac OSX platform. Extraction of chlorophyll and coccolithophore requires Ocean Color Science Software (OCSSW) maintained by the Ocean Biology Processing Group and distributed to the public with the SeaDAS (NASA Goddard Space Flight Center, 2014) package which only runs only Linux and Mac OSX platforms. The data from 2013 to 2018 were downloaded using Earth explorer interface by chasing minimum cloud cover. SST and Chl extracted from images using SeaDAS using OCSSW L2GEN module then output processed by QGIS ((QGIS), 2009) (A Free and Open Source Geographic Information System) to conduct statistical calculation.

The known parametrization that used by the L2GEN is not going to work there because it has been created for ocean waters. One parameter to same extend that we can change in order to

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work in inland water bodies with Landsat data is the aerosol parametrization so in this case, no aerosol obstruction was selected and this is because the atmospheric correction tends to fail in the areas in water bodies contain very turbid water. Calculation anomalies (take average CHL and SST from all images and subtract the mean from each image) may be able to say relative increase or decrease in these parameters. In order to register on exact point SST calculated from the mask in which CHL extracted.

Table 1. Downloaded Landsat OLI dataset.

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3	LC08_L1TP_170033_20130622_20170503_01_T1_B10.TIF	33	LC08_L1TP_170033_20160801_20170322_01_T1_B10.TIF
4	LC08_L1TP_170033_20130708_20170504_01_T1_B10.TIF	34	LC08_L1TP_170033_20160817_20170322_01_T1_B10.TIF
5	LC08_L1TP_170033_20130724_20170503_01_T1_B10.TIF	35	LC08_L1TP_170033_20160918_20170321_01_T1_B10.TIF
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10	LC08_L1TP_170033_20140321_20170425_01_T1_B10.TIF	40	LC08_L1TP_170033_20170601_20170615_01_T1_B10.TIF
11	LC08_L1TP_170033_20140609_20170422_01_T1_B10.TIF	41	LC08_L1TP_170033_20170617_20170629_01_T1_B10.TIF
12	LC08_L1TP_170033_20140625_20170421_01_T1_B10.TIF	42	LC08_L1TP_170033_20170703_20170715_01_T1_B10.TIF
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17	LC08_L1TP_170033_20140913_20170419_01_T1_B10.TIF	47	LC08_L1TP_170033_20171007_20171023_01_T1_B10.TIF
18	LC08_L1TP_170033_20140929_20170419_01_T1_B10.TIF	48	LC08_L1TP_170033_20171023_20171107_01_T1_B10.TIF
19	LC08_L1TP_170033_20150308_20170412_01_T1_B10.TIF	49	LC08_L1TP_170033_20180401_20180416_01_T1_B10.TIF
20	LC08_L1TP_170033_20150409_20170410_01_T1_B10.TIF	50	LC08_L1TP_170033_20180417_20180501_01_T1_B10.TIF
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23	LC08_L1TP_170033_20150628_20170407_01_T1_B10.TIF	53	LC08_L1TP_170033_20180620_20180703_01_T1_B10.TIF
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27	LC08_L1TP_170033_20150831_20170404_01_T1_B10.TIF	57	LC08_L1TP_170033_20180823_20180829_01_T1_B10.TIF
28	LC08_L1TP_170033_20150916_20170404_01_T1_B10.TIF	58	LC08_L1TP_170033_20180908_20180912_01_T1_B10.TIF
29	LC08_L1TP_170033_20151018_20170403_01_T1_B10.TIF	59	LC08_L1TP_170033_20180924_20180929_01_T1_B10.TIF
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RESULTS AND DISCUSSION

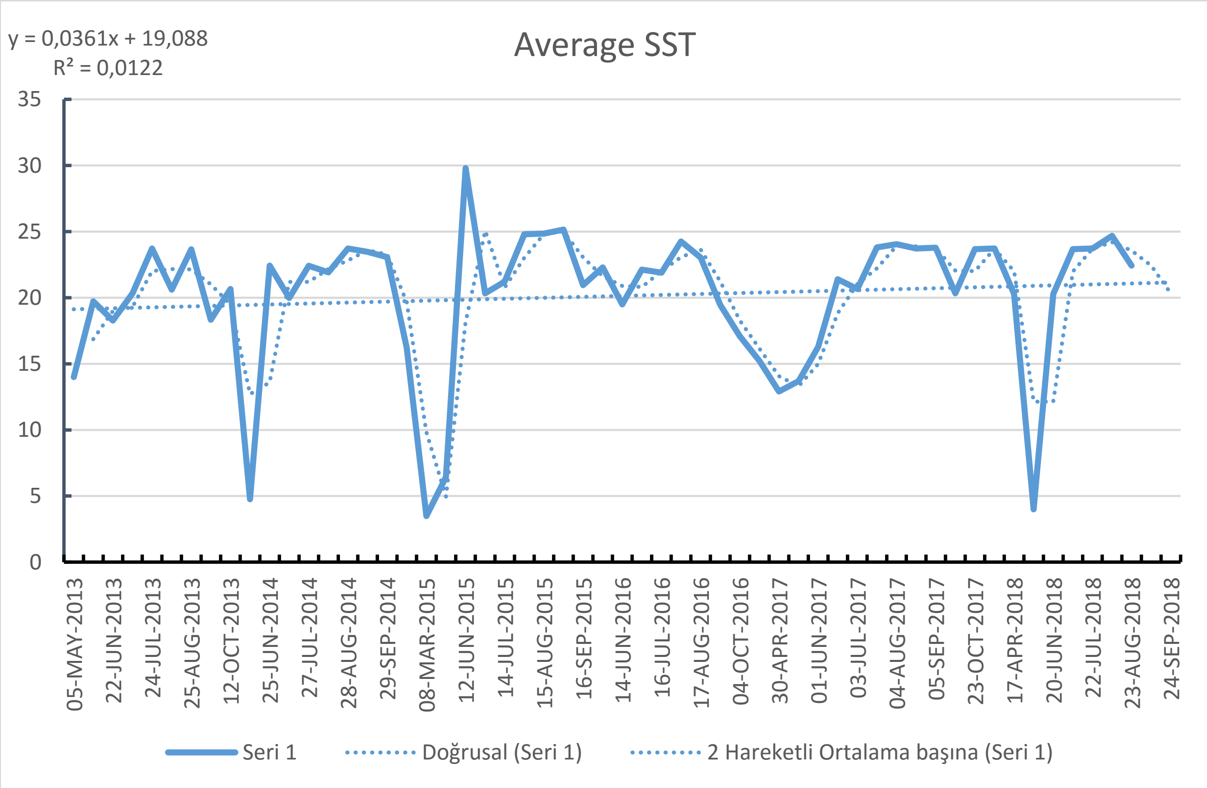

Figure 2. Five years of averaged cloud free SST (in Celsius) variation of the lake.

SST value of 9 June 2014, 8 March 2015, 4 June 2018 remained below the trend curve of the graph whereas SST value of 12 June 2015 remained above the trendline. These results may be attributed to meteorological condition and tectonic activities of the region which may be investigated separately.

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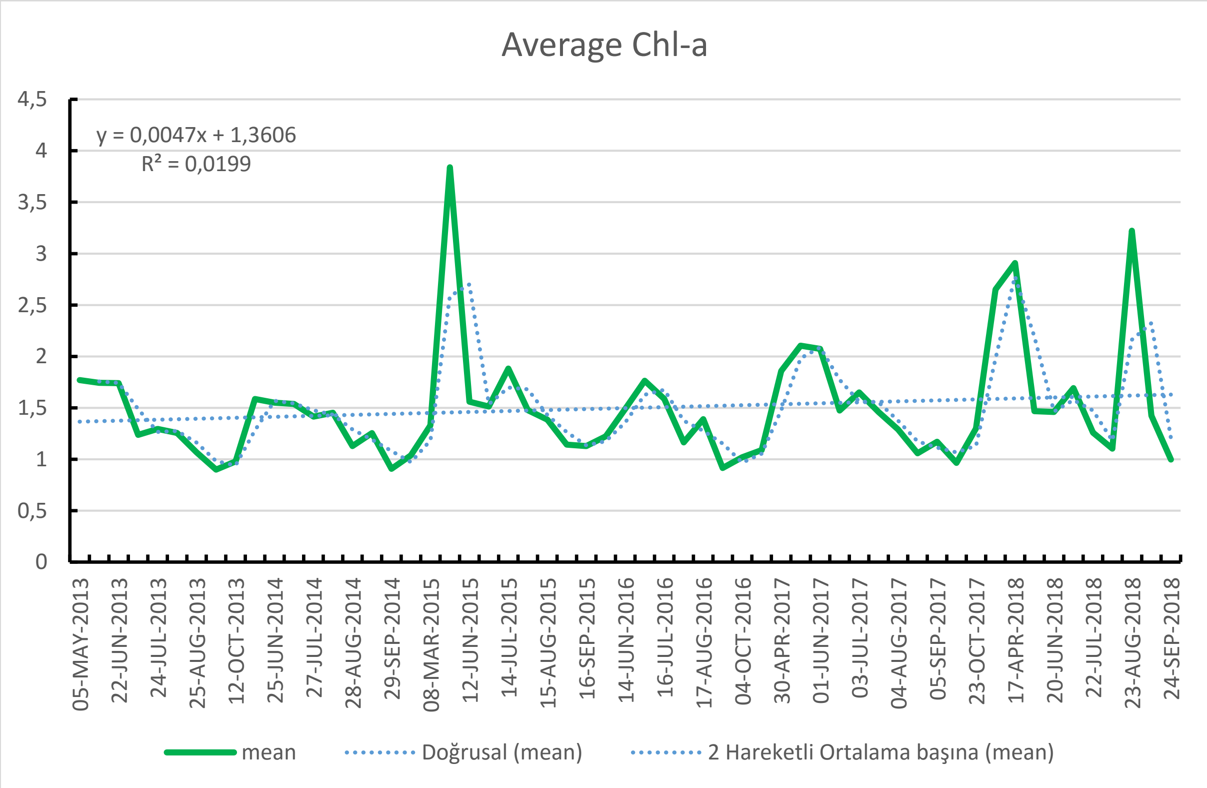

Figure 3. Five years averaged cloud free Chl-a (mg/m3) variation of the lake.

Chl value of 9 April 2015, 17 April 2017 and 23 August 2018 were higher than the general trend line. Although this Chlorophyll-a excess is beneficial for global warming, the phytoplankton activity may increase the algae formation and threaten the ecosystem of aquatic life. So this Chl-a amount balance will be an issue to be investigated and kept under the control by institutions nearby.

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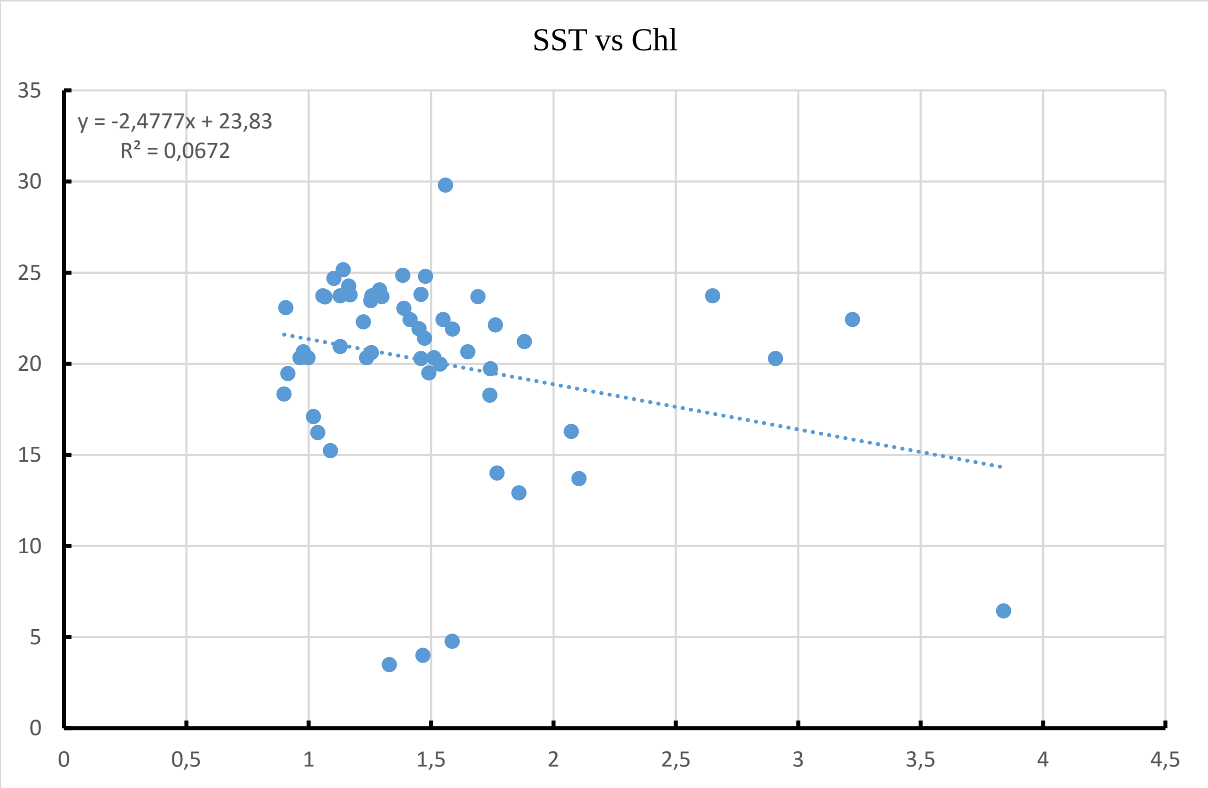

Figure 4. Cross plot of SST and Chl

Although no significant correlation was found between SST and Chl for the whole lake, investigating of estuary and river discharged points may change these results.

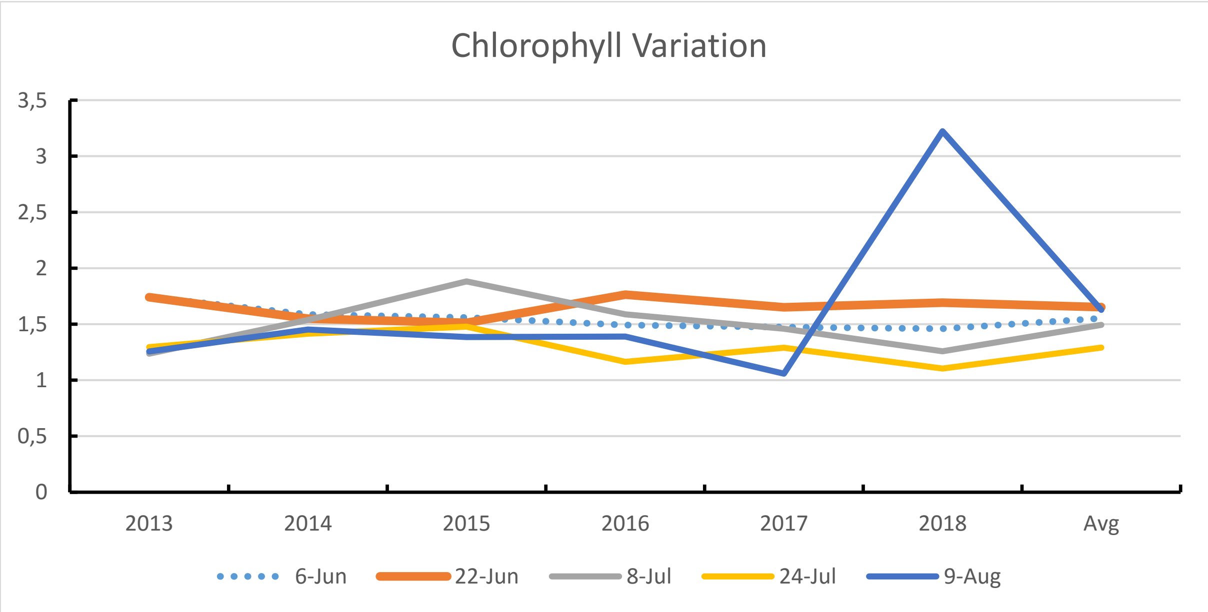

Figure 5. Variation of Chl on certain days by years.

When the graph analyzed 9 August 2018 is far from the average. This result may have observed with environmental factors varying from year to year, and the search for this rise may be important for the marine ecosystem.

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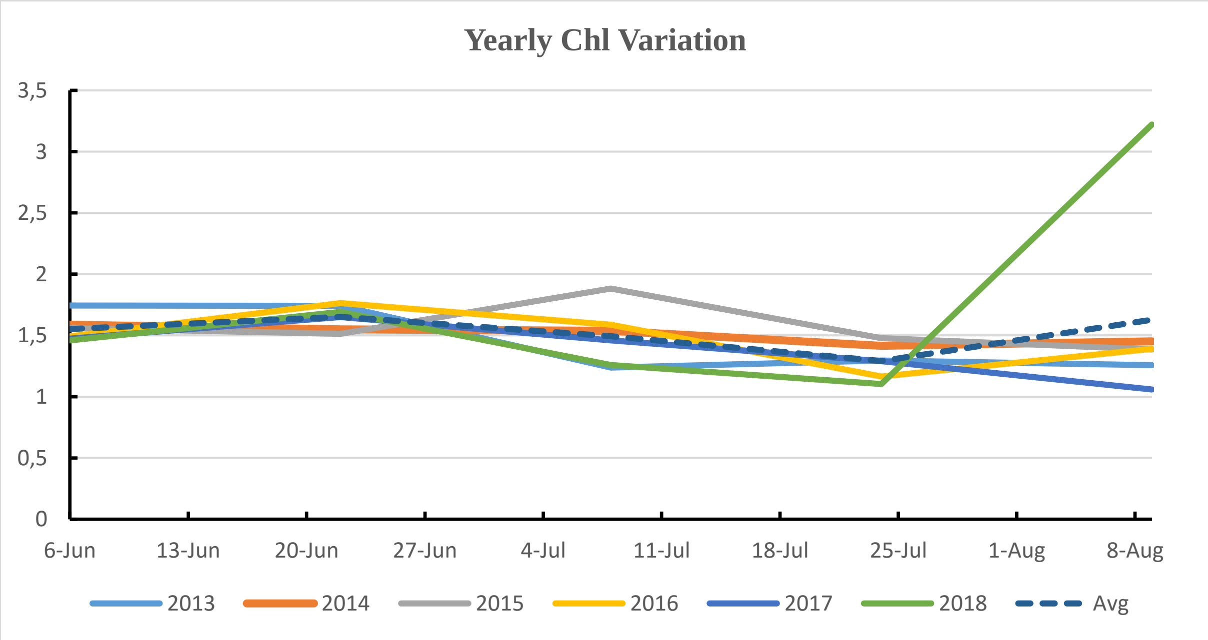

Figure 6. Variation of Chl on certain years by days.

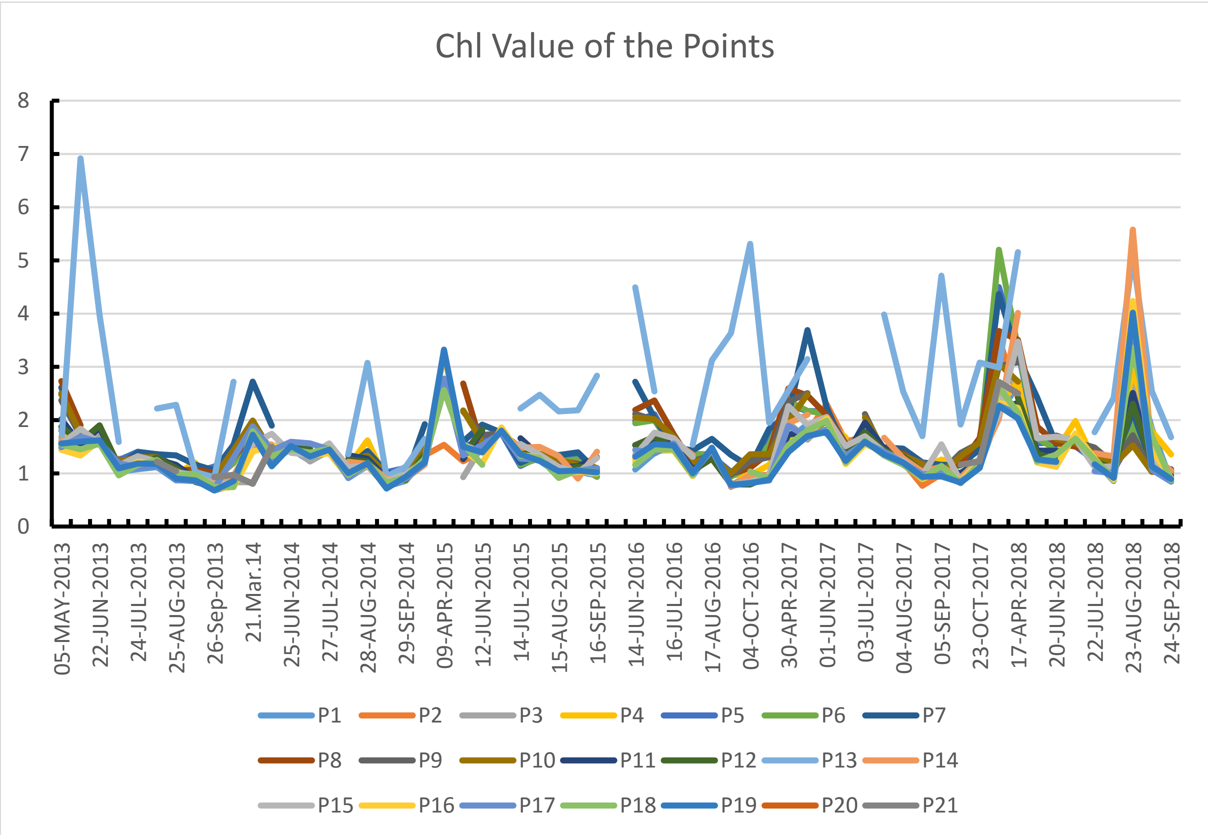

Figure 7. Chl behavior some locations of Lake Van. Coordinates are given and may be accessed below via QR code reader.

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Table 2. Coordinates of selected points

	Longitude:	Latitude:
P1	42°54'22" E	38°41'58" N
P2	42°23'54" E	38°37'08" N
P3	42°31'02" E	38°46'23" N
P4	42°44'30" E	38°48'29" N
P5	43°09'56" E	38°56'28" N
P6	43°13'06" E	38°56'15" N
P7	43°16'15" E	38°57'18" N
P8	43°26'32" E	38°58'09" N
P9	43°30'20" E	38°57'32" N
P10	43°30'07" E	38°57'06" N
P11	43°10'47" E	38°45'06" N
P12	43°08'16" E	38°42'36" N
P13	43°16'53" E	38°33'58" N
P14	43°11' E	38°30'24" N
P15	42°57'32" E	38°26'11" N
P16	42°47'14" E	38°39'01" N
P17	42°58'48" E	38°37'32" N
P18	42°44'05" E	38°42'48" N
P19	42°56'42" E	38°39'01" N
P20	42°26'12" E	38°45'45" N
P21	42°26'12" E	38°45'45" N

Table 3. Statistical table

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	2013SST	*2014SST*	*2015SST*	*2016SST*	*2017SST*	*2018SST*	*2013c*	*2014c*	*2015c*	*2016c*	*2017c*	*2018c*
2013SST	1.000											
2014SST	0.369	1.000										
2015SST	0.646	0.529	1.000									
2016SST	0.644	0.014	0.770	1.000								
2017SST	0.780	0.661	0.947	0.629	1.000							
2018SST	0.430	-0.363	0.594	0.844	0.434	1.000						
2013c	-0.646	-0.610	-0.986	-0.664	-0.974	-0.506	1.000					
2014c	-0.214	-0.740	-0.718	-0.449	-0.622	-0.051	0.695	1.000				
2015c	-0.591	-0.946	-0.695	-0.317	-0.794	0.118	0.735	0.805	1.000			
2016c	-0.943	-0.536	-0.543	-0.516	-0.704	-0.159	0.548	0.331	0.730	1.000		
2017c	-0.569	-0.842	-0.708	-0.479	-0.737	0.012	0.703	0.882	0.958	0.719	1.000	
2018c	-0.217	0.513	0.251	0.140	0.109	-0.264	-0.203	-0.843	-0.513	-0.002	-0.652	1.000

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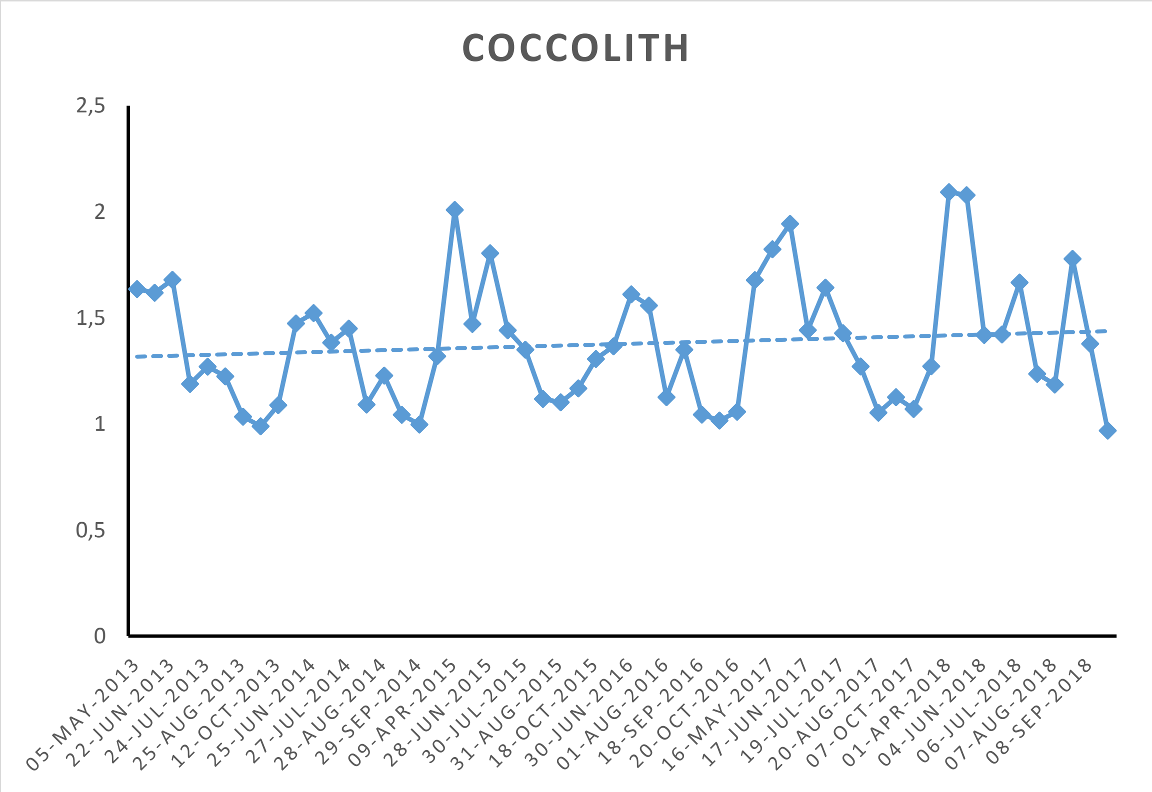

Figure 8. Five years averaged cloud free coccolithophore (mg/m3) variation of the lake.

According to trend line, amount of coccolithophore increases with irregular distribution which will damage the lake in the long-term.

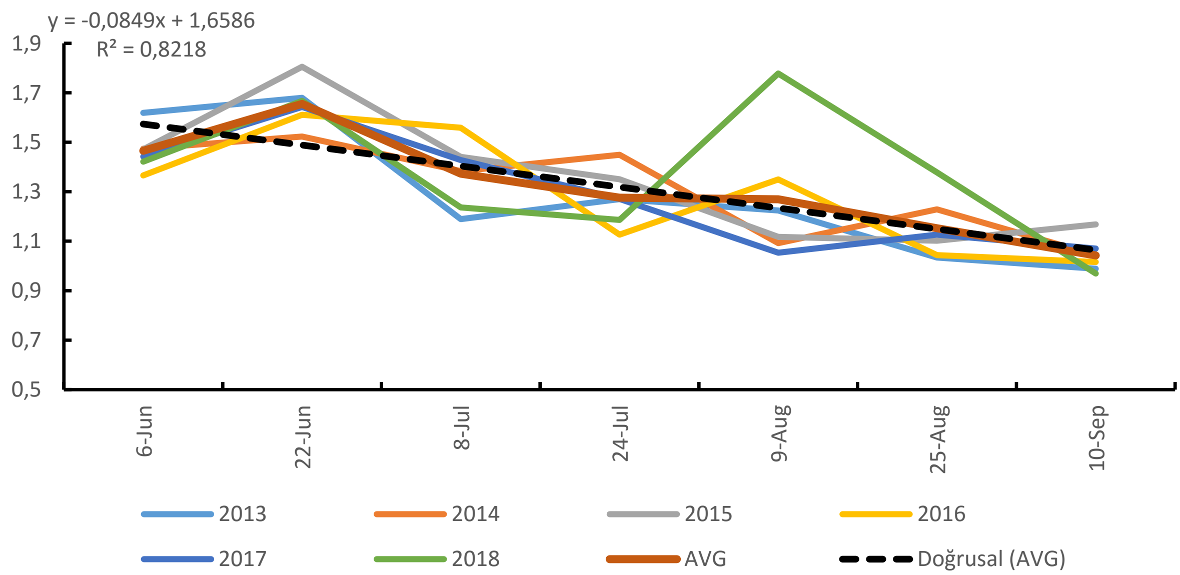

Figure 9. Coccolith concentration variation for summer times.

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Although Figure 9 contradicts the Figure 8 that increases in a long term, the amount of coccolith is in the direction of decreasing from average 6 June to 10 September. Decrease in amount of coccolithophore may be due to the stratification that can be encountered frequently in summer months and retain aquatic creatures from accessing sufficient food.

CONCLUSION

Current study is investigated chlorophyll-a (Chl-a) pigment concertation and its relationship with Sea Surface Temperature (SST) using 59 cloud free Landsat-The Operational Land Imager (OLI) images covering Lake Van of Turkey from 5 May 2013 to 8 September 2018. These analyses have shown that Chl-a concentration are not correlated with SST in this region.

According to the research, although the amount of coccolithophore increases according to the years, whereas it tends to decrease in summer times. This could be due to strong stratification and local climate condition that need to be studied separately.

When SST concentrations are interpreted SST value of 9 June 2014, 8 March 2015, 4 June 2018 remained under the trend curve of the graph whereas SST value of 12 June 2015 remained above the trendline. These results may be attributed to meteorological condition and tectonic activities of the region which may be investigated separately.

When the behavior of Chl concentrations between working times is examined Chl values of 9 April 2015, 17 April 2017 and 8 23 August 2018 were higher than the general trend line. Although this chlorophyll-excess is beneficial for global warming, phytoplankton activity may increase the formation of algae and threaten the aquatic ecosystem. So, this Chl-a balance of amounts will be an issue to be investigated and kept under the control of the nearby institutions.

Lastly, coccolithophores concentrations were examined. coccolithophores are an important parameter in the study of global climate changes, so the time-dependent concentration change of coccolithophores, a kind of phytoplankton, has been studied. Although Figure 9 contradicts Figure 8 which increases in the long term, the amount of coccolith is in the direction of a decrease from the average of 6 June to 10 September. Decrease in the amount of coccolithophore may be due to stratification that can occur frequently during the summer months and may prevent aquatic creatures from accessing adequate food. Although there are a lot of studies on coccolithophores, it is necessary to examine the effects of global warming and aquatic life in more detail, therefore these data can be investigated with more specific parameters in this region.

Negative correlation coefficients of 74% and 73.7% were found for 2014 and 2017, respectively, and these were not statistically significant. Although the information does not give meaningful results, it may be useful in future studies about the effects of global temperature changes and the marine life for particular region.

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Researching this chlorophyll and SST parameters can provide important steps to protect the marine ecosystem and global warming. Although the findings were discussed above the main deficiency of this work is the lack of in situ data. This could be overcome by working of local authorities

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