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Determination of Water Surface and Vegetation Change in Akkaya Reservoir Basin Using Remote Sensing Method

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A B S T R A C T

In the study, the temporal change analysis of Akkaya Reservoir in Niğde was made. The Reservoir was established in 1964. The change of reservoir between 1999, 2009 and 2019 was analyzed using remote sensing method. Satellite images used in the study belong to August (1999, 2009, 2019). MNDWI (Modified Normalized Difference Water Index) analysis was used. With the results of this analysis; the amount of water surfaces in the reservoir basin was calculated by years. After this analysis, NDVI (Normalized Difference Vegetation Index) analysis was used and land cover types were determined by CORINE. It has been determined that the water surface map of 2009 covers a larger area compared to other years. When only the area where the reservoir is located is evaluated by the polynomial equation (2^{nd} degree), there may be a decrease of approximately 26% in the reservoir water surface area within 15 years. As a result of the study, it has been determined that Landsat satellite data can be used to determine the water surface amounts. If study in smaller areas will be done, use the lower resolution satellite images are suggested. In this study, MNDWI analysis was found more successful than NDVI analysis to find water surface area. Multi-band satellite images provide important qualitative information in evaluating the functions used in ecosystem-based planning studies.

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Introduction

With the increasing population, people need new settlements. These new settlements often cause the destruction of natural areas and the reduction of water surfaces in the city. As a result of human activities, the land cover types of cities change. One of the most important methods used in detecting this change is the remote sensing method. Thanks to satellite images, changes occurring in cities are detected and suggestions are developed. Rapid increase in the world's population in recent years, rapid and unplanned urbanization, tourism, failed land planning, and the domestic wastes, petrol, oils, detergents, radioactive wastes, pesticides, artificial and natural agricultural fertilizers, and heavy metals reach of the aquatic media as a result of intense industrial and technological development. The arrival of these pollutants to the water resources disturbs the balance of aquatic systems (Uncumusaoğlu et al., 2016).

With natural resources, technological development and change in the world, it is very important for catching this change especially for developing countries to make use of the resources more effectively and to ensure its continuity. The need for food, water, fuel and other natural resources continues to increase as long as the population increases globally and economic and commercial activities continue to develop. In recent years, due to the increase in the need for natural resource use, the issue of efficient use of resources, ensuring continuity and transferring to future generations is frequently on the agenda in national and international platforms (Yıldız and Erzurumlu, 2020).

Water is a very important material having vital importance for human and other organisms. It is used for drinking, cleaning, domestic and agricultural purposes (Kaptan and Özan, 2014; Mutlu et.al., 2016; Mutlu and Emin Güzel, 2019). Throughout the history, people have preferred the sites around the sources, where it has been easy to access the water, and the river sides as residential areas (Alaş and Çil, 2002; Mutlu and Uncumusaoğlu, 2016).

Reservoirs are the most basic structures that meet the water needs of people today. Reservoir lakes are built for producing energy, protecting from floods and obtaining irrigation water in developing countries and have a greater importance than thermal and nuclear power plants in terms of their environmental effects (Küçükyılmaz et al., 2010; Çulha and Erdoğuş, 2018). Therefore, it is important to analyze the change of reservoir lakes with various software and to determine the changes that occur over the years for ecological development.

Remote sensing technology contains accurate and reliable information as the main data source of many research topics in spatial analysis. With remote sensing technology, land use classes, water presence and their change over the years can be examined. Remote sensing technology is the most widely used analysis method today, as data provides fast and reliable results (Büyüksalih, 2016).

With the help of the maps obtained, changes on the land cover can be determined precisely. Analyzes are not made only on the presence of green spaces or structures. Using the remote sensing method, water surfaces can be detected and the changes of these surfaces can be determined. Required scale in study is possible for research. One of these methods is NDVI (The normalized difference vegetation index) and focuses on the detection of the presence of green space. Another land cover detection method is MNDWI (Modification of normalized difference water index) and is mostly used for the detection of water surfaces (Lira, 2006; Ouma and Tateishi, 2006; Ji et al., 2009; Anim et al. 2013). Previous studies have shown that MNDWI gives better results for extracting water featured from Landsat, SPOT, ASTER and MODIS imagery (Xu, 2006; Xu, 2007). NDVI analysis is mostly used to specify green areas. Therefore, MNDWI analysis was conducted in order to determine the water surfaces more clearly in study. The purpose of this is only to prove the accuracy of the results. It is thought that the similar increase or decrease in the two analysis methods will prove the accuracy of the results of the study. Therefore, both analysis methods were used.

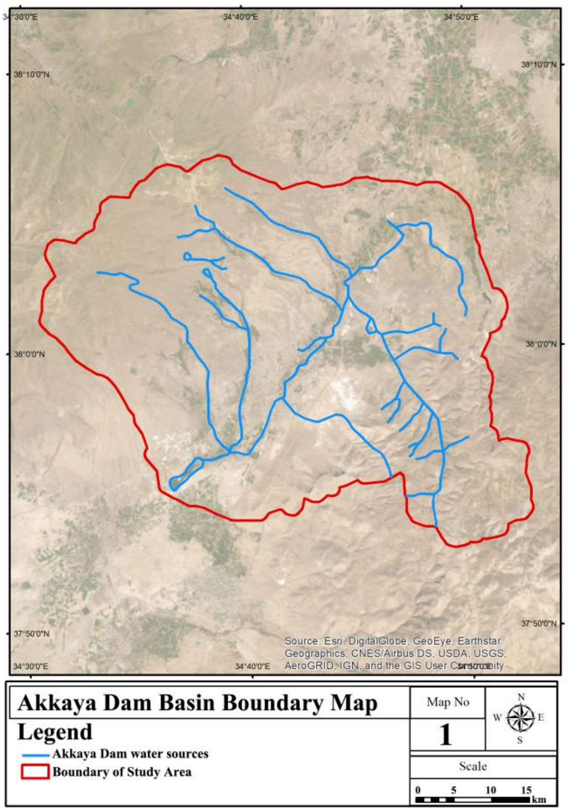
Within the scope of this study, the temporal change analysis of Akkaya reservoir in Niğde was made. The reservoir established in 1964. The change of reservoir between 1999, 2009 and 2019 years was analyzed using remote sensing method. Satellite images used in the study belong to August month (1999, 2009. 2019). MNDWI (Modified Normalized Difference Water Index) analysis was used, with the results of this analysis; the amount of water surfaces in the reservoir basin was calculated by years. After this analysis, NDVI (Normalized Difference Vegetation Index) analysis was used and land cover types were determined.

Material and Method

The study area covers the Akkaya Reservoir basin within the borders of the Niğde Turkey. Niğde located in 34°30'10"-34°45'00" eastern longitude and 37°54'00"-38°06'30" northern latitudes. The size of the study area is 580.00 km² (Figure 1). Akkaya Reservoir Lake where located in the study area, is an irrigation pond formed on the Karasu Stream, which progresses within the city of Niğde and reaches the Bor Plain.

Landsat satellites images belong to 3 different years (1999, 2009 and 2019) were used to calculating the water surface area of the study area. This data is provided for research purposes at USGS (USGS, 2020). Times and properties of satellite images used in the study are given in Tables 1 and 2 (Estoque et al., 2017). All of the image processing stages were carried out with ArcGIS 10 software. In order to increase the working sensitivity, the digital numbers of the bands of Landsat images have been converted to reflection values. In addition, geometric correction processes were applied for satellite images. Then, the band proportioning formulas used in the index calculation were made with ArcGIS 10 software. Reservoir lake water surface areas and vegetation change analyzes were carried out using the indices given in Table 3.

The band proportioning was carried out with the Image Analysis plug-in in ArcGIS software. Raster calculator plug-in in ArcGIS software was used in field calculations. Raster data produced from MNDWI (Modification of normalized difference water index) reflection values have been divided into 2 classes as water and other area by uncontrolled classification method in ArcGIS software using Iso-cluster plugin. Using the classified data, water surface areas were identified in the ArcGIS software with the Conditional "Con" plugin under the Spatial Analyst plugin.



Raster data produced from NDVI reflection values have also produced in ArcGIS. NDVI values include value ranges from -1 to +1. Produced map values were divided into 4 classes by CORINE land cover classification. These are water surfaces, bare areas, sparse vegetation or bush areas and agricultural areas or forest areas.

Table 1. The bands and their dates which have been used in the study

City	Landsat	Time	Season
Niğde	LC08L1TP176034201908042019082001 (Landsat 8)	August 8, 2019; 11:20;45	Dry
Niğde	LT07L1TP176034200908242016102101 (Landsat 7)	August 8, 2009; 11:35;35	Dry
Niğde	LE07L1TP176034199908052017021801 (Landsat 7)	August 8, 1999; 12:55;27	Dry

Table 2. Features of a Landsat-5-7-8 OLI/TIRS image (Estoque 2017)

Electromagnetic region	Landsat 8		Landsat 5 - 7		Spatial resolution (m)
	Band	Wavelength (μm)	Band	Wavelength (μm)	
Coastal aerosol	1	0.43 – 0.45	-	-	30
Blue	2	0.45 – 0.51	1	0.44 – 0.51	30
Green	3	0.53 – 0.59	2	0.52 – 0.60	30
Red	4	0.64 – 0.67	3	0.63 – 0.69	30
Near infrared (NIR)	5	0.85 – 0.88	4	0.77 – 0.90	30
Short wave infrared (SWIR) 1	6	1.57 – 1.65	5	1.55 – 1.75	30
Short wave infrared (SWIR) 2	7	2.11 – 2.29	7	2,06 – 2.34	30
Panchromatic	8	0.50 – 0.68	8	0.51 – 0.89	30
Cirrus	9	1.36 – 1.38	-	-	30
Thermal infrared (TIR) 1	10	10.60 – 11.19	6	10.31 – 12.36	30
Thermal infrared (TIR) 2	11	11.50 – 12.51			30

Table 3. Simple band proportioning equations

Index	Equation	Description	References
MNDWI	$\frac{\text{Green-NIR}}{\text{Green+NIR}}$	>0 = Water surfaces < 0 = Other surfaces	(Xu, 2006; Gülci et al., 2019)
NDVI	$\frac{\text{NIR-Red}}{\text{NIR+Red}}$	< 0 = Water surfaces >0 = Other surfaces	Rouse et al.,1973; Gülci et al., 2019)

The study area is divided into grids with dimensions of 5 × 5 km. Corner point values of each grid were determined. Measurements were taken at approximately 112 points in the study area (Study area size = 580 km² - 580 km²/25 km² × 4 corner of grid). Land cover type of the determined points was determined by field observations. Land cover which was determined as a result of NDVI analysis and field observations, were transferred to SPSS.20 software. The accuracy of the results was evaluated by statistical analyzes.

Results and Discussion

Reservoir Lake Water Surface Area Change

Akkaya reservoir lake area was built as a total of 1.40 km² in 1965. Water surface maps produced with MNDWI were prepared for the summer months of 1999, 2009 and 2019 years. The water surface area covered by the reservoir area changed each year. The highest water surface area in the reservoir lake was 2019 year. The year in which the reservoir lake surface was the least was found to be 1965 which is reservoir was built considering the reference surface area in other years, an average increase of 37% was found in the reservoir lake water surface area (Table 4).

In Figure 2, comparative maps of reservoir surface water area changes by years are given. It has been determined that the water surface map of 2019 covers a larger area compared to other years. As a result of field observations, 96% of the determined points are in the correct areas.

The amount of water increased only in areas that supply water to the reservoir. This indicates that the water level in the reservoir will decrease with the next time. When only the area where the reservoir is located is evaluated by the polynomial equation (2nd degree), there may be a decrease of approximately 26% in the reservoir water surface area within 15 years (Figure 3). This estimate provides only one view in ecosystems with dynamic structure. Because other factors such as climate change, land use type changes should be handled by adding to the forecast model as a variable. Especially important ecosystems such as in-forest water edge should be monitored and evaluated with different perspectives and a multidisciplinary approach (Naiman and Decemps, 1997). Therefore, the use of GIS and remote sensing systems is needed (Mendoza and Martins, 2006).

Analysis of Vegetation Change

Vegetation change maps were produced using the NDVI index and Landsat images for the summer months of 1999, 2009 and 2019. Plant density and positional distribution are significantly higher in 2009 compared to other years.

The forest areas take up more space in the northeast and southeast parts of the reservoir. There is an increase in the density of the structure in the area to the northeast of the reservoir. Compared to August of other years, the plant reflection values decreased in August 2019 (Figure 4)

Relationship of Reservoir Lake Water Surface Area and Vegetation

When the changes in the reservoir lake water area depending on the years to the environment and vegetation are examined, NDVI values vary between -0.89 and 0.98. Values less than 0 are classified as water area, values between 0 and 0.3 are classified as bare soil, values between 0.3 and 0.5 as a mixture of plants and bare soil, and values greater than 0.5 are dense plant area (Table 5).

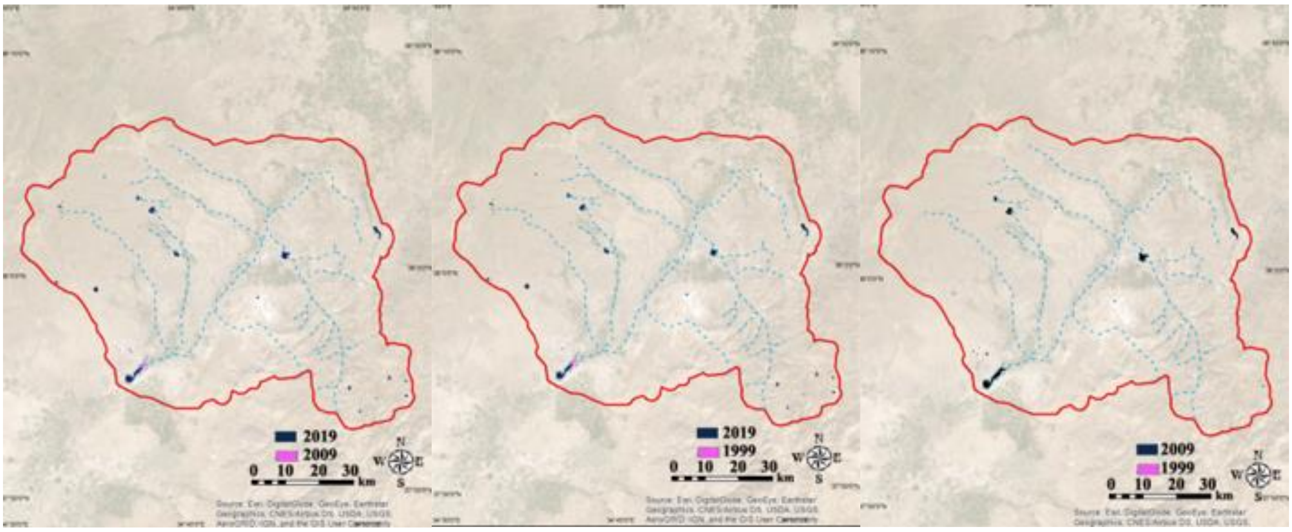


Figure 2. Spatial and temporal change maps of reservoir lake areas by years

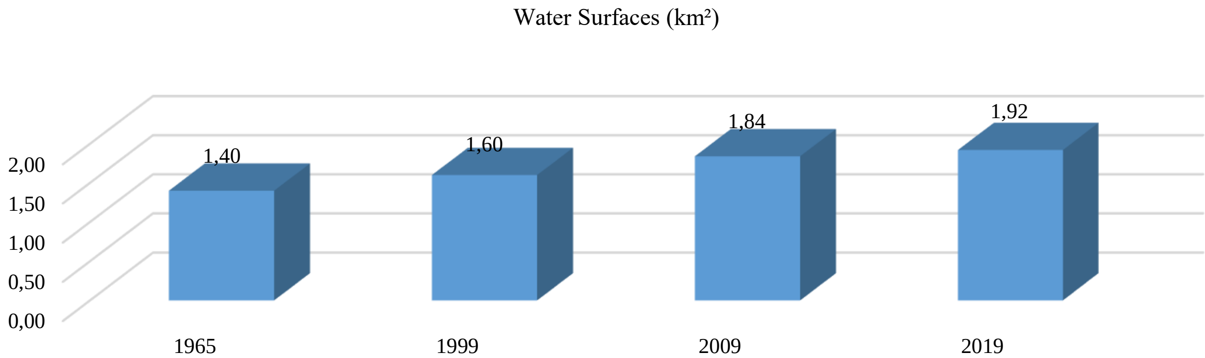


Figure 3. Estimation of water surface area changes by years

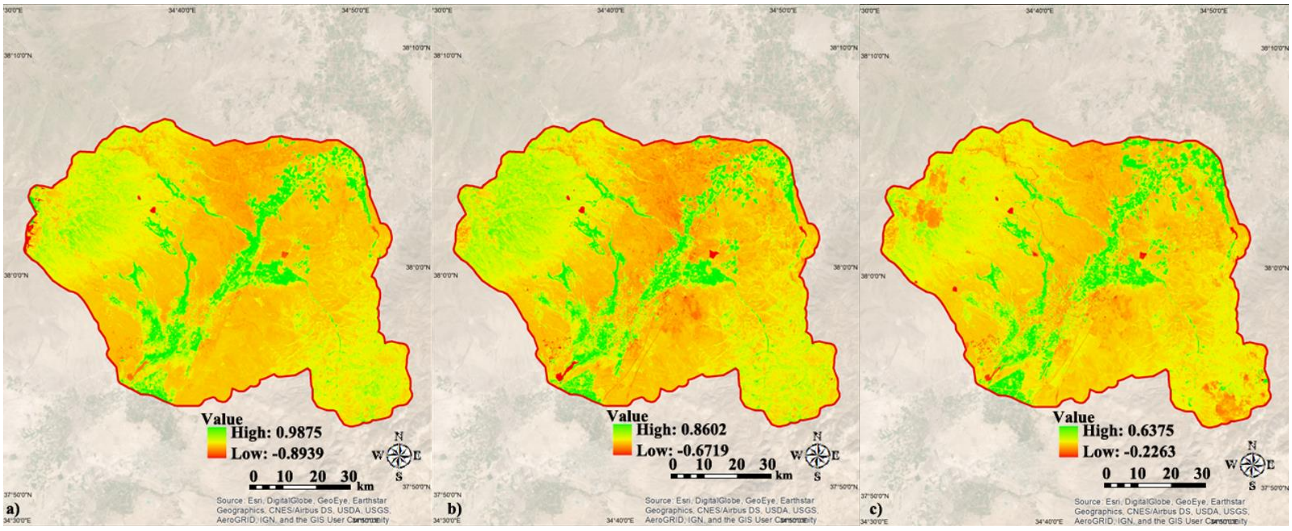


Figure 4. Vegetation maps produced by NDVI analyses a) 1999, b) 2009, c) 2019

Table 4. Reservoir lake surface area changes by years

		Reservoir Areas (km²)	Water Surface (%)	Change by years	Change
Years	Reference*	1.40	100		(+)
	1999	1.60	0.28	0.04	(+)
	2009	1.84	0.32	0.01	(+)
	2019	1.92	0.33		

Table 5. NDVI classes and descriptions

NDVI values	Code	Explanation
< 0	A	Water and moist soil
0 – 0.3	B	Bare soil, rocks, bushes and grasslands
0.3 – 0.5	C	Vegetation (Sparse tree, areas with mainly shrub species and partially covered with healthy plant species)
> 0.5	D	Vegetation (Agricultural plants, broad-leaved tree species, healthy forests in tight enclosure)

Table 1. Land cover type distribution rates of different years of the research area

Years	A (%)	Change	B (%)	Change	C (%)	Change	D (%)	Change	Total (%)
1999	0.27		27.55		51.,36		20.81		100
		(+)		(-)		(-)		(+)	
2009	0.35		17.63		48.99		33.04		100
		(-)		(+)		(+)		(-)	
2019	0.42		28.10		54.04		17.53		100

Table 2. Comparison of reservoir lake water areas obtained by MNDWI and NDVI methods

		NDVI		MNDWI		$NDVI_{water}$ - $MNDWI_{water}$
		Surface Area (km²)	Change	Surface Area (km²)	Change	Change (km²)
Years	1999	1.57		1.60		- 0.03
			(+)		(+)	
	2009	2.03		1.84		- 0.19
			(+)		(+)	
	2019	2.44		1.92		0.52

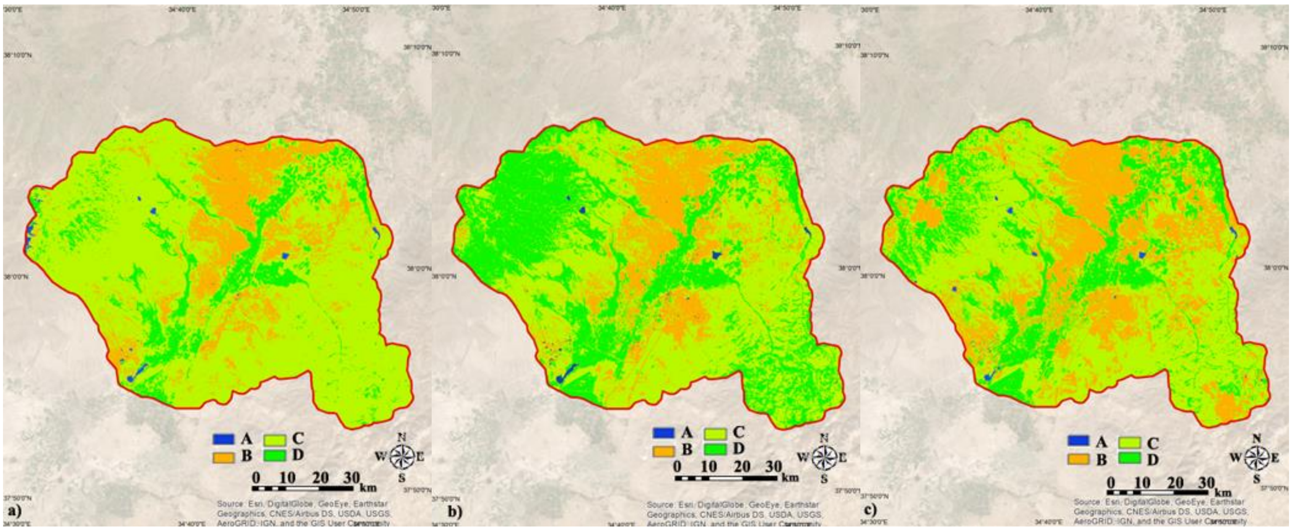


Figure 5. Classified NDVI maps a) 1999, b) 2009, c) 2019
A=Water surfaces, B=Bare soil, rocks, bushes, grasslands, C= Vegetation (Sparse tree, areas),
D= Vegetation(Agricultural plants, broad-leaved tree species, healthy forests in tight enclosure)

When the classified NDVI images are examined, the reservoir lake water area determined by MNDWI in 2009 has determined the largest area compared to other years (Figure 2; Figure 5). The changes in the amount of water in the Akkaya reservoir over years are given Figure 2-3 using MNDWI analysis.

According to result of the analysis, the reservoir was first built in 1965 as 1.40 km^2. In 1990, the water level in the reservoir increased to 1.60 km^2. In 2009, the water level in the reservoir increased to 1.84 km^2. In 2019, the water level in the reservoir increased to 1.92 km^2. The ratios of water surfaces in the city of Niğde were determined by using MNDWI analysis. Water surfaces area 0.28% of the Niğde city in 1999, 0.32% in 2009 and 0.33% in 2019 as land cover. The increase in water surfaces between 1999 and 2009 was 0.04% and between 2009 and 2019 was 0.01%. NDVI analysis was done after these analyses (NDVI). The reason for this is that the differences between the two analyzes are determined and which analysis gives the most accurate result. The results of the NDVI analysis are given in Figure 4 and 5.

The results of NDVI analysis are between -1 and +1. As the results get closer to -1, there is less green area, as we get closer to + 1, more green area becomes. The minimum value in 1999 was -0.89, -0.67 in 2009 and -0.22 in 2019 (see Figure 4). The maximum value in 1999 was 0.98, 0.86 in 2009 and 0.63 in 2019. Looking at these results, we can say that 1999 has the highest green area value and 2019 has the lowest green area value. Land cover analysis has been made after NDVI analysis (Figure 5). The reason for this is the change of land covers according to years. The value ranges used to determine land covers are given in Table 5. According to the results of the NDVI analysis, the water surface has increased in the last 20 years. However, there are differences in the amount of water surfaces between MNDWI and NDVI analysis. According to NDVI analysis, the area of the reservoir was 1.57 km^2 in 1999, 2.03 km^2 in 2009, and 2.44 km^2 in 2019.

With the decrease of the surface area of the reservoir water, areas covered with bare soil, bushes and grasslands increase in the study area. In 2019, when the Akkaya reservoir has the highest water surface area, vegetation cover constitutes 17.53% of the area. In 1999, when the

Akkaya reservoir water was the lowest, the rate of vegetation was found to be 20.81% (Table 6). In 2009, the vegetation rate was 33.04%. The amount of vegetation in the immediate vicinity of the Akkaya reservoir has increased.

In the research area, it is observed that August is a drier period than July. The highest value for 1999, which was evaluated by NDVI, was calculated as 0.98. During this period, there was not much construction in Niğde city. Having a rural appearance, Niğde concentrated more on agriculture in 1999 year. We can say that the amount of green areas of the Niğde city has increased until 2009 year. However, in this period, forest areas were transformed into agricultural areas. The amount of open and green areas increased in the city of Niğde between 1999 and 2009 years, but this was mostly due to agricultural production. In addition, studies on this subject prove this change. Olgun examined that during the 15-year period between 2002-2017 years, 533.69 ha (48.8%) increase in residential areas and 84.44 ha (2.8%) increase in agricultural areas, while 483.92 ha (16.3%) decrease in green areas. The results of comparison of the water surface areas mapped with MNDWI and NDVI and the conditions of the water surface areas evaluated according to the reference surface areas are given in Table 7. There was no difference in cases of increase and decrease in water surface area change. The difference of NDVI and MNDWI water surface area appeared most in the 2019 comparison. The total squares mean error (Root Mean Square Error = RMSE) value of the comparisons between the indexes was calculated as 2.73.

Conclusion

According to the results of the analysis, a correct relationship was determined between the water surface and the amount of green areas. Between of 1999-2009, an increase was observed in both the water surface and the amount of green areas. This change was 0.08% increase in water surfaces and 12.23% increase in green areas. Between of 2009-2019, while an increase was observed in water surfaces, a decrease was observed in forest areas.

However, there was an increase in sparse vegetation or shrub areas between of 2009-2019. From this, we can say that the increase in water surfaces in the last 10 years was not effective on urban green areas, but on small plant groups or agricultural production. In many studies has been determined that agricultural lands in Niğde have increased.

According to the CORINE classification of the Ministry of Agriculture and Forestry, the agricultural areas in Niğde are 45.18% in 1990, 45.89% in 2012 and 45.94% in 2018. Data were obtained from Ministry of Agriculture and Forestry (CORINE, 2020). Especially between of 1999-2009, the amount of green areas of Akkaya reservoir and its immediate surroundings is higher compared to 2009-2019. This shows that water and green area are interrelated and water is of great importance in the ecological cycle. The decrease in the amount of water in Akkaya reservoir has caused a decrease in forest cover and green areas.

Niğde is located on the migration route of birds. The most important factor that it should have on the migration routes is water. Akkaya Reservoir is one of the most preferred habitats of birds. Problems such as fishing, hunting of the duck are seen in Akkaya Reservoir. Such prohibited actions damage the Akkaya reservoir reduce the quality of the water. The decrease in the water surface and quality of the Akkaya reservoir affects the green areas in its immediate vicinity and a healthy vegetation cannot be obtained. In terms of agricultural production, agricultural problems such as degradation of water quality, low yield in agricultural products of vineyards and garden areas and drying and death of vegetables are observed. Therefore, proper use of water resources and establishing policies for this will be effective on green areas.

Evaluation of water resources and surrounding land cover conditions is one of the common methods modeling with remote sensing methods. The study is an important study in terms of revealing past and future situation such as water-forest, water-agriculture, water-health interactions or developing prediction models. Within the scope of the study, the water surface change of Akkaya Reservoir between 1999 and 2019 was determined by classification of LANDSAT 7-8 satellite images and its changes were observed annually by comparison method. As a result of comparison, annual change data of Akkaya reservoir was obtained. As a result of the study, it has been determined that Landsat satellite data can be used to determine the water surface amounts. Satellite images with a resolution of 30 × 30 meters were used in the study. This resolution is suitable for further studies. Because if there are areas less than 30 meters in the reservoir basin, data loss may occur. Therefore, if the working area is small, satellite images with a resolution of 15 × 15 meters or 10 m × 10 m can be used.

It provides the opportunity to make more effective analysis with the development of remote sensing methods in the management of natural resources. Before and after the planning (observation and evaluation) to be carried out in large areas, the base provides data to researchers and practitioners and saves time. Accessible time series archives such as Landsat reduce research costs. In short, remote sensing and GIS applications provide useful data in revealing the effects of the reservoir and its immediate surroundings on the ecology of the region, its impact on the climate, its impact on vegetation, planning of recreational activities and touristic activities.

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