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Spatio-temporal change detection of forest canopy cover density in the Golestan National Park, Iran

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Abstract

In this study, spatio-temporal forest canopy cover density changes in the Golestan National Park (Iran) were assessed from 1967 to 2016 using aerial photos and satellite images in a Geographical Information Systems environment. The digital aerial orthophoto mosaics were created after georeferencing photos of the years 1967 and 1994. A special canopy interpretation key was used for interpreting and determining the forest canopy cover classes on the digital orthophoto mosaics and Google earth images and for providing the canopy cover density maps. The results indicated that throughout the period from 1967 to 1994, the non-forest areas in some places were converted into forest due to physical and technical management measures. Results also showed that between 1967 and 2016, the canopy cover class 10-25% had the highest increase (16.6%) followed by the 25-50% class that increased by 21.17%. Our research exhibited that applying the physical preservation and protection management plans are the major factors in conversion of non-forest to forest areas and increase of the canopy cover density. These results emphasize that active physical protection and proper implementation of management methods are required for forest restoration in the study area.

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Introduction

Evaluation of forest density and canopy is one of the major strategies of management and monitoring over time, particularly in the protected areas (Banerjee et al. 2014). The first important measure in this connection entails evaluation of the current situation, monitoring of trends, and updating actual data. Therefore, precise information on changes of spatio-temporal land features are crucial to understanding the relationships and interactions between human activities and natural phenomena and to making better decisions for optimal use of resources (Ghanbari and Shataee, 2011). Change in forest canopy has been used to detect forest resource modifications over time (Mahdavi et al., 2014). Forest canopy has been one of the important features of forest resources so that the stability and decline of forest stands largely depends on the density of the forest canopy cover. Besides, forest canopy cover positively affects various factors such as light, humidity, airflow resulting in convenient circumstances for humus production (Abdollahi et al., 2010). Furthermore, forest resources management could be facilitated through proper canopy density zoning (Akhavan et al 2012). Since, field harvesting operations are usually time-consuming and costly, using aerial photos and satellite images to calculate the amount of forest canopy cover have recently shown exponential growth in many areas around the world (Taefi Feijani et al 2020). In the current years, remote sensing (RS) as a science and technology of spatial information have been used to study and discover land-use changes (Roudgarmi and Amozadeh Mahdiraji, 2019). In this context, several studies (Bagheri and Shataee, 2010; Ghanbari and Shataee, 2011; Modaberi and Soosani, 2016; Feyissa and Gebremariam, 2018; Fokeng et al. 2019; Garcia et al. 2016) have been conducted for monitoring of the forest extent changes, most of them showing that the forest has decreased and changed into other land uses such as agricultural, residential, gardens and so on. Researchers including Coulston et al. (2014), Bruggeman et al. (2018), Amin Amlashi, and Mirakhorlou (2019), and Ahammad et al. (2019) have concluded that creating a protection zone in forest area increases forest canopy and decreases deforestation. Golestan National Park is a famous protected area in the north east of Iran and includes forest and rangelands. The main aim of this study is detection of any changes in forest extent and canopy cover of the Golestan National Park using aerial photos and satellite images over a range of 50 years.

Materials and methods

Study area

Golestan National Park is located in the northeast of Iran, with an area of 85,495.2 hectares. Due to the influence of the Caspian Sea humidity and northern climate waves as well as the Alborz Mountain, the north-western sector of the Park has a dense cover of old-growth broadleaf forest, lush and green in spring and summer (Figure 1). For approximately six decades, the Park has been managed and protected by the Iranian Department of Environment. The region is semi-dry, mean annual precipitation ranges from 150 to 700 mm and the annual average temperature is 12 °C, and elevation is 450-2411m above sea level (Ghorbani et al., 2018).

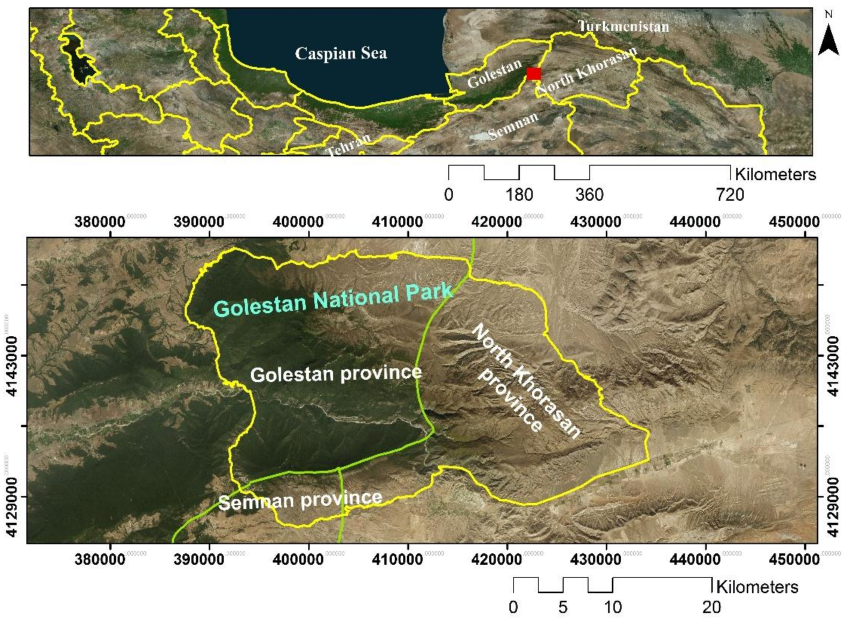

Figure 1. Location of Golestan National Park in Golestan, North Khorasan, and Semnan Provinces, Iran.

Forest canopy cover density mapping

For mapping of the forest canopy cover density and its changes from 1967-2016, black and white aerial photos of 1967 and 1994, and satellite images of Google Earth of the year 2016 were used. First, the accurate boundary of the study area was updated through field survey. Afterwards, to prepare digital orthophoto mosaics, the aerial photos of 1967 and 1994 were scanned and georeferenced using ground control points and a digital terrain model. Then, canopy cover density classes interpretation key (CIK) already prepared by the Forest, Range, and Watershed Management Organization (FRWO) (Farzaneh and Baiani, 2008) was used for visual interpretation of aerial photos. This helped in detecting and classifying forest canopy cover classes (FCC). The CIK is comprised of six canopy cover density classes including 1-5%, 5-10%, 10-25%, 25-50%, 50-75% and >75% (Figure 2). In the process, the boundary of each canopy cover density class on the image of the year 2016 was separated considering the CIK classes by an extension of ArcBruTile in ArcGIS software and online Google satellite images.

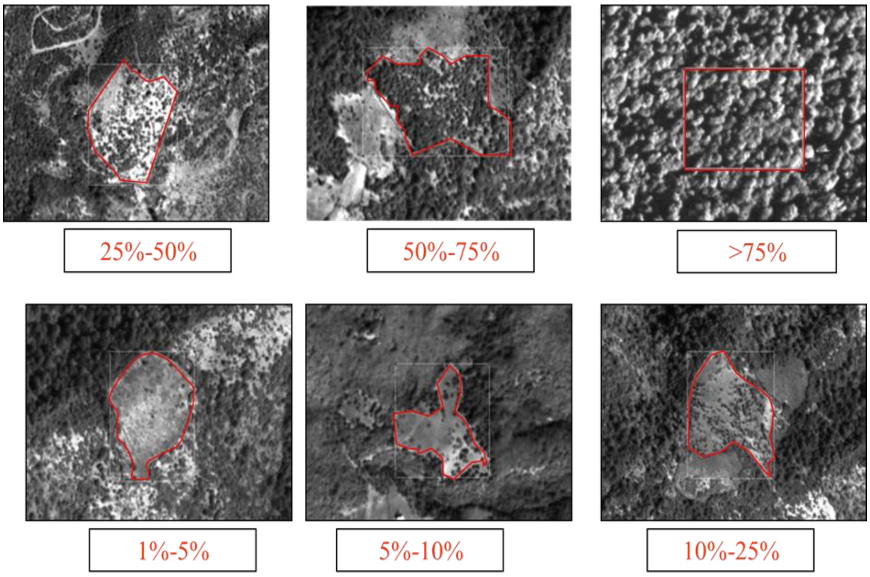

Figure 2. Canopy cover density classes interpretation key samples on the black-white aerial photos

Quantification of forest extent and canopy cover density changes

Quantification of forest extent as well as canopy cover density classes provides useful evidences for appropriate forest management and conservation and devising policies. The most basic forest extent change can be represented by Equation 1.

Current forest extent = Previous forest extent + gain – loss (1)

where, the gain is the increase in forest extent and loss is the forest extend decrease (Coulston, 2014).

The forest canopy classes were assessed and compared in terms of area and cover percentage over the periods 1967-1994, 1994-2016, and 1967-2016 to monitor changes in the study area. This was implemented after generating maps of the forest canopy density classes of the years 1967, 1994, and 2016. The Crosstab extension in TerrSet software, was used to illustrate forest canopy changes (Abdolalizadeh et al., 2019, Koranteng A, Zawila-Niedzwiecki, 2015).

Results and Discussion

Forest extent and canopy cover density maps

Figure 3 shows forest canopy density classes of Golestan National Park in 1967, 1994, and 2016. Based on the produced forest canopy of the year 1967, the category >75% (30930 hectares) of forest canopy and non-forest (18304 hectares) category were the largest classes, respectively (Table 1, Figure 3).

Similarly, by 1994, the highest and lowest area was found for the classes 50- 75% and 1-5%, respectively (Table 1, Figure 3) and then in 2016, the forest canopy category >70% accounted for 38.29% of the study area. As such, the non-forest area shows a drop by approximately 1413 hectares (Table 1, Figure 3).

It is evident from the results that the non-forest zone had the largest area during 1967-1994. This zone consists of agricultural lands located in the northwest and southwest. The non-forest natural areas show increase in the east and southeast of the study area. Likewise, the majority of forest lands are located in the west and central part of Golestan National Park. Also, given the fact that in 1994 and 2016, the non-forest area merely included natural lands, so this area lacked agricultural lands.

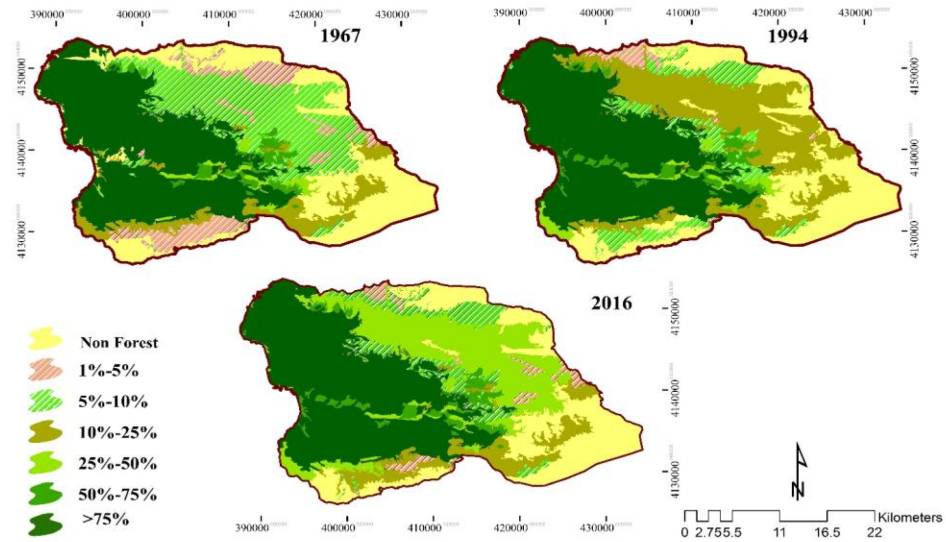

Figure 3. The map of forest canopy density classes of Golestan National Park in 1967, 1994, and 2016.

Table 1. The forest canopy cover density changes of Golestan National Park in the studied periods.

Forest canopy density class (%)	1967		1994		2015	
	%	ha	%	ha	%	ha
Non-forest	21.42	18304.04	21.31	18209.46	19.76	16891
1-5	7.77	6637.06	1.77	1508.51	1.18	1004.78
5-10	21.09	18027.04	8.42	7199.19	7.17	6124.56
10-25	8.46	7231.4	25.06	21419.81	8.45	7221.05
25-50	1.79	1531.34	2.55	2175.71	21.17	18091.26
50-75	3.27	2798.25	3.95	3375.83	3.98	3403
>75	36.19	30930.03	39.94	31570.84	38.29	32723.5

Forest extent changes

The results depicted that the forest extent increased by 0.11% and 1.54% over the years 1967-1994 and 1994-2016, respectively (Table 2, Figures 4 and 5). The non-forest extent generally declined by approximately 1.65% during the past half-century (1967-2016). Over the whole period, from 1967 to 2016, the canopy cover class 5-10% underwent a significant decline by 13.93%, and similarly, the 10-25% class saw an increase of 0.01% in forest area. By contrast, over the same time period, the 25-50%, 50-75%, and >75% classes increased by 19.38%, 0.71%, and 2.1% respectively. (Table 2, Figures 4 and 5).

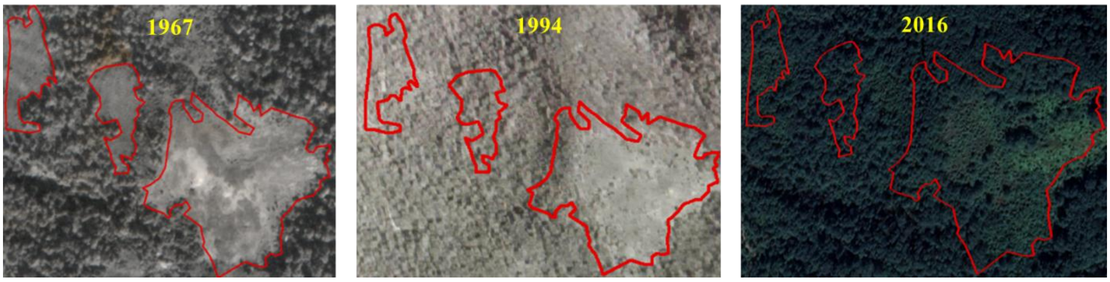

Figure 4. A sample of increased forest canopy in 1967-1994, 1994-2016, and 1967-2016 periods.

Table 2. The forest extents and canopy cover changes from 1967-1994, 1994-2016, and 1994-2016.

Forest canopy density class (%)	Area (1967-1994)		Area (1994-2015)		Area (1967-2015)	
	%	ha	%	ha	%	ha
Nonforest	0.11*	-94.85*	Nonforest	-1318.46*	-1.65*	-1413.04*
1-5	-6*	-5128.88*	1-5	-503.73*	-6.59	-5632.28
5-10	-12.67*	10827.85*	5-10	-1074.63*	-13.93*	-11902.47*
10-25	16.6	14188.41	10-25	-14198.76*	-0.01*	-10.34*
25-50	0.75	644.37	25-50	15915.56	19.38	165992.92
50-75	0.68	577.85	50-75	27.16	0.71	604.75
>75	0.75	640.61	>75	1152.86	2.1	1793.47

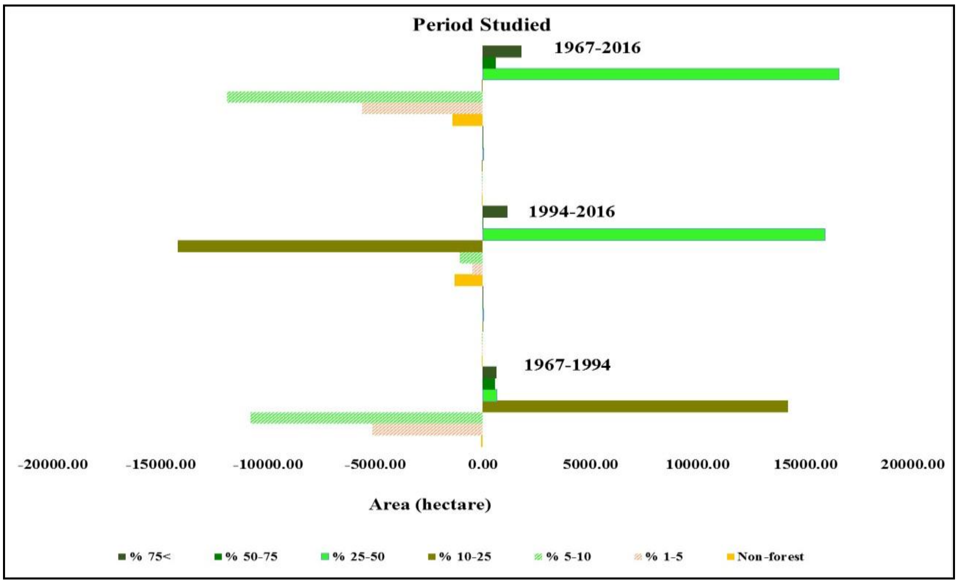

Figure 5. The forest canopy cover density changes between 1967-1994, 1994-2016, and 1967-2016.

Forest canopy cover changes

Regarding the results from an investigation of forest canopy changes over the period 1967 to 1994, it was found that the most significant forest canopy changes occurred in the northern, southern, and southeastern parts of the study area. This can be the consequence of converting the non-forest area into forest areas with 1-5% FCC. Likewise, the FCC 1-5% was converted into 5-10% and 10-25% classes in the northern and southern parts of the study area (Figure 6). However, by far the most significant change to take place during the period from 1967 to 2016 was the increase of FCC in 25-50% class to upper classes (Figures 7 and 8).

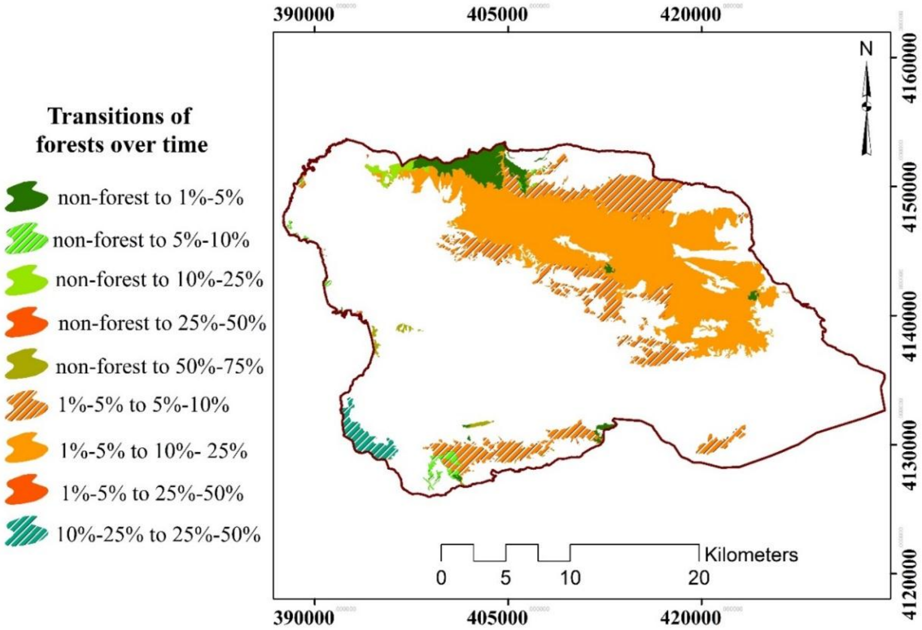

Figure 6. The forest canopy cover changes from 1967-1994.

During the studied period, following the decline of non-forest area, the forest area witnessed a considerable increase. It is interesting to note that this profound change has mostly occurred in abandoned agricultural lands. These results are not in line with the obtained results of Ahammad et al. (2019) claiming that the forest canopy has been always decreasing over time. However, we could confirm the findings of Abdolalizadeh and Ebrahimi (2016) and Bruggeman et al. (2018). One of the major causes of this trend can be that over the study period, the Golestan National Park has been protected by the Iranian Department of Environment not permitting any land-use/cover changes.

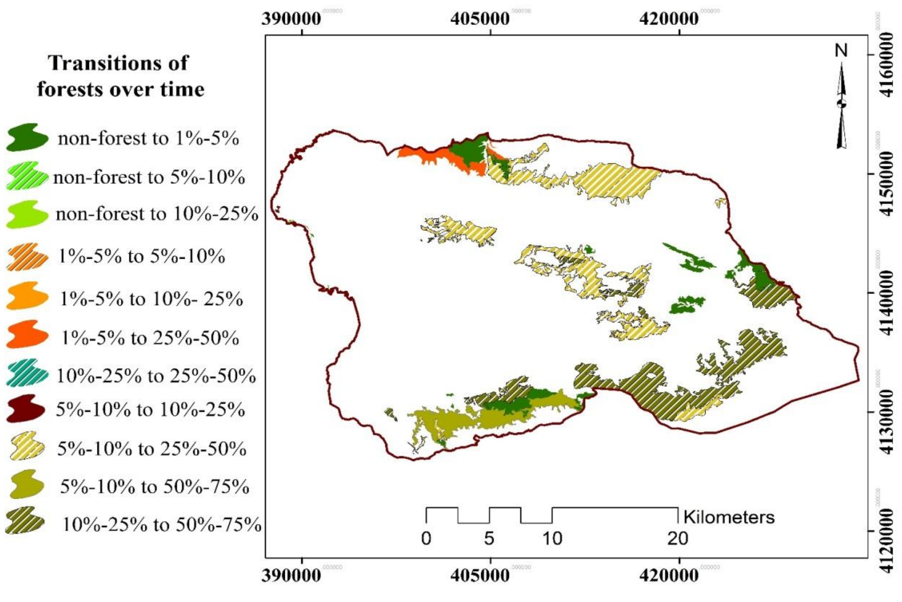

Figure 7. The forest canopy cover changes from 1994-2016.

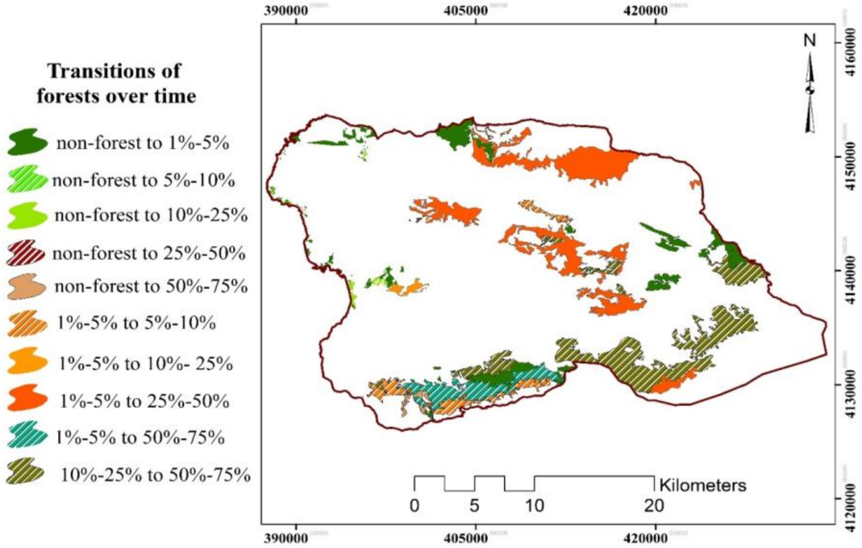

Figure 8. The forest canopy cover changes from 1967-2016.

Therefore, active protection in GNP has facilitated the way for converting the abandoned croplands inside the area into forest such that the non-forest or cropland areas experienced a decline of 1.54% from 1967 till 1994. Furthermore, the comparison of pixels revealed that the majority of FCC classes transformed into higher classes over time. Although there has not been much change in the dense forest area from 1967 to 1944, at the same time, most changes occurred in low-density forests due to conversion of croplands to forest areas earlier detected in Feyissa and Gebremariam's (2018) research. Regarding pixel to pixel comparison, we came to recognize that the highest area increase has occurred in FCC classe 25 -50% and it is highly likely that the majority of this change is because of the entry of trees from the lower canopy class to upper ones. The result indicates that forest recoveries are potentially possible if there is no intense pressure on natural areas or destructive factors. It is also worth noting that such development indictes the long-term process of stand evolution. Even though there may also be a negative evolutionary process, applying rehabilitating and nurturing meaures can aid to achieve the normal conditions. Studying forest cover changes over the conservation of more than half-century depicted that forest cover witnessed increase from lower to higher cover canopy classes. These results confirm the Li et al. (2013), Abdolalizadeh and Ebrahimi (2016), Castillo et al. (2015), and Bruggeman et al. (2018) findings that have reported the increase of forest cover, while, are in contrast with the results of Garcia et al. (2016), Naseri et al. (2017) that have reported decrease in forest cover.

Driving forces of changes

Cegielsk et al. (2018) and Fokeng et al. (2019) pointed out that the conversion of forest to croplands and residential areas are the major contributing factor of deforestation. Apart from that, Li et al. (2013), Hu et al. (2016), Feyissa and Gebremariam (2018) showed that how forest harvest, road construction, and physiographic elements can be the secondary factors of forest degradation. The spatial distribution of villages around the Golestan National Park reveals the park is not confined by rural communities. Subsequently, there has not been any deforestation and land-use change pressure exerted by the local communities. Although there are three low-populated villages on the Park's edge, the pressure from the rural people has been negligible due to low value of areas inside the park for agriculture and peoples' reluctance towards expanding the agricultural lands. This research indicated that in the Golestan National Park the forest cover has remarkably increased during the past 50 years. The results are consistent with the results of Li et al. (2013) and Abdolalizadeh and Ebrhimi (2016) who studied protected areas and changes in landcover. The most interesting fact is that the forest cover rise just occurred within the protected zone area and not outside the preserved areas. In unprotected areas, forest is starting to turn into cropland, residential, industrial, and other land uses. Bruggeman et al. (2018) pointed out that protection of vulnerable stands in small management units with their specific programs could be one of the most useful methods to preserve forest and ensure forest stability. They, furthermore, indicated that in the production stands, the management procedures should be carried out along with sustainable exploitation, and protection. The actual finding conveys that without management, the possibility of rehabilitation would be almost none in destroyed forest areas while forest degradation trend would be keeping on. Therefore, one way to assure sustainable management of forest areas seems to be enforcing management and practicing appropriate conservation policies.

Conclusions

This study focused on forest cover changes in a protected zone outside the forestry plans using the canopy cover density classes interpretation key (CIK) of Forest, Range, and Watershed Management Organization. The Golestan National Park is considered as one of the most appropriate areas in the north of Iran for this study because it has a forest zone protected for over 50 years now. For this purpose, its forest canopy density map was produced and compared for the years 1967, 1994, and 2016. There are relatively little research on forest canopy change in Golestan National Park, and our results imply no decrease in the forest land cover. Here we claim that most areas with low forest canopy cover in Golestan National Park, now have forest with dense canopy cover. This result clearly conveys the importance of continuous active protection that is successful in preservation of natural areas. Being far from rural areas and having low value in terms of agricultural lands were perhaps some of the causes for not creating conflicts of interest between local communities and the management of the park.

In general, the result of the study revealed that merely abandoning cannot guarantee the forest areas against gradually degrading, rather we require appropriate protection and management methods for reforestation and rehabilitation purposes.

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