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Assessment of the forest productivity according to leaf chlorophyll content in Samur-Yalama National Park of Azerbaijan

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Abstract: Most forests in Azerbaijan are distributed in mountain ecosystems, and lowland forests cover very small area. The biodiversity of these lowlands has faced the danger of depletion over the last 100 years. From this point of view, a comprehensive study of the forests of the Samur-Yalama National Park is of special importance. Initially, it is expedient to study the changes of vegetation cover, which later will allow us to investigate reasons for the formation of stressful areas. Normally there is a high correlation between changes of the chlorophyll content of the vegetation and their health, density, stress, and photosynthetic processes. Chlorophyll content was studied by using Chlorophyll Index green algorithm. Multispectral images were obtained from the Landsat 5 TM and 8 OLI program of the USA for 1989-2019 years. The best indicators of chlorophyll content were observed in June. During 30 years, the forest cover density with high chlorophyll content (on index 3) decreased from 765 ha to zero. In general, there is a reduction of about 12% in the density of forest cover. Although there is a decrease in agricultural areas (on 0 index), which is related with the rapid shift of interest to horticulture and increasing of the forest plantations in the last years.

Key Words: *change rate, Chlorophyll Index, Landsat, remote sensing, vegetation cover*

INTRODUCTION

Biologically rich region Samur-Shabran lowland can be distinguished as a significant biotope from the ecological point of view in Azerbaijan [Foster-Turley, 2020]. This ecosystem has changed dramatically under the pressure of environmental and anthropogenic factors over the last 100 years [Asadova et al., 2017]. According to fertile soil, large forest of the coastal lowland landscape were used for agriculture, also the reforestation here is difficult due to the low precipitation and other factors [Gurbanov, 2015]. At present, relevant remains of this type of forest can be found at the Samur-Yalama National Park, which has been given a national park status for the protection of the coastal forest ecosystem [Asadova et al, 2019]. Increase of stress and declines of species threaten the persistence of broad-leaved forest at the Samur-Yalama National Park [Dieterich, 2012]. There is urgently need complex monitoring of processes in the forest which will create a scientific foundation for understanding interactions between human and natural phenomena [Schmidt, Uppenbrink, 2009].

The study of forest changes by remote sensing is preconditions for sustainable use of biodiversity [Fescenkoб Wohlgemuth, 2017]. The abundant data produced by optical remote sensing technology is important for understanding of the processes in forest ecosystem [Bayramov et al., 2019]. The principle of operation of remotely sensed imagery is interpreted on the differential absorption, transmission, and energy reflection of the electromagnetic spectrum, such as red, blue, green, and infrared using passive sensors [Wu et al., 2012].

The spectral analysis of the vegetation is viewed as a reasonable to estimate plant health conditions [Brown et al., 2019]. The reflectance spectrum of green leaves is affected by their biochemical and biophysical features [Hunt et al., 2013]. The monitoring of chlorophyll content is supported for understanding the physiological status of plants, production and nutrient status, senescence and stress due to water, disease outbreak [Verrelst et al., 2010]. As a simple, fast, inexpensive, and non-destructive method, Chlorophyll index green (CIgreen) is widely used to identify leaf chlorophyll content [Kamenova et al., 2017]. The CIgreen is linearly correlated with the difference between the reciprocal reflectance of broad green and near-infrared wavelengths [Yin et al., 2016].

Because of the importance of photosynthetic function the assessment of the vegetation chlorophyll content by using the remote sensing system have been the subject of hundreds of studies since the middle of

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the last century: estimation chlorophyll content in an open-canopy conifer forest [Zarco-Tejada et al., 2019], mapping leaf chlorophyll content in spruce stands using the invertible forest reflectance model [Darvishzadeh et al., 2019], estimation of broadleaved forest leaf chlorophyll content, leaf mass per area, leaf area index and leaf canopy biomass [Le Maireet et al., 2008], estimation of chlorophyll content in tolerant hardwoods [Sampson et al., 2002].

We studied the dynamics of the vegetation cover of the National Park by NDVI [Abiyev et al, 2020]. According to the research plan, we monitored forest processes using various methods (NDVI, CIgreen, artificial intelligence, various satellite images, dendrochronology, carbon stock, diversity, dependence on environmental factors, etc.). The purpose of this paper, which is a continuation of the previous study, is to compare the chlorophyll content change of the vegetation cover of the Samur-Yalama National Park by using the Chlorophyll Index green [Gitelson et al., 2003]. Compare with the previous article, the ArcGIS10 program automatically classifies the areas into unique values by classifying them. Dividing NDVI values into unique values in any way made it difficult to calculate area by number of pixels.

The study of the chlorophyll content change of vegetation cover by remote sensing has not been carried out in the region. For this reason, this article has a great importance in terms of studying the vegetation changes. Through complex monitoring we will be able predicting future changes that may occur in the study area.

MATERIAL AND METHODS

Site description. The Samur-Yalama National Park is situated in the north-east part of Azerbaijan, in a flat plain between foothills of the Greater Caucasus and the coast of the Caspian Sea [Dieterich, 2012]. The park covers 11.172 ha area. The land use is characterized by board-leaved forest in the lowland area, grassland or agriculture and settlements (19.536 ha) [Arnegger et al., 2014].

The climate of the Samur-Yalama district is characterised by distinct dry, hot semi-deserts and dry steppes with mild winter and annual precipitation of 250 mm (minimum rainfall is 185 mm and maximum is 390 mm) [Atlas of Ecology, 2009]. The area is characterized by semi-desert, forest, forest-shrub; dry steppe landscapes [Asadov et al., 2009]. Depending on the groundwater level and soil moisture the vegetation composition of the Yalama forests is different [Seyfullayev, 2013; Alekperov, Mamedova, 2017]. The dominated species are oak (*Quercus pedunculuflora* C. Mey., *Q. iberica* Stev. *Q. castaneifolia* C.A. Mey.), *European hornbeam* (*Carpinus caucasica* Grossh.), field elm (*Ulmus minor* Mill.), field maple (*Acer campestre* L.). White poplar (*Populus alba* L.) is spread out in the temporal herbaceous and alder (*Alnus glutinosa* sub. *barbata* C.A.Mey.) in swampy parts of the study area (Fig. 1.) [Asadova et al., 2019].

Data sources. For chlorophyll content dynamics multispectral images were acquired from the Landsat satellite in the Earth Resources Observation and Science (EROS) data center (USGS) between 1985-2020 years for this study. Also, the images of the 1989 (12 months) and 2019 (12 months) years were used for the determination chlorophyll content change rate. When selecting the images, attention was paid to the clear sky in the study area. For this reason, June has been chosen to keep the cloudiness close to zero and the plant's vitality to be high. The boundary of study area was used to clip out the Samur-Yalama National Park for processing of the bands of the images. No images were available for 2003 and 2012.

Methods. Chlorophyll index green is calculated by using ArcGIS 10.6 software for infrared and green bands of the images [Gitelson et al., 2003; Muramatsu. 2019].

$$\text{CIgreen} = \frac{\text{NIR}}{\text{GREEN}} - 1$$

Here, “NIR” is near infrared (Landsat 5 and Band 4; Landsat 8 and Band 5) and “GREEN” is green (Landsat 5 and Band 2; Landsat 8 and Band 3) in satellite images captured with the Landsat sensor. The CIgreen values calculated from pixel values of NIR and GREEN are also tabulated to find out the extent and the area under different CIgreen class intervals. The CIgreen was computed temporally to understand the change of chlorophyll content during the study period since it is the most common measurement used for measuring vegetation cover.

Areas that occupied by classified threshold values were calculated according to the number of pixels during classification:

Area=cell count ×cell area

Here, *cell count* is given during classification by ArcGIS 10.6; *cell area* represent per pixel, resolution is 30 m in Landsat images.

$$\textit{Cell area} = 30\ m \times 30\ m = 900\ m^2 = 0.09\ ha$$

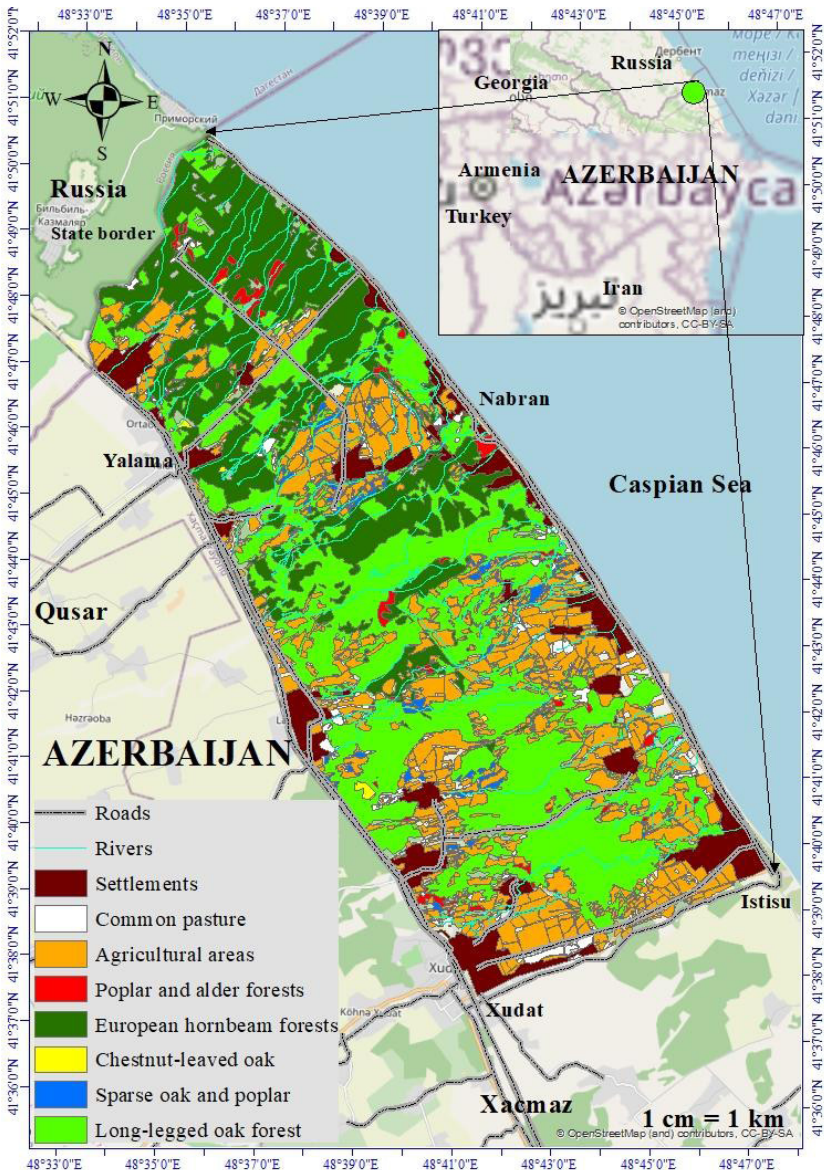

Figure 1. Land use and vegetation cover of the Samur-Yalama National Park.

Change rates were analyzed using the following formula [Badamasi, Yelwa, 2010]:

$$\textit{Change rate} = D_{last} - D_{first}$$

Here, D_{first} and D_{last} are the area of the target vegetation cover type at the beginning (1989) and the end (2019) of the study period, respectively.

RESULTS AND DISCUSSION

Change rate of the chlorophyll content between 1989-2019. In our results, the index values vary between -1 and 3. The value of -1 represents the area of water and snow; the value of 0 represents the soil area; the value of 1 shows shrubs, grassland, and senescence crops, 2 and 3 represent dense and healthy vegetation (forest) [Croft et al., 2013]. The maps show the vegetation vitally process of the forests throughout the year (Fig. 2, 3). Areas were calculated due to the number of pixels occupied by the values during classification. The area occupied by the values for the months of both years and the amount of change over 30 years is shown in Table. The results show that there is a significant decrease in high values, as well as a proportional increase in low values. Due to the best indicators of chlorophyll content are observed in June, we discussing only sixth month. In the June of 2019, the forest cover with high chlorophyll content decreased from 765 ha to zero. The approximate causes are discussed on page 26. Although there is a

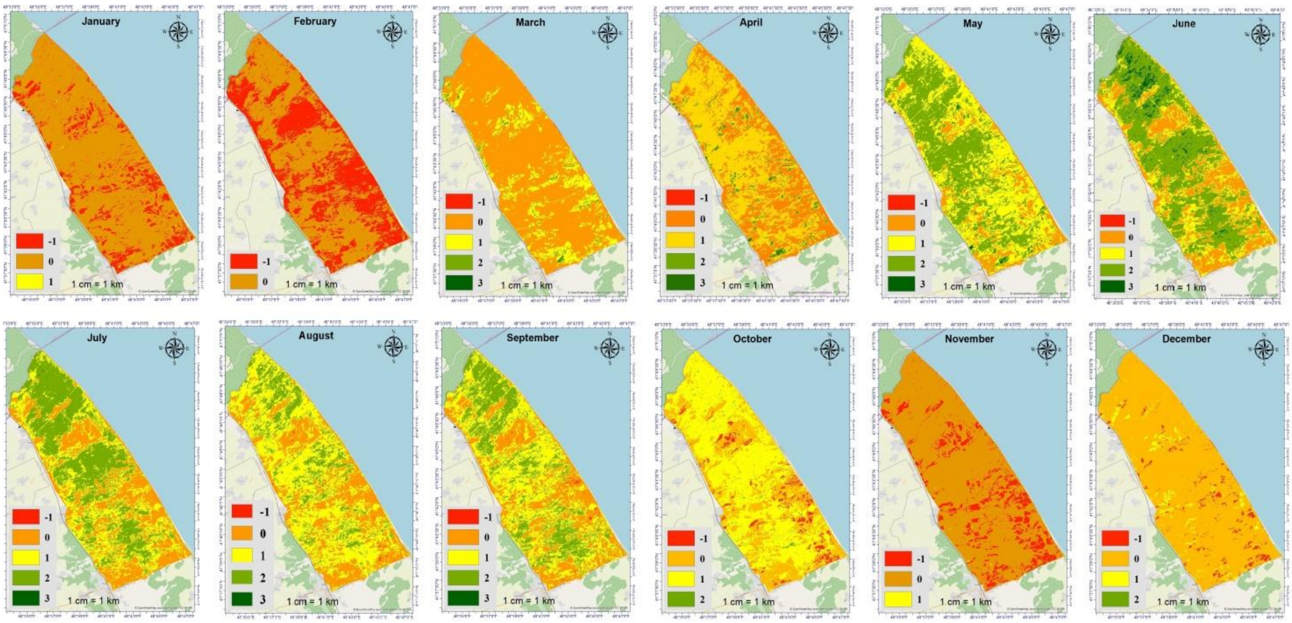

Figure 2. Vegetation indicators and classification of values by months in the 1989.

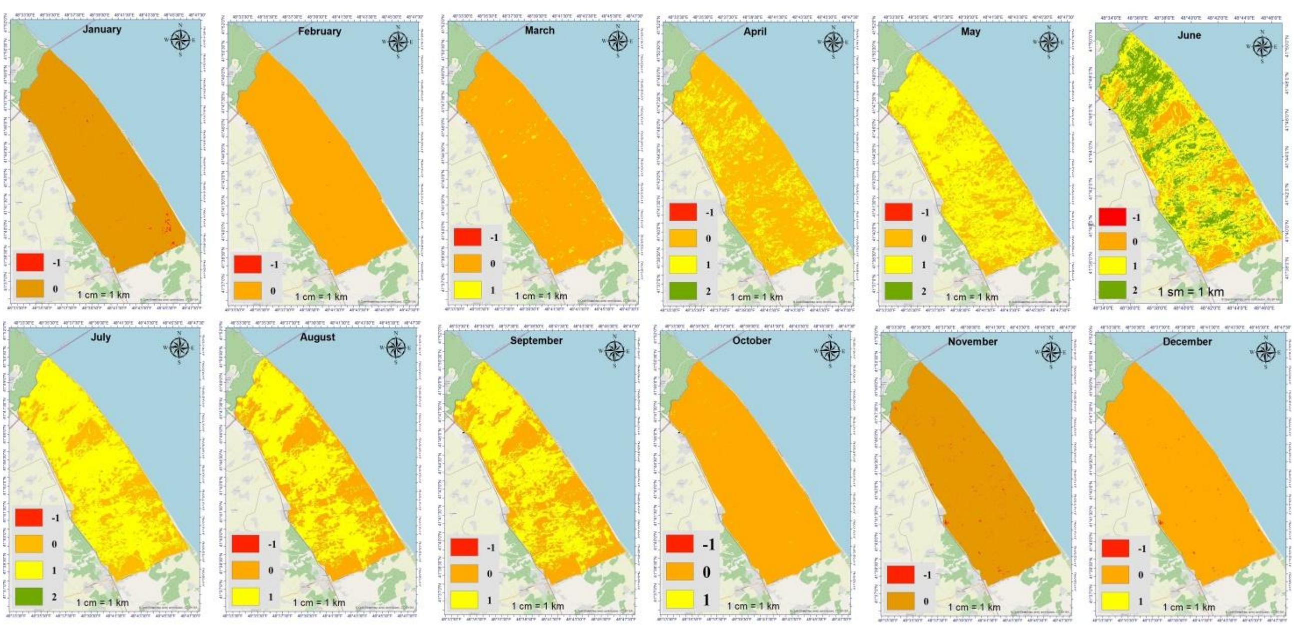

Figure 3. Vegetation indicators and classification of values by months in the 2019.

decrease in agricultural areas (0), this is due to the rapid shift of employment to horticulture and increasing of the forest plantations in the last years.

Dynamics of the chlorophyll content of the vegetation cover. The vegetation cover of the Samur-Yalama National Park was classified due to the threshold values (from -1 to 3) of the Chlorophyll Index green every 5 years among 1985-2020 (Fig. 4). According to the analyses, during 36 years the dynamics of the vegetation chlorophyll content show negative value. The fluctuation of the mean values of the Chlorophyll Index green is given by years. In addition, the applied the NDVI shows same dynamics. The Chlorophyll Index green had a correlation of 0.78 with the NDVI (Fig. 5) [Abiyev et al., 2020]. The lowest mean value was 0.67 in 2001, and the highest value was 2.19 in 2007.

According to the analysis, the increase of the stress in the vegetation cover and the decrease in chlorophyll content are connected with the reduction of vegetation density. Same time densely forested areas are gradually

Table. Areas by values due to number of pixels and change rate.

Months	Values	Cell count (1989)	Area (ha)	Cell count (2019)	Area (ha)	Change rate (ha)
01	-1	35088	3157.92	966	86.94	-3070.98
	0	183554	16519.86	214959	19346.31	2826.45
	1	215	19.35	0	0	-19.35
02	-1	90326	8129.34	88	7.92	-8121.42
	0	128531	11567.79	216815	19513.35	7945.56
03	-1	254	22.86	18	1.62	21.24
	0	178085	16027.65	213403	19206.27	3178.62
	1	35858	3227.22	3301	297.09	-2930.13
	2	4490	404	0	0	-404
	3	170	15.3	0	0	-15.3
04	-1	71	6.39	18	1.62	-4.77
	0	83725	7535.25	170444	15339.96	7804.71
	1	123884	11149.56	48043	4323.87	-6825.69
	2	9657	869.13	352	31.68	-837.45
	3	1520	136.8	0	0	-136.8
05	-1	16	1.44	7	0.63	-0.81
	0	31294	2816.46	64376	5793.84	2977.38
	1	92669	8340.21	152047	13684.23	5344.02
	2	94120	8470.8	482	43.38	-8427.42
	3	758	68.22	0	0	-68.22
06	-1	31	2.79	8	0.72	-2.07
	0	56401	5076.09	49512	4456.08	-620.01
	1	43757	3938.13	111849	10066.41	6128.28
	2	108363	9752.67	55685	5011.65	-4741.02
	3	8502	765.18	0	0	-765.18
07	-1	42	3.78	10	0.9	-2.88
	0	64789	5831.01	65244	5871.96	40.95
	1	67071	6036.39	151427	13628.43	7592.04
	2	86786	7810.74	539	48.51	-7762.23
	3	169	15.21	0	0	-15.21
08	-1	286	25.74	6	0.54	-25.2
	0	67833	6104.97	90459	8141.31	2036.34
	1	112646	10138.14	126438	11379.42	1241.28
	2	37853	3406.77	0	0	-3406.77
	3	30	2.7	0	0	-2.7
09	-1	739	66.51	11	0.99	-65.52
	0	65020	5851.8	99442	8949.78	3097.98
	1	94082	8467.38	116934	10524.06	2056.68
	2	59321	5338.89	0	0	-5338.89
	3	15	1.35	0	0	-1.35
10	-1	8980	808.2	19	1.71	-806.49
	0	74023	6662.07	215607	19404.63	12742.56
	1	130071	11706.39	761	68.49	-11637.9
	2	3313	298.17	0	0	-298.17
11	-1	32643	2937.87	1777	159.93	2777.94
	0	186064	16.745.76	215216	19369.44	2623.68
	1	150	13.5	0	0	-13.5
12	-1	7517	676.53	631	56.79	-619.74
	0	203076	18276.84	216263	19463.67	1186.83
	1	8584	772.56	9	0.81	771.75

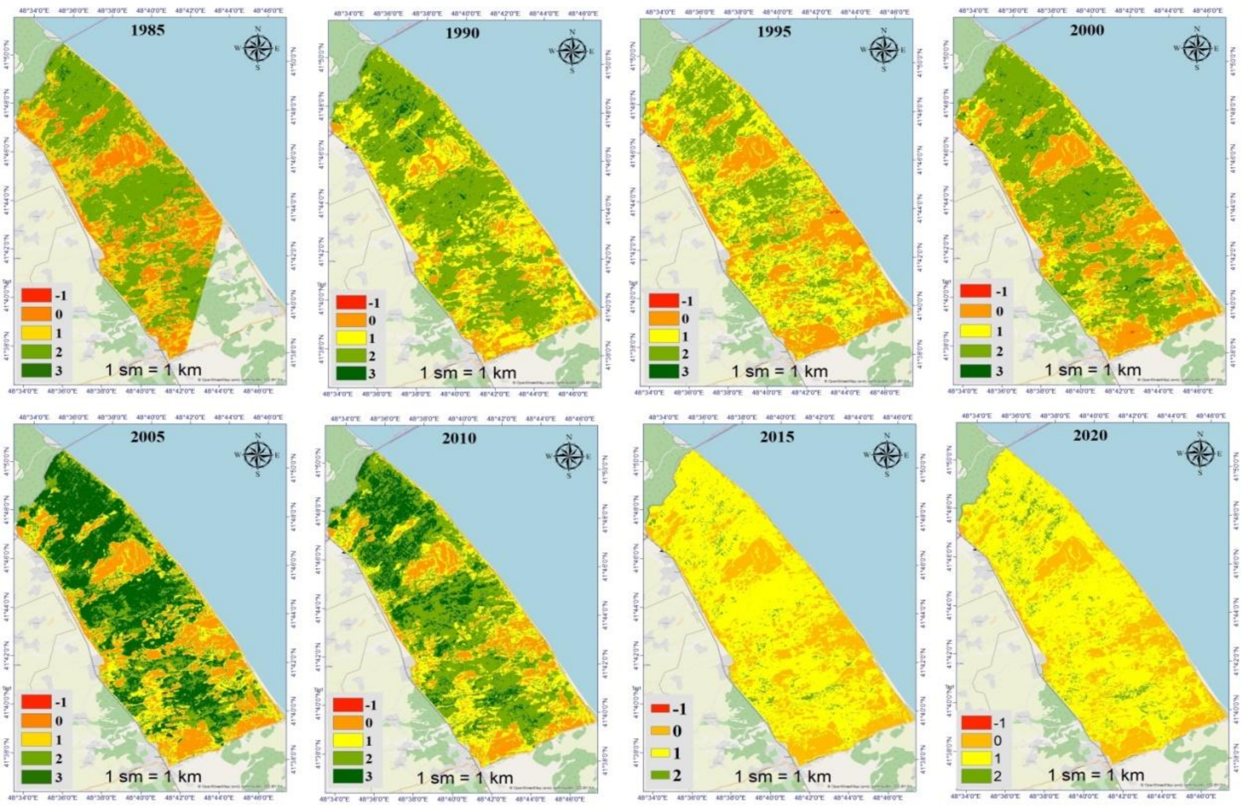

Figure 4. Dynamics of the chlorophyll content in the Samur-Yalama National Park. The problematic part of the image for 1985 was cut off.

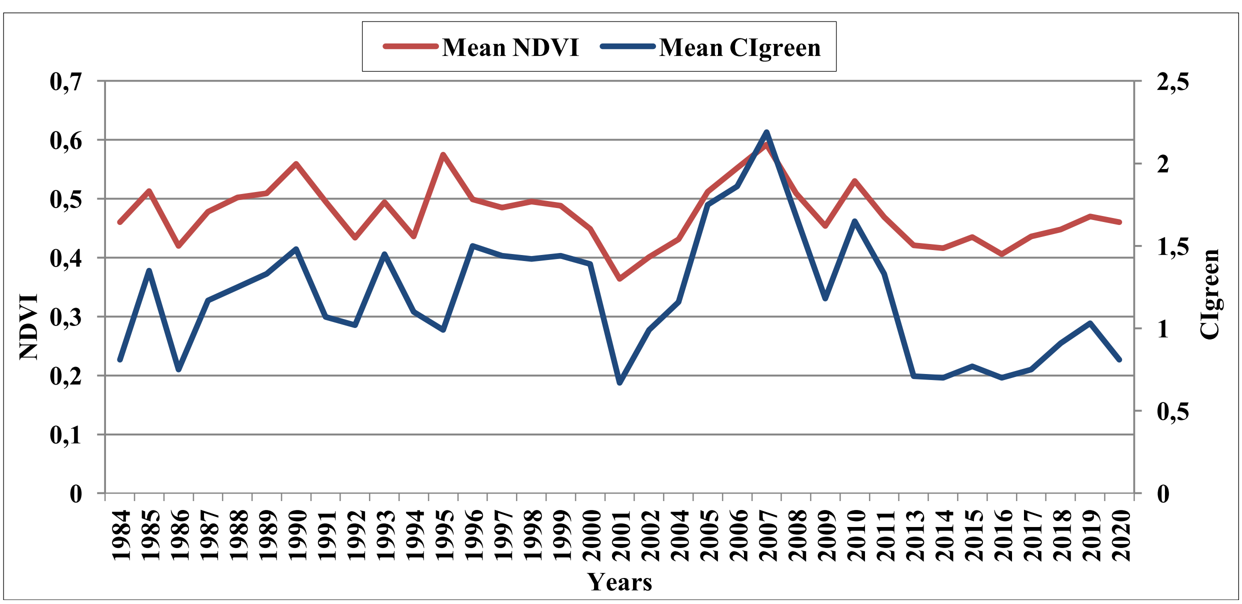

Figure 5. Correlation between CIgreen and NDVI fluctitation.

being replaced with sparse forest-shrub. In general, there is a reduction of about 12% in the density of forest cover.

Based on the results, we assessed the probabilities that led to the changes.

Hazards. The high population and low level of awareness create a risk of fire here. Between 2015 and 2020, more than 300 fires of dry grass, bushes and harvested grain area were recorded around the National Park. In addition, a total of more than 1.000 fires occurred in the surrounding settlements. However, fires and other natural calamity states were not registered by the Ministry of Emergency Situations of Azerbaijan in the National Park for the last five years. Due to the proximity of groundwater (1-3 m) to the surface in the territory, soil humidity (max. 75%) increase and surface vegetation enrich. Above mentioned factors reduce the risk of fire.

Climate. Statistical analysis was contucted among the average values of the obtained chlorophyll index, the average temperature in May and June, also the amount of monthly precipitation. There is not any correlation [Abiyev et al., 2020]. These indicators can be considered normal depending on the climate type (temperate) of the area, as because, anomaly wheather in the area is not usually observed. The scope of these factors does not strongly affect the process of photosynthesis in forests. Previous tree ring investigations on chestnut-leaved oak show similar results. Any correlations between climate parameters (monthly temperature and precipitation) and annual radial growth were not observed. They explained it with the level of the groundwater. Due to the high level of the groundwater trees have no water stress and independent from most of the climate anomalies [Seyfullayev, 2013].

Mass extinction of species. In the past, oak and elm forests have dried up en masse due to diseases and pests. For this reason the *Quercus pedunculuflora* C. Mey. forests were replaced gradually by the *Carpinus caucasica* forests during long term [Abiyev et al, 2019]. The scientific literature and official data do not mention the mass extinction of plant species in the forests of the National Park in the last 10 years. The natural reforestation of the *C. caucasica* is higher than other species. However, the main forest cover has not been able to restore its previous dense structure. During other purposeful researches in the area, we visually observed that there is a partial drying of adult oak, acacia, walnut, pine and hawthorn species. We attribute the reason for this process to the decline in groundwater level.

Social pressure. Social pressure. The Samur-Yalama National Park's area implies potential land-use conflicts among conservation, agriculture and tourism. Studies showed that the primary forest cover has been damaged and thinned due to long-term human economic activities (illegal cutting, grazing etc.) [Arnegger et al., 2014]. Stressful vegetation is mainly in high-population areas. Due to preliminary results, social pressure considered the main reason of the changes.

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Azərbaycanın Samur-Yalama Milli Parkında yarpağın xlorofil tərkibinə görə meşə məhsuldarlığının qiymətləndirilməsi

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Azərbaycanda meşələrin əksəriyyəti dağ ekosistemlərində yerləşir və düzən meşələr çox kiçik ərazini əhatə edir. Düzənliklərin biomüxtəlifliyi son 100 ildə ciddi təhlükələrlə üz-üzə qalmışdır. Burada insan fəaliyyətinin təsiri nəticəsində ilkin meşəliklər böyük dəyişikliyə uğramışdır. Bu baxımdan Samur-Yalama Milli Parkının meşələrinin hərtərəfli öyrənilməsi xüsusi əhəmiyyət kəsb edir. İlkin olaraq bitki örtüyünün dəyişməsini öyrənmək məqsədəuyğundur, belə ki, bu da sonradan stresli sahələrin yaranma səbəblərini araşdırmağa imkan verəcəkdir. Adətən bitki örtüyünün xlorofil tərkibinin dəyişməsi ilə sağlamlığı, sıxlığı, stresi və fotosintetik proseslər arasında yüksək korrelyasiya var. Xlorofilin tərkibi "Xlorofil İndeksi yaşıl" alqoritmi istifadə edilərək öyrənilmişdir. 1989-2019-cu illər arasında ABŞ-ın Landsat 5 TM və 8 OLI proqramından multispektral görüntülər əldə edilmişdir. Xlorofil tərkibinin ən yaxşı göstəriciləri iyun ayında müşahidə olunur. 30 il ərzində yüksək xlorofil tərkibli (3 indeksi üzrə) meşə örtüyünün sıxlığı 765 ha-dan sıfra enmişdir. Ümumiyyətlə, meşə örtüyünün sıxlığında təxminən 12% azalma var. Əkinçilik sahələrində azalma (0 indeksi) müşahidə olunur ki, bu da son illərdə marağın bağçılığa sürətlə yönəlməsi və meşə əkinlərinin artması ilə əlaqədardır.

Açar sözlər: *dəyişmə dərəcəsi, Xlorofil indeksi, Landsat, məsafədən zondlama, bitki örtüyü*

Оценка продуктивности леса по содержанию хлорофилла в листьях Самур-Яламинского Национального Парка Азербайджана

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Большинство лесов в Азербайджане распространены в горных экосистемах, а равнинные леса занимают очень небольшую площадь. За последние 100 лет биоразнообразие равнин столкнулось с серьезными угрозами. В результате человеческой деятельности, первичные леса претерпели значительные изменения. В связи с этим комплексное изучение лесов Самур-Яламинского Национального Парка имеет особое значение. Представлялось целесообразным вначале изучить изменения растительного покрова, чтобы в дальнейшем исследовать причины возникновения стрессовых участков. Обычно существует высокая корреляция между изменениям содержание хлорофилла в растениях и их здоровьем, плотностью, стрессом и фотосинтетическими процессами. Содержание хлорофилла было изучено с применением алгоритма «Индекса Хлорофилла зелёный». Для этого исследования мультиспектральные изображения были получены с помощью программ США Landsat 5TM и 8 OLI в период с 1989 по 2019 год. Наилучшее содержание хлорофилла наблюдалось в июне. Плотность лесного покрова с высоким содержанием хлорофилла (на 3 индекс) за 30 лет спустился с 765 га до нуля. В целом плотность лесного покрова снижается примерно на 12%. Уменьшение сельскохозяйственных площадей (на 0 индекс) в последние годы связано с быстрым сдвигом интереса к садоводству и с увеличением лесных насаждений.

Ключевые слова: *степень изменения, индекс Хлорофилла, Landsat, дистанционного зондирования, расө тительный покров*