ASSESSMENT AND MAPPING OF THE DIVERSITY OF COLOR SHADES OF LANDSCAPES IN SUMMER SEASON USING SATELLITE IMAGES (on the example of Syunik Region)

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The landscape, bearing certain pressure from the society, simultaneously has an aesthetic potential and actively affects the emotional and psychological comfort of a person. Among the many factors affecting the aesthetic qualities of the landscape (relief, vegetation, water, etc.), colour is also separated. The color diversity of the landscapes is impossible to appreciate with only using eyes.

The article presents a unique methodology for separating colour shades, which are one of the important aesthetic factors of the landscape. For the first time, an attempt was made to distinguish the color tones that have a great influence on the aesthetic qualities of landscapes and to group them by analyzing the spectral curves of satellite images. In contrast to the traditional field method, satellite images allow us to assess color tones over a short period of time and over a large area.

Red, green and blue are considered the main physiological colours, and almost all true colours can be obtained by the combination of these three radiations. An attempt was made to separate the colors in the landscapes by analyzing spectral curves in green (543–578 nm), red (650–680 nm), blue (458–523 nm) spectral ranges of the Sentinel-2A, Sentinel 2B TCI (true color image) space images taken in the summer with a resolution of 10 m. In a professional software environment, 50 classes were obtained using “unsupervised” classification method, and for each class, the curves with the average values of spectral reflection of three visible colour ranges were obtained. By grouping the classes, a map of five colour groups (blue-green, green, red, gray and yellow, white) of the landscapes of Syunik Region was created for the summer season. Since the most important factor of colour harmony is the balance of colour shades, an attempt was made to determine the colour diversity of landscapes.

Based on the obtained colour groups, in the summer season the colour diversity of the landscapes of Syunik Region was assessed and mapped using Shannon’s coefficient of heterogeneity. As a result, it was found that 52% of the landscapes of Syunik Region have green colouring in summer. The latter is considered a positive feature of the aesthetic appeal of landscapes and has a calming effect on a person. White colour has the smallest percentage share. 36% of the territory of the region has a high and very high diversity indicator, and 17.6% has a very low degree of

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diversity. In summer, the North-Eastern part of the region, the areas adjacent to the lower and middle streams of the Vorotan River, the Voghji and Meghri River basins are distinguished by colour diversity. However, from the point of view of aesthetic perception, the average degree of diversity is highly assessed, which is 27.2% in Syunik Region. The Southern part of Syunik has an average degree of diversity, especially the valley areas of the Araks River, the area of the Spandaryan reservoir.

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**Keywords:** color of landscapes, landscape aesthetics Syunik Region, spectral curves, mapping, satellite images.

**Introduction.** Landscape aesthetics studies the beauty, attractiveness of natural and anthropogenic landscapes, as well as the features of aesthetic perception and evaluation [1]. The landscape, bearing certain pressure from the society, simultaneously has an aesthetic potential and actively affects the emotional and psychological comfort of a person [2, 3].

The aesthetic qualities of the landscape are greatly influenced by colour, which is an important aesthetic factor of the landscape. The psychophysical effect of colour on a person has been studied quite deeply in the fields of medicine, applied psychology, as well as art history [4]. A part of the light falling on the surface of the object is reflected from the object, another part is absorbed, and the other part passes by the object. If the predominant part of the reflected rays belongs to the green range of the spectrum, you can see green colour [4].

Red, green and blue are considered the main physiological colours. For the first time, the Russian scientist Lomonosov approached the explanation of the three-colour nature of vision, but only in 1802, the English physicist and doctor T. Jung explained the variety of perceived colours according to the structure of the eyes. He conceived that there were three types of photosensitive nerve fiber endings in the eye and exposure to light leads to irritation [4, 5].

It has been experimentally proven that almost all true colours can be obtained by the combination of three radiations: blue, green and red. The process of obtaining other colours by mixing multi-coloured radiation is called colour synthesis. Mixture of the maximum amount of the three main radiation produces white colour, while the mixture of some amount produces gray shade. Mixture of red and blue produces purple. Red with green creates yellow and a mixture of green and blue creates bluish-green [5].

The aim of the work is assessment and mapping of the variety of colour shades of the landscapes of Syunik Region according to the colour spectrum, using the analysis of the spectral curves of the satellite images taken in the summer.

**Scientific Novelty.** A methodology for the separation of color shades of landscapes in large areas and evaluation of color diversity was developed using the spectral curves of satellite images.

**Materials and Methods.** Based on the judgments put forward by the aforementioned various authors, an attempt was made to distinguish the color tones that have a great influence on the aesthetic qualities of landscapes and to group them by analyzing the spectral curves of satellite images for the first time. In contrast to the traditional field method, satellite images allow us to assess color tones over a short period of time and over a large area.
The analysis was carried out using satellite images taken during the summer months: as due to the large difference in altitudes, the leaves of plants in the whole area of Syunik Region look greener, especially in summer [6], when the number of chlorophyll grains reaches the maximum. Considering the fact that all colours can be obtained by mixing green, red, blue colours [4], Sentinel-2A, Sentinel 2B TCI (true colour image) images with 10-meter resolution were used for the research, which represent combinations of band 4 (red, 650–680 nm wavelength), band 3 (green, 543–578 nm), band 2 (blue, 458–523 nm) visible spectral ranges.

In a professional software environment, 50 classes were obtained with satellite images using the “unsupervised” classification method (max iteration 20, change threshold 4%), and for each class, curves with average values of spectral reflection of three visible colour ranges were obtained.

According to the similarity of the spectral reflection curves, classes are grouped into 5 colour groups, based on the combination and synthesis of the values of spectral domains of green, red, blue, as well as expert field routes in Syunik Region.

Since the main factor of colour harmony is the balance of colour shades [4], an attempt was made to assess the colour diversity of Syunik Region in summer based on the obtained colour groups.

The color diversity of the landscapes is impossible to appreciate with only using eyes. Colour diversity was determined using Shannon’s coefficient of heterogeneity [7]

\[
E = -\frac{H}{H_{\text{max}}} = -\frac{\sum_{i=1}^{S} p_i \cdot \ln p_i}{\ln S},
\]

where \( E \) is the coefficient of heterogeneity, \( H \) is the coefficient of diversity, \( p_i \) is the fraction of the area occupied by each colour group in the area of the square \( \left( p_i = \frac{n_i}{N} \right) \), \( S \) is the number of colour groups, and \( \ln S = H_{\text{max}} \).

**Result and Discussion.** As a result of grouping, a colour map of Syunik Region for summer was obtained, which consisted of 5 groups (Fig. 1).

*The first colour group* (blue-green) includes dark blue, blue-green water basin, dark green and covered with shadows forests, which have dark colour from distance. Classes with spectral curves with relatively low (up to 42) spectral reflectance average values in the red range (up to 42) and relatively high and close to each other in the green (51–63) and blue (52–63) ranges have been grouped together.

*The second colour group* (green) includes green grassy, green tree and green water basin areas. Here classes with spectral curves with average values of spectral reflection lower (40–86) in the red range, while relatively lower (55–87) in the blue range compared to the green range, and relatively higher (57–89) in the green range have been grouped together. In general, the absorption of sunlight by chlorophyll in healthy green leaves occurs mainly in the blue and red areas, and here the green rays, on the contrary, are reflected, which defines the green colour of the leaves [8].

*The third colour group* (red) includes mainly greenless soil and rocky areas with red colouring, arable lands of brown colouring and alpine lawns covered with dense purple flowers (the reflection value in the blue range of the latter was slightly higher compared to other areas of the group, but since the deviation was very small, the system did not distinguish it as a separate class). Spectral reflectance values in
the mentioned areas are close to the previous group, simply the spectral reflection values of the red range increase slightly compared to the other two ranges (74–88).

The fourth color group (gray, light yellow) includes ground roads and highways, areas devoid of green vegetation, rock exposure and arable lands with light gray, yellow shades, as well as dense lawns with white flowers, where green grass is very faint. The gray areas of this group often turn yellow under the influence of sunlight, especially in summer, for this reason, with the help of spectral analysis, it became impossible to separate gray and yellow in summer photos.

The fifth color group (white) includes areas with shades close to white and snow spots. Classes of curves with high values of spectral reflection pixels (160–255) have been grouped together.

Figs. 1 and 2 show that more than 50% of the territory of the Syunik Region has green colouring in summer. White colour has the lowest percentage share, which is followed by yellow, gray shades (12%).
Based on the colour groups obtained by Shannon’s coefficient of heterogeneity, colour diversity of the landscapes of Syunik Region was estimated and mapped according to grades using GIS (Geographic Information System) (Fig. 3).

![Colour diversity map of the landscapes of Syunik Region in summer.](image)

In summer, Syunik volcanic high plateau in the North-Eastern part of the region and especially lake regions are distinguished with colour diversity provided by green grasslands, multi-coloured alpine lawns, blue-green lakes, multi-coloured volcanic rocks. The Southern parts of Goris Region, the areas adjacent to the lower and middle streams of the Vorotan River, the Voghji and Meghri Rivers basins are
of high value, which are distinguished by rock outcrops, tree and grass vegetation and the presence of rivers.

_Distribution of the colour diversity of Syunik Region in summer_

<table>
<thead>
<tr>
<th>Degree of colour diversity</th>
<th>Territory</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>very low (0–0.2)</td>
<td>793.2</td>
<td>17.6</td>
</tr>
<tr>
<td>low (0.2–0.4)</td>
<td>860.9</td>
<td>19.1</td>
</tr>
<tr>
<td>middle (0.4–0.6)</td>
<td>1220.0</td>
<td>27.2</td>
</tr>
<tr>
<td>high (0.6–0.8)</td>
<td>1351.4</td>
<td>30.1</td>
</tr>
<tr>
<td>very high (0.8–1.0)</td>
<td>267.7</td>
<td>6.0</td>
</tr>
<tr>
<td>total</td>
<td>4493.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Southern dense wooded areas characterized by widespread green and blue-green shades have low index of diversity. Similar pattern is observed in the upper reaches of the Vorotan basin.

**Conclusion.** The obtained results allow the following conclusions to be drawn.

1. For the first time, an attempt was made to distinguish the color tones that have a great influence on the aesthetic qualities of landscapes and to group them by analyzing the spectral curves of satellite images. In contrast to the traditional field method, satellite images allow us to assess color tones over a short period of time and over a large area (see Table).

2. 52% of the landscapes of Syunik Region have green colouring in summer. The latter is considered a positive feature of the aesthetic appeal of landscapes and has a calming effect on a person.

3. 36% of the territory of Syunik Region has a high and very high diversity indicator, and 17.6% has a low degree of diversity. However, from the standpoint of aesthetic perception the average degree of diversity is highly estimated (27.2% in Syunik Region).

4. The North-Eastern part of the region, the areas adjacent to the lower and middle streams of the Vorotan River, the basins of the Voghji and Meghri Rivers are distinguished by colour diversity in summer. The Southern part of Syunik has an average degree of diversity, especially the valley regions of the Araks River and the region of the Spandarian reservoir.

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**REFERENCES**

Արտիգունի Ն. հատուկ գույների ամբողջականության դասարանում սովորողների համար հաջող դպարտում: Անհրաժեշտ է համարել, որ լանդշաֆտի գույները հաճախ մարդու զգայական-հոգեբանական հարմարավետության վրա զուգահեռու են։ Լանդշաֆտի գույների սոցիալական ուղղակիություններ և դերը, որոնք մանրամասնության մեջ են, մասնավորապես՝ լանդշաֆտի գույների արտահայտման մեջ, գնահատվում են։

Լանդշաֆտի գույների բազմազանությունը դուրս է գալիս լանդշաֆտի ածխագրության ձևաչափային տեսական բազմազանությունից, իսկ սակայն դասարանականության ճանաչումից բազմաթև բնական, սրահային, քաղաքային և այլ տեսակների ծառայության մեջ է գտնվում։

Լանդշաֆտի գույների բազմազանությունը գրեթե բոլոր այն գույների (բացի բազմազան գույներից) հետագաբանական բազմազանության տեսակներից է։ Արտահայտվում է հաշվերի տարբերության մեջ, որոնք բնության բազմազանության և գույների բազմազանության չափազանց մասն են։
Ландшафты Сюникеского марша отличаются значительной цветовой разнообразием в летний сезон. Определено, что в ранний сезон в Сюнике 52% ландшафтов имеют зеленый цветовой оттенок, что подтверждается его значением в естественном окружении района в биосферном аспекте. Эта область имеет высокую степень окраски растительности, что подчеркивается сходными условиями света и характером почв. В свою очередь, зеленый цветовой оттенок ландшафтов важен для оценки их декоративных качеств, так как他认为 красный, зеленый и синий — основные физиологические цвета, из которых все остальные цвета можно получить их комбинацией. Попытка разделения цветов в ландшафтах путем анализа спектральных кривых с применением спутниковых снимков TCI (true colour image) Sentinel-2A, Sentinel-2B, сделанных летом с разрешением 10 м. В профессиональной программной среде методом "неконтролируемой" классификации получено 50 классов, для каждого класса получены кривые спектрального отражения видимых трех
цветовых диапазонов. Была составлена карта пяти цветовых групп ландшафтов Сюникской области на летний сезон (сине-зеленый, зеленый, красный, серо-желтый, белый). Поскольку важнейшим фактором цветовой гармонии является баланс цветовых оттенков, была предпринята попытка определить цветовое разнообразие ландшафтов.

На основании полученных цветовых групп с помощью коэффициента неоднородности Шеннона оценено цветовое разнообразие ландшафтов Сюникской области в летний сезон. В результате оказалось, что летом 52% ландшафтов Сюникской области зеленые. Последнее считается положительной чертой эстетической привлекательности пейзажей, оказывающей успокаивающее действие на человека. У белых самый низкий процент. 36% площади области характеризуются высокой–очень высокой степенью разнообразия, а 17,6% – очень низкой степенью разнообразия. Летом по цветовому разнообразию выделяются северо-восточная часть области, районы, прилегающие к нижнему и среднему течению р. Воротан, бассейны рек Вохчи и Мегри. Однако с точки зрения эстетического восприятия высоко ценится средняя степень разнообразия, которая в Сюникской области составляет 27,2%. Южная часть Сюника имеет среднюю степень разнообразия, особенно долины реки Аракс и Спандарянское водохранилище.