Remote clustering of pastures

S.A. Oleinik, *T.S.* Lesnyak*, *V.S.* Skripkin, and *D.B.* Litvin

Stavropol State Agrarian University, 355017, Stavropol, Russia

Abstract. This article discusses the problem of pasture clustering, where the objective is to separate the territory into groups with similar characteristics of vegetation cover and conditions of use. The authors propose to perform multi-time clustering of pastures using the k-means technique in SNAP software. The latter was applied to the remote sensing data of the Normalized Difference Vegetation Index (NDVI) for March-October 2023 based on the images obtained from the Sentinel-2 satellite group. The number of clusters that were discovered changed from three to five as a consequence of data processing. The authors decided to investigate the option with three clusters after comparing the collected data with the results of ground study. Planning resource management, vegetation assessment, yield forecasting, and controlling soil degradation can all be optimized with the help of clustering results. This important ecosystem can be managed and protected more effectively with the help of the suggested clustering technique, which divides the region into homogeneous pasture sections in a stable and informative manner. The suggested approach may be applied to different climate zones, and the authors intend to investigate this potential further in their future research.

1 Introduction

With the increasing population, changing climate, and increased need for forage resources, modern pasture management practices are becoming more and more relevant. The clustering of pastures is a crucial technique for their efficient management. The technique of grouping a region into clusters according to specific criteria is known as clustering. Clustering can be used to determine which pasture areas are most productive and fit for cattle grazing, as well as which ones need to be improved or restored [1-3].

In order to assess the efficacy of conservation and restoration efforts, it is particularly important to monitor changes in pasture conditions in real-time through the use of remote clustering. It is possible to improve pasture resource management efficiency and drastically lower the cost of field research by using remote clustering. The quality and availability of source data, as well as the requirement to take into account regional characteristics and the particulars of each individual site, are some of the limitations associated with remote clustering, despite all of its benefits [4-6].

In the fields of environmental protection and natural resource management, the analysis and clustering of satellite data is crucial for managing pasture ecosystems. Real-time

* Corresponding author: alexandrova_026@inbox.ru

information on pasture ecosystems' production and suitability for cattle grazing is obtainable through satellite data [7-9].

Numerous details about the Earth's surface, such as information on flora, soils, water resources, etc., are contained in satellite photos. Data on grazing lands across a wide region can be obtained using different image processing techniques, and the data can be clustered based on several criteria [10,11].

Spectral indices are one method used to analyze data from satellites. Spectral indices offer a means of evaluating many aspects of plants, including biomass and chlorophyll concentration. These data allow for the determination of pasture productivity and appropriateness for cattle grazing [12,13].

Averages of the NDVI index are frequently analyzed in studies of long-term changes in the index. Low spatial resolution data (1 km and less) over a vast region or better resolution data, but only for a restricted area, can be used for lower or integral averaging over extended periods of time (harvest months or vegetative season) [14].

Satellite data is also analyzed using machine learning techniques like neural networks and tree models. These methods make it possible to automate the process of classifying grazing and analyzing data.

Therefore, remote clustering is an indispensable tool for improving the efficiency of pasture management and ensuring their sustainable use.

The objective is to study and test remote techniques of clustering of pastures in the conditions of the breeding economy of the Stavropol Territory.

2 Material and method

To achieve this objective, we have performed research on the pastures of the breeding farm for the breeding and raising of fine-wool sheep, Dzhalginsky Merino. The farm is located in an arid area in the south of Russia.

2.1 Climate conditions

The climate on the farm is sharp continental, with an amplitude of fluctuations in maximum and minimum air temperatures in summer up to +42°C and in winter up to 34°C. The average annual precipitation is 320–412 mm and rises as you move from the north-eastern part of the district to the south-western.

Geographically speaking, the property is located in an arid region. With an average monthly temperature of +28 °C in July, the summer is long, hot, and dry. Although autumn is long and mild, frosts occur frequently. The heat of the Central Asian deserts is carried by the east wind during the summer. It is associated with dust storms and droughts that start at 15 to 20 m/s winds. Droughts and dry winds of varying intensity are a standard phenomenon for pastures in the South of Russia; in summer there are 85-100 dry days.

2.2 Data collection and processing

Monitoring of the condition of natural pastures was performed from March to November 2023 at pre-selected coordinates. To perform the studies, a unique scientific installation (USI) “Vega-Science” was used, which is part of the Center for Collective Use “ICI Monitoring Center” [15].

Sentinel-2A/-2B, Terra, and Aqua spacecraft provided satellite data for the collection. Using 13 spectral channels ranging from the visible to the short-wave infrared range of the spectrum within a 290 km broad capture band, the MSI (MultiSpectral Instrument) multizone survey equipment is installed aboard the Sentinel-2A/-2B satellite. The spatial resolution of the shooting system varies from 10 to 60 m depending on the spectral range.

The MODIS imaging technology on board the Terra and Aqua spacecraft is capable of taking images in 36 spectral channels (visible, near, medium, and thermal infrared) with a spatial resolution ranging from 250 m to 1 km across a capture band that is 2,330 km wide. The data that were of interest in this paper were gathered in two channels: near infrared (841-876 nm) and red (620-670 nm), with a resolution of 250 m).

Meanwhile, in the context of this investigation, the products developed on the basis of the original satellite data were mostly used, as indicated by photographs of the NDVI index. In the case of MSI instrument data, NDVI images obtained from individual scenes were used, and MODIS instrument data – weekly interpolated NDVI composites. The index is calculated using the following formula:

$$NDVI = (NIR – Red) / (NIR – Red), \quad (1)$$

where NIR – reflection in the near infrared region, RED – in red one.

NDVI ranges from -1 to 1. Negative index values are usually specific to water bodies, snow, clouds, and some man-made features (for example, paved roads). The vegetative ground cover is marked by positive index values. Meanwhile, the greener phytomass there is within the studied area, the higher the index values will be. Users do not need to perform additional calculations while using Vega-Science's pre-made NDVI images.

Pasture plots in the Ipatovsky district of the Stavropol Territory were the subject of the investigation. Vector data containing the boundaries of the experimental areas were imported into the system (by the system administrator) for ease of processing the data supplied by Vega-Science.

In addition to Vega-Science, the following software products were used to perform multi-temporal clustering of pastures:

– open-source software for processing satellite observations, the so-called SNAP (Sentinel Application Platform);
– QGIS – open-source geographic information software.

The data obtained were chosen according to the following criteria:

– the shooting period should be from March to October 2023.;
– data processing level: L2A (data which was adjusted in the atmosphere and characterizes the reflectivity values at the lower boundary of the atmosphere);
– full one-time coverage of the territory of all experimental areas with satellite data scenes;
– absence of clouds, cloud shadows and other disturbing factors over the territory of the experimental areas at the time of shooting.

Clustering was performed directly in the SNAP software, where the multichannel NDVI image and vector boundaries of the experimental areas were previously imported.

2.3 Data collection by the contact method

Data was gathered via the contact method from satellite services in order to provide an unbiased and trustworthy assessment of the NDVI values that were acquired. The vegetation index was defined using a GreenSeeker handheld crop sensor by Trimble (USA). The sensor emits short pulses of red and infrared light, and then measures the amount of reflected radiation of each type. The sensor screen displays values in NDVI index values (it is able to take values from 0.00 to 0.99).

3 Results

The resulting images were exported from Vega-Science as a multichannel file in GeoTIFF format, where the channels are arranged in chronological order (Channel 1 – NDVI for March 3, 2023, channel 2 – NDVI for March 8, 2023, etc.) (Fig. 1). The “Data Correction” function was used to export the data.

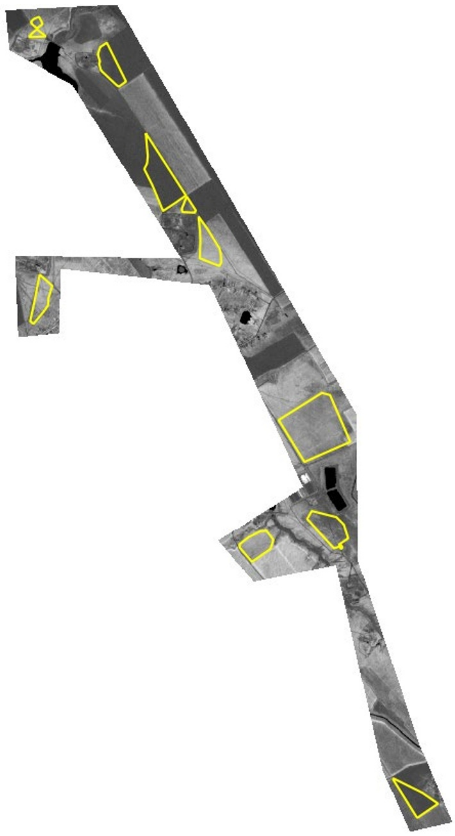

Fig. 1. NDVI images exported from Vega-Science, March 3, 2023. Yellow contours are the boundaries of experimental areas.

Clustering was done directly in the SNAP software, where a multichannel NDVI image and vector boundaries of the experimental areas were previously imported. Clustering (Raster → Classification → Unsupervised Classification) using the k-means method was carried out only within these areas (for this, the vector layer was used as the ROI-mask parameter). The processing was performed with the allocation of a different number of clusters: from 3 to 5. The results of clustering are given in Figure 2.

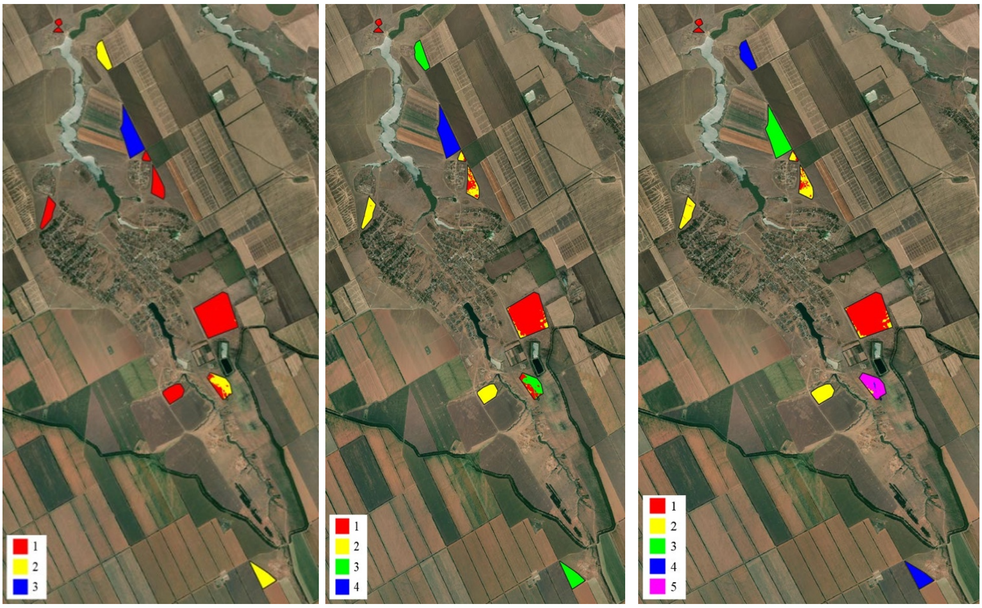

Fig. 2. The results of multi-temporal clustering of pastures on 13 NDVI images based on Sentinel-2 data for the period from March to October 2023 with a different number of clusters: a – 3, b – 4, c – 5.

Table 1 gives data on the share of the cluster area from the total one of the classified experimental plots.

Table 1. The share of cluster area from the total one of the classified experimental plots, %.

The number of clusters in the classification	Cluster number				
	1	2	3	4	5
3	62.7	21.4	15.9	-	-
4	41.7	21.8	20.6	15.9	-
5	36.7	23.7	15.9	14.3	9.4

Similar NDVI dynamics over the studied period characterise pixels that belong to one of the chosen clusters. After exporting the clustering results from SNAP, the “Zonal statistics of the raster layer” tool in QGIS was used to evaluate the data and determine statistics for each cluster. The area, number of pixels, minimal, maximum, and average values of a certain indicator (the NDVI in this case) are all provided by this tool for each class. “Time portraits” of the average NDVI values for each cluster were created as a consequence of computing the regional statistics (Fig. 3).

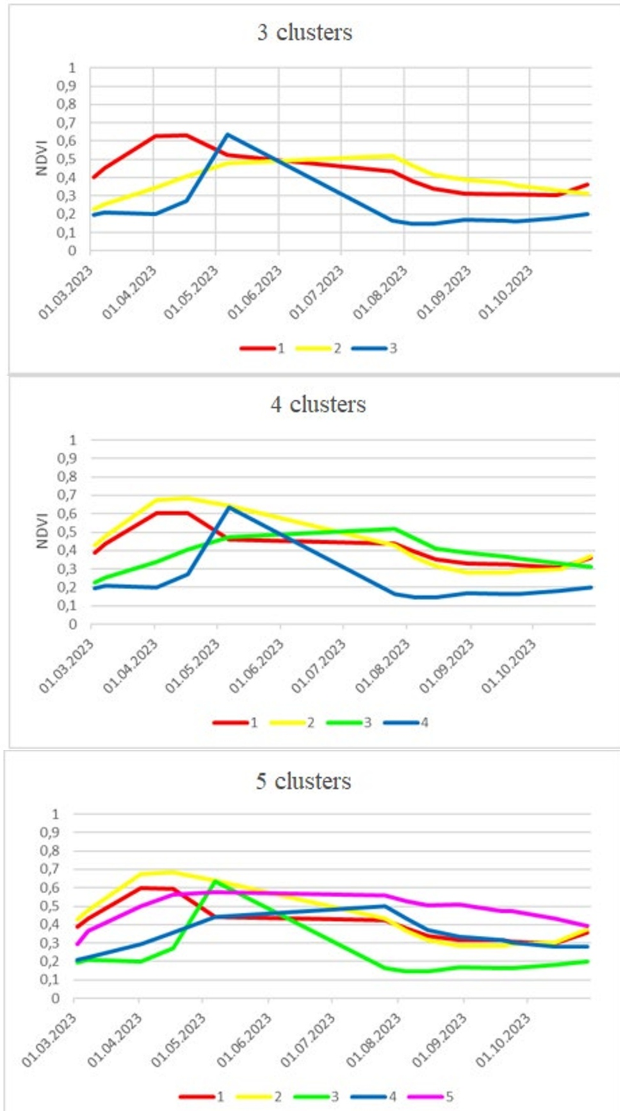

Fig. 3. Graphs of the progress of the average values of NDVI clusters.

As the number of clusters increases, the detail of the analyzed items decreases due to the introduction of extra interference. Following a contact method research phase and a comparison of the findings with the clustering process, a three-cluster separation system was implemented for the subsequent phase of the study.

The study of the clustering of native grasslands in pastoral stock-breeding is an urgent issue. Still, categorization and grouping are challenging technological procedures because of the characteristics of the grasslands.

In the study by A.N. Zolotokrylin et al., the pastures were split into two ecological degradation levels, and they used MODIS data to remotely analyze each level [3].

As a result, remote monitoring, specifically pasture clustering, provides an objective assessment of the vegetation status of the examined regions in real time and without any extra expense. The timely detection of the negative effects of biotic and abiotic environmental factors, as well as the implementation of agronomic measures to level them, allows for an increase in the efficiency of pastoral stock-breeding.

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