Научная статья

Original article

УДК 91

doi: 10.55186/2413046X_2024_9_9_367

THE RESEARCH OF THE SOILS IN THE EASTERN ZANGEZUR REGION AND THE CALCULATION OF THE SOIL TEMPERATURE ANALYSIS USING GIS TECHNOLOGIES

ИССЛЕДОВАНИЕ ПОЧВ ВОСТОЧНОГО ЗАНГЕЗУРСКОГО РЕГИОНА И РАСЧЕТ ТЕМПЕРАТУРНОГО АНАЛИЗА ПОЧВ С ИСПОЛЬЗОВАНИЕМ ГИС-ТЕХНОЛОГИЙ

Telman Faig Abdurahmanov, PhD Candidate, Geography Department, Baku State University, Baku, E-mail: faigabdurahmanov4@gmail.com, https://orcid.org/0009-0009-4456-8494

Тельман Фаиг Абдурахманов, докторант, Кафедра Географии, Бакинский Государственный Университет, г.Баку, E-mail: faigabdurahmanov4@gmail.com, https://orcid.org/0009-0009-4456-8494

Abstract. In this article, we have calculated the soil temperature analysis using GIS technologies. For this purpose, the Eastern Zangezur region, encompassing the territories of Kalbajar, Lachin, Gubadli, Zangilan and Jabrayil, was chosen as the research area. The selection of this region is particularly due to its long-term occupation and subsequent liberation after 30 years, creating the necessity for research in the establishment and development of agriculture.

In our research, we used images obtained from LANDSAT-8 and LANDSAT-9 satellites. Attention was given to ensure minimal cloud cover in the images at the time of acquisition, and the selected capture dates covered the same period.

Subsequently, using GIS technologies and mathematical-statistical methods, analysis was conducted, and the result of the research was presented as a map-scheme of the area.

Given the scientific-practical significance of this article, it can be of paramount importance in the research of engineers, scientists, meteorologists, etc., when it comes to understanding the importance of research.

Аннотация. В данной статье мы рассчитали анализ температуры почвы с использованием ГИС-технологий. Для этого в качестве района исследований был выбран регион Восточный Зангезур, охватывающий территории Кельбаджара, Лачина, Губадлы, Зангелана и Джебраила. Выбор данного региона обусловлен, в частности, его длительной оккупацией и последующим освобождением через 30 лет, что создало необходимость в исследованиях в области становления и развития сельского хозяйства.

В нашем исследовании мы использовали снимки, полученные со спутников LANDSAT-8 и LANDSAT-9. Было уделено внимание обеспечению минимальной облачности на снимках во время получения, а выбранные даты съемки охватывали тот же период. Впоследствии с использованием ГИС-технологий и математико-статистических методов был проведен анализ, и результат исследования был представлен в виде карты-схемы местности.

Учитывая научно-практическую значимость данной статьи, она может иметь первостепенное значение в исследованиях инженеров, ученых, метеорологов и т. д., когда речь идет о понимании важности исследований.
Keywords: The Eastern Zangezur economic region, agriculture, soil, Geographic Information Systems (GIS), plant cultivation, temperature, map

Ключевые слова: Восточно-Зангезурский экономический район, сельское хозяйство, почва, Географические Информационные Системы (ГИС), растениеводство, температура, карта.

INTRODUCTION

Soil is not only the upper productive layer of the earth's surface where plants grow but also a provider of food for humanity. Soil serves several functions in human life. Firstly, it provides plants and animals with essential minerals, water, and other substances necessary for their survival. During the process of photosynthesis, plants derive nutrients from the soil and absorb water needed for their growth. This plays a significant role in the development and productivity of vegetation cover. Secondly, soil acts as a primary safeguard against natural disasters such as floods, erosion, and other calamities. It plays a crucial role in preventing such natural events and ensures the stability and security of infrastructure. Soil also acts as a buffer against climate change: the microorganisms in the soil decompose dead animals and plants, sequestering three times more carbon from the atmosphere, thus maintaining carbon content. According to P. Groffman, a gram of healthy soil contains 100 million bacteria, as well as other microorganisms such as viruses and fungi living among decaying plants and various minerals. This means that soils not only provide us with food but also serve as the source of all our existing antibiotics, offering the best hope for combating antibiotic-resistant bacteria [9]. For these reasons, scientists have long been interested in the physical and chemical properties of soil and have studied its applications in industry, engineering, and agriculture. These studies have covered important topics such as soil productivity, soil nutrition, toxic elements, and safety issues. Currently, extensive research on soil is ongoing worldwide [5].

The study of the natural soil and vegetation cover of the Eastern Zangezur region began relatively late. References to soil cover materials can be found in V.V. Dokuchayev's works at the end of the 19th century. After Azerbaijan joined the Soviet Union in 1920, extensive and comprehensive researches were initiated by Russia in all territories, including the Lesser Caucasus for developing of economy. During this period, various researchers gave valuable contributions to the understanding of the ecological situation and the reasons behind their formation and development processes of the soils in the south-eastern slope of the Lesser

Caucasus. For instance, S.I.Mirzayev defended a candidate dissertation on “The mountain-forest soils of oak and hornbeam forests and their characteristics in the upper part of the Hakari River basin”. During a scientific activity, he extensively studied the genetic-geographical and agricultural characteristics of developed mountain-forest soils in the the south-eastern slope of the Lesser Caucasus, along with the biological cycle of ash elements in forest types under stationary conditions. Moreover, he provided scientific-practical proposals regarding afforestation characteristics, bonitrovka and their efficient using, increasing of soil fertility and restoration of forests of the forest soils [6]. The scientist who had the publications of more than 40 scientific works and a monograph titled “Mountain-forest soils of the Hakari River basin and their efficient use”, also created soil maps and agricultural production charts. A.P. Mammadov focused on the contamination of soils around the Tartarchay River basin with heavy metals in their dissertation work titled “The amount and propogation patterns of heavy metals (Hg, Pb, Cu) in the landscapes of the Tartarchay River”. As we know that heavy metals not only cause the degradation of landscapes, but also affect on human health when released into soil and water basins. T.M.Salmanova determined the composition, reserve and transformation of humus, the impacting of composition of mineral fertilizers for vineyard soils and the relationship between the quantity of absorbed elements and the productivity of grapes in nitrogenous soils in the vineyards of the lower and middle mountain zone in the south-eastern part of the Lesser Caucasus during her scientific activity [1].

After 2020, a reevaluation of the soils in the Eastern Zangezur region for agricultural purposes resulted in interesting facts are analyzed the soils of the territory for agricultural establishment and management and the potential of these soils is assessed using the bonitrophic scale in A.H.Valiyev's article titled “Evaluation of the potential of agricultural soils in the occupied territories”. The article also includes tables with indicators of agricultural activities in the area. In his other published article titled “Soil and climatic factors of agricultural development in the liberated territories” he provided information about the composition, usability and quality characteristics of soils and the climatic characteristics in the previously occupied territories. F.F.Fikratzade and S.I.Hajiyeva did a research about damages caused by wars and conflicts to economic fields, world experience of recovery and development of agriculture in the post-conflict zones, directions of agricultural restoration in the liberated areas, possible variants for land reform, economic fields and their prognosis in their "Directions for the recovery and forecasting of production indicators of agriculture in liberated territories" titled article. Data from the Agrarian Research Center and the State Statistical Committee of Azerbaijan is extensively analyzed in this article. In A.M. Asgarov's "Flora and vegetation of the occupied territories of Azerbaijan" titled article, various plant species in the landscape zones of Karabakh are recorded. In L.A. Jabbali's "Directions of agriculture development in the territories released from occupation" titled article, agricultural indicators of the area by regions and years are investigated [2, 3, 4].

Based on the analysis of various literature and archival materials, maps, and landscape photographs, it has been determined that the research area, The Eastern Zangezur economic region, possesses diverse soil cover, rich biodiversity, and a complex natural landscape. The soil cover has developed in accordance with the principles of landscape ecology. Specifically, landscapes undergo changes in accordance with the law of zonation as one moves from the foothills to the mountain peaks, or vice versa [7]. This is influenced by the variations in temperature and moisture levels that occur with increasing elevation. As a result, vegetation, fauna, and soil cover adapt to these natural conditions as the altitude increases. The Eastern Zangezur economic region exhibits different types of soil cover corresponding to the spread of landscape units [4,5,6].

The following soil types have been identified based on the distribution of landscape units in the region. In addition, we want to note that the formation and distribution of these soil types are influenced by the topography, climate, and vegetation patterns of the region. The identification and classification of these soil types provide valuable information for land use planning, agricultural practices, and environmental management strategies in The Eastern Zangezur economic region [5, 6, 7, 8].

1. The high mountain landscapes covering approximately 3000 meters and above in elevation are characterized by intensive fragmentation of the relief, consisting of exposed rocky cliffs and screes, and the prevalence of a mountain-tundra climate, resulting in the presence of permanent snow and glaciers. As a result, the soil cover in these landscapes has not developed extensively. In these areas, the initial stages of soil formation can be observed on wind-sheltered sunny spots on sharply fragmented rocky slopes and scree slopes. However, since the soil formation process is in its early stages, the soils do not differ significantly from the parent materials, and fertile soils are only found in favourable locations (Valiyev A.H. (2020)).

2. The high mountainous areas of the Eastern Zangezur region, ranging from 2000 to 3000 meters in elevation, including the Shahdag, Murovdagh, Zangezur mountain ranges, and the Karabakh plateau, are characterized by highly fragmented relief in alpine, subalpine, and montane-desert landscapes. The climate in these areas is cold, and they predominantly feature grassy and calcareous mountain-steppe soils. These soils exhibit high productivity and are mainly utilized as summer pastures, while partial cultivation, such as haymaking, is also possible.

3. The wide-ranging upland forest and subsequent calcareous-desert landscape of the middle mountainous zone, which occupies a more significant area among the mountainous landscape zones of the country, covers elevations of approximately 1200 to 1800 meters, reaching 2000-2200 meters in some places, in The Eastern Zangezur region. The terrain is characterized by intense fragmentation and predominantly denudation-structural relief. Mountain peaks and ridges are extensively distributed. The climate is cold and moderate. Coniferous forest, rubble-calcareous forest, typical and leached mountain forest soils are prevalent. Although these soils possess high fertility, their extensive utilization in agriculture is hindered due to their predominantly forested nature (Museyibov M.A. (1998), Khalilov Sh. (2006), Mammadov G.Sh. (2007)).

4. Mountain-black soils are scattered in limited areas on the northern slopes of Murovdagh and the Karabakh mountain ranges in The Eastern Zangezur region. They are characterized by a deep black color throughout the profile and have a variable humus-rich accumulation layer ranging from 50 to 150 cm. Due to the gradual degradation of the vegetation cover specific to desert zones, a considerable residual component accumulates in these soils. The climate is characterized by a mild, warm, and dry summer season with cool winters. These soils are considered highly productive and of good quality, suitable for cultivation primarily of grain crops, potatoes, vegetables, fodder, and partly for tobacco cultivation. Although they are of high quality, they are considered unsuitable for cotton, grapes, and dry subtropical crops.

5. The mountain-xerophytic landscape, developed in the intermediate mountainous region of the Zangazur mountain range, covers elevations ranging from approximately 1100 to 2000 meters. The area is characterized by a cold climate. The prevalence of dry summers in the region has led to the development of the xerophytic landscape. The area is covered with mountain-steppe and brown mountain-forest soils. Livestock farming, cultivation, horticulture, and beekeeping have developed in this region.

6. The low mountainous region, covering elevations ranging from 100 to 150 meters up to 1000 meters, exhibits a desert and partly forest-steppe landscape with a relief structure characterized by structural erosion and arid denudation. The surface is moderately to heavily fragmented. The climate in the area is mild and temperate. The soils found in this region include brown mountain-steppe, brown forest-steppe, and brown mountain-forest soils. They are primarily used as winter pastures.

7. Finally, the plains where the Karabakh lowland meets the foothills in the southern regions are characterized by a dry-desert landscape encompassing intermountain depressions, cone-shaped hills, terraces, and alluvial-proluvial plains. The area has a mild to warm semi-arid and arid desert climate. The soils found in this region include gray-brown desert, salinized gray, and light-brown

soils. Irrigated agriculture has developed, and the plains are used as winter pastures.

Noted information has got a very important role to calculate of the soil temperature. It is well-known that soil temperature plays a crucial role in regulating the energy exchange between the Earth's surface and the atmosphere. The temperature of the soil surface is a significant parameter in many ecological modeling studies, including weather forecasting, global ocean circulation, climate change and temperature variations, climate diversity, energy and water circulation between the atmosphere and the surface, underground tunnels, and drought indices. Remote sensing of soil surface temperature relies on electromagnetic radiation emitted by the soil. Thermal methods are based on the measurement of soil heat flux and moisture. The thermal regime of the soil is influenced by atmospheric climate, relief conditions, and the influence of vegetation and snow cover. The primary indicator is the soil temperature, which depends on the amount of solar radiation and the soil's physical properties [9]. The influence of relief is manifested in uneven radiation distribution on rough and heterogeneous surfaces. Soil temperature of the soil surface is considered a crucial measure for controlling energy exchange between the Earth's surface and the atmosphere. Soil temperature plays a vital role in many ecological modeling studies, including weather forecasting, global ocean circulation, climate change and temperature variations, climate diversity, energy and water circulation between the atmosphere and the surface, underground tunnels, and drought indices. The analysis of soil temperature is also considered a significant factor during agricultural and infrastructure development [2].

Soil temperature should be within various optimal ranges for different plant species. Considering soil temperature during planting is crucial for the germination, development, and yield of the plant. For example, some of them are indicated in the table below (Table 1).

Table 1. Available soil temperature for various growings

Plants	**Available soil temperature (^{0}C)**
Wheat	20-25
Paddy	30-37
Maize	20-25
Vegetables	18-24
Citrus fruits	23-34
Other fruits	20-30

MATERIALS AND METHODS

During the research to calculate of the soil temperature in the Eastern Zangezur region, we have used various literary and archival materials, as well as the analysis of maps prepared for the territory in different periods and the analysis of satellite images obtained from LANDSAT-8 and LANDSAT-9 satellites. When obtaining satellite images, preference was given to images with cloud cover levels of 0-1% and taken during the same period. We selected the end of July and the first week of August which is the most suitable time for this research for all obtained images from LANDSAT. We have used ArcGIS software in our research. The calculation procedure and obtained results are extensively documented in the "Results and Discussion" section.

RESULT AND DISCUSSION

Firstly, we obtained satellite images from the LANDSAT-8 satellite for months (Figure 1), and we are currently conducting the processing work to align one of them with our research area.

Figure 1. The satellite image of the Eastern Zangezur region obtained from LANDSAT-8

From the satellite image, it is evident that the high mountainous areas, as well as the low mountains, foothills, and plains in the region, are unevenly distributed and interspersed. This can be mainly attributed to the past orogenic uplift processes in the Lesser Caucasus Mountains and subsequent peneplanation and pediplanation.

Thus, considering the brightness of electromagnetic radiation during the acquisition of the satellite image of the area, we can perform calculations using the following principle. To do this, it is necessary to use the following guideline [10];

$$L_\lambda = \frac{L_{max} - L_{min}}{Q_{max} - Q_{min}} \times (Q - Q_{min}) + L_{min}$$

According to the above formula, it is possible to calculate the reflectance brightness of the given area initially. Here;

L_λ – The brightness on the diaphragm of the satellite sensor,

L_{max} and L_{min} – The spectral brightness values, calibrated during the capture of the photograph, including both maximum and minimum values,

Q_{max} and Q_{min} – The corresponding maximum and minimum values of the pixel values calibrated according to spectral brightness during the capture of the photograph,

Q – It is the calibrated overall pixel value at the time of the capture.

We note that, these numbers are given in obtaining the images from LANDSAT. Within the cosmic image we obtained, the calibrated spectral brightness has a maximum value (L_{max}) of 30.03944 and a minimum value (L_{min}) of -2.48067. Considering that the LANDSAT-8 and LANDSAT-9 sensors operate with the 16-bit UNICODE system, and noting that the UNICODE system consists of 65536 (2^{16} = 65536) symbols, during the capture of the photograph, the calibrated pixel value corresponding to spectral brightness will have a minimum value (Q_{min}) of 1 and a maximum value (Q_{max}) of 65535 pixels. It should be noted that since the pixel value 0 represents "absence," it is excluded, and considering that 0 is included in the encoding system, the maximum value is 65535. The calibrated overall pixel value during the capture is calculated according to the CIS technology based on the obtained image. Therefore, by substituting the provided indicators, we obtain the following result. For this, we can Raster Calculator in the software to calculate easily.

$$L_\lambda = \frac{30.03944 - (-2.48067)}{65535 - 1} \times (Q - 1) + (-2.48067)$$

After solving the example, we find the value of L_λ, and subsequently, we convert the temperature (T) values using the following procedure based on the information obtained later.

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)}$$

Here,

K_1 and K_2 – Calibration constants,

L_λ - The brightness values on the diaphragm of the satellite sensor.

Considering that in our cosmic image K_1=799.0284 and K_2=1329.2405, we can perform the calculation by substituting the given numbers, yielding the following result.

$$T = \frac{1329.2405}{\ln\left(\frac{799.0284}{L_\lambda} + 1\right)}$$

It should be noted that the result obtained from the above procedure is based on measurements in the Kelvin scale, commonly used in scientific research. The Kelvin scale is anchored on the temperature at which the radiation entropy of the smallest particles is zero, known to be -273.15°C. Thus, considering that 0 K = -273.15°C, it is possible to convert to the Celsius scale. To do this, it is sufficient to use the following formula.

$$t^0C = T - 273{,}15$$

Finally, we have calculated the surface temperature of the soils in the Eastern Zangezur region. It should be noted that, by generalizing all these processes, direct calculation is also possible using the following formula.

$$t = \frac{K_2}{\ln\left(\frac{K_1}{\frac{L_{max} - L_{min}}{Q_{max} - Q_{min}} \times (Q - Q_{min}) + L_{min}} + 1\right)} - 273{,}15$$

However, in such a case, the formula may become sufficiently large and complex, leading to the possibility of errors. Therefore, we utilized a step-by-step approach in our calculations to mitigate this issue.

Thus, in Figure 2 below, we present a map scheme derived from the analysis of the results we calculated for our research zone based on the above-mentioned formulas.

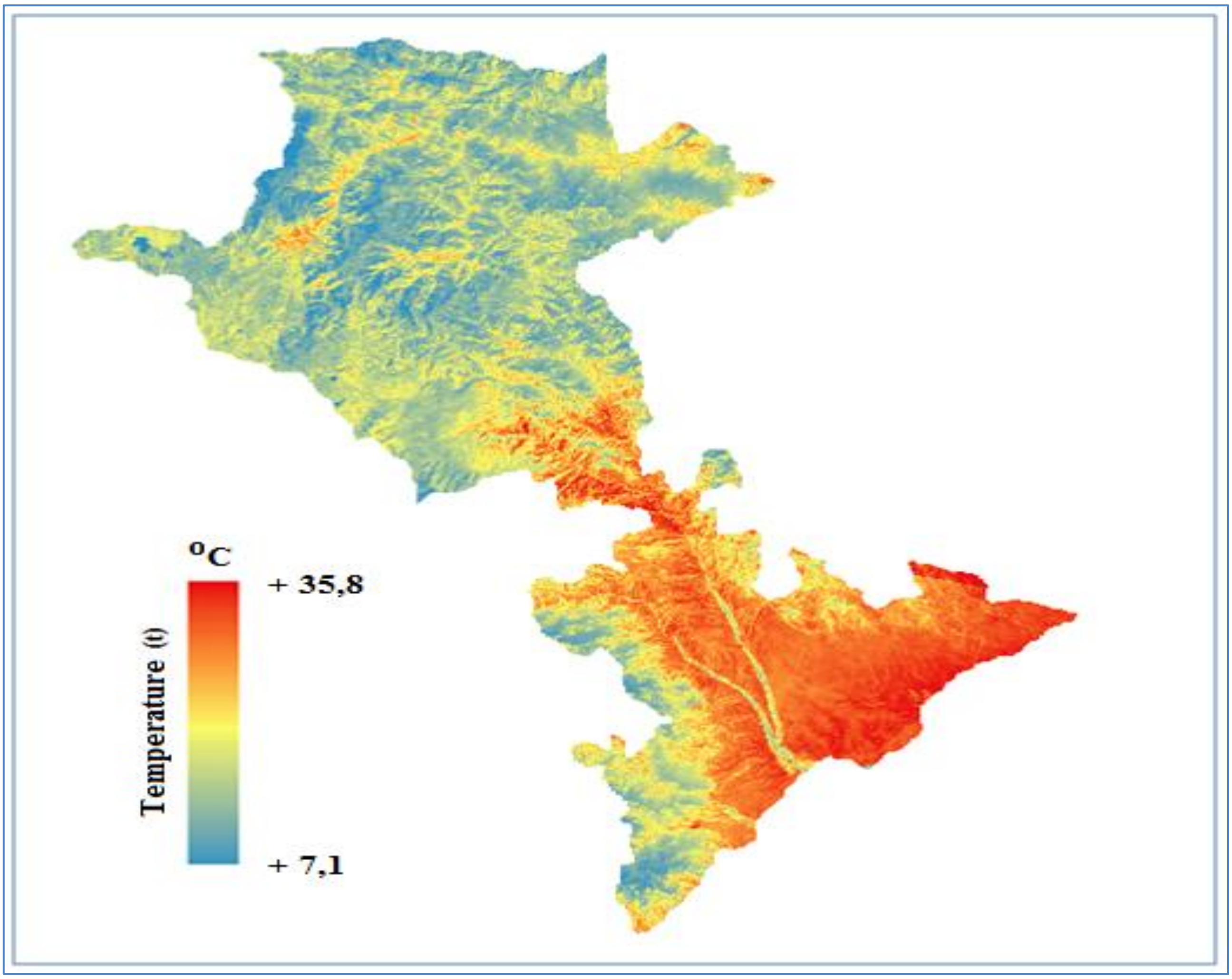

Figure 2. Map-scheme illustrating the average temperature of the soil in the Eastern Zangezur region

As a result of the analysis, as shown in Figure 2 above, the south-eastern part of the region, specifically the Jabrayil district, exhibits higher soil surface temperatures, while the northern and western parts show lower temperatures. This can be attributed to the presence of flat plains and arid relief forms in the southern region, whereas the northern and western regions are characterized by the presence of high peaks [1]. Additionally, the proximity of the area to the Aras River and the Iranian plateau, as well as the influence of dry and warm air masses from the south, contribute to the higher temperatures in the southern part. The cold air masses from the north are intercepted by the high Murovdagh mountain range, preventing their direct penetration into the area. However, according to the principle of altitudinal zonation, the decrease in temperature and atmospheric pressure with increasing altitude results in lower soil temperatures in the northern and western parts. The dominance of cold air at higher peaks and the consequent lower soil temperatures have contributed to the formation of initial soils in these areas.

Based on all of the above, it can be noted that the Eastern Zangezur region offers ample opportunities for the cultivation of dense crops (such as wheat), fruits and vegetables, while in the southern areas, there are favourable conditions for planting citrus fruits.

CONCLUSION

Based on the information provided, we have obtained the following conclusions;

1. The Eastern Zangezur region exhibits a diverse range of soil types due to variations in relief and natural conditions. The region is characterized by the presence of different soil types such as mountain-tundra soils, mountain-steppe soils, mountain-forest soils, mountain-black soils, and desert soils.
2. The distribution of these soil types is influenced by factors such as climate, topography, and vegetation patterns. The identification and classification of these soil types provide valuable information for land use planning, agricultural practices, and environmental management strategies in the region. The soil types in the region offer opportunities for various agricultural activities, including the cultivation of field crops, fruits, vegetables, and cotton production. The formation and distribution of soil types in The Eastern Zangezur region are influenced by factors such as climate, relief, and the presence of high peaks, as well as the interaction between warm and dry air masses from the south and cold air masses from the north. The presence of high peaks in certain areas results in lower soil

temperatures, influencing soil formation processes and the development of initial soils.

3. The south-eastern part of the region, specifically the Jabrayil district, exhibits higher soil surface temperatures compared to the northern and western parts. This can be attributed to factors such as the presence of flat plains, arid relief forms, and the influence of warm air masses from the south. The northern and the western parts of the region have lower soil temperatures, primarily due to the presence of high peaks, which result in decreased temperature and atmospheric pressure with increasing altitude. The proximity of the area to the Aras River and the Iranian plateau, as well as the influence of dry and warm air masses from the south, contribute to the higher temperatures observed in the southern part of the region. The interception of cold air masses from the north by the high Murovdagh mountain range prevents their direct penetration into the region, leading to lower temperatures in the northern and western parts. The altitudinal zonation principle plays a role in determining soil temperature variations, with higher peaks experiencing colder temperatures due to the dominance of cold air. The observed temperature variations have contributed to the formation of different soil types and their distribution across the region.

Due to the broad applicability of soil temperature analysis, it is possible to benefit from this information for various fields and research endeavours.

1. In agriculture, soil temperature analysis provides crucial information for the seasonal cultivation, germination of plants, and forecasting yields. This information can be used in agricultural fields to ensure effective plant development.
2. In construction and other engineering fields, knowing the soil temperature can be crucial for assessing its impact on the construction of buildings and construction processes.
3. These data can provide important information for meteorologists to investigate the relationship between soil temperature analysis, weather conditions, and the development of crops.

4. Furthermore, researchers can use these calculations and technologies to calculate soil temperature analyses for other regions as well.

References

1. Geographers of Azerbaijan / Institute of Geography of the National Academy of Sciences of Azerbaijan. - Baku, 2013. - 204 p.

2. Valiyev A.G. Assessment of the potential of agricultural soils in the liberated territories // Agricultural Economics. 2020. No. 3 (33).

3. Jafarov, M. I. Soil Science / M. I. Jafarov. - Baku: Elm, 2005. - 460 p.

4. Khalilov, I., Jafarova, F. Prospects for Sustainable and Innovative Development of Livestock in the Economic Regions of Karabakh and Eastern Zangezur in the Republic of Azerbaijan // Assessment of the Sectoral Potential of the Economy of Karabakh and Eastern Zangezur: Proceedings of the International Scientific Conference on Economic and Management Research (ISCEMR) 2022. - 2022. - P. 86-108.

5. Khalilov, Sh. Ecogeographical Issues of Azerbaijan: Textbook / Sh. Khalilov. - Baku, 2006. - 160 p.

6. Mamedov, K. Sh. Soil Science and Fundamentals of Soil Geography: Textbook for Higher Education Institutions / K. Sh. Mamedov. - Baku: Elm, 2007. - 660 p.

7. Atlas of Soil Resources of the Republic of Azerbaijan / edited by K. Sh. Mamedov. - Baku, 2007. - 127 p.

8. Museyibov, M. A. Physical Geography of Azerbaijan (General Part) / M. A. Museyibov. - Baku: Maarif, 1998. - 400 p.

9. Saving the Soil // Cambridge IELTS 13 Academic. - UK, 2018. - P. 85.

10. Landsat 7 Science Data Users Handbook / National Aeronautics and Space Administration (NASA). - 186 p.

Список источников

1. Географы Азербайджана / Институт Географии Национальной Академии Наук Азербайджана. – Баку, 2013. – 204 с.

2. Валиев А.Г. Оценка потенциала сельскохозяйственных почв на освобожденных территориях // Экономика сельского хозяйства. 2020. № 3 (33).
3. Джафаров, М. И. Почвоведение / М. И. Джафаров. — Баку: Элм, 2005. — 460 с.
4. Халилов, И., Джафарова, Ф. Перспективы устойчивого и инновационного развития животноводства в экономических районах Карабаха и Восточного Зангезура в Азербайджанской Республике // Оценка секторального потенциала экономики Карабаха и Восточного Зангезура: труды Международной научной конференции по исследованиям в области экономики и управления (ISCEMR) 2022. — 2022. — С. 86-108.
5. Халилов, Ш. Экогеографические вопросы Азербайджана: учебник / Ш. Халилов. — Баку, 2006. — 160 с.
6. Мамедов, К. Ш. Почвоведение и основы почвенной географии: учебник для высших учебных заведений / К. Ш. Мамедов. — Баку: Элм, 2007. — 660 с.
7. Атлас почвенных ресурсов Азербайджанской Республики / под ред. К. Ш. Мамедова. — Баку, 2007. — 127 с.
8. Мусейибов, М. А. Физическая география Азербайджана (общая часть) / М. А. Мусейибов. — Баку: Маариф, 1998. — 400 с.
9. Saving the soil // Cambridge IELTS 13 Academic. — UK, 2018. — С. 85.
10. Справочник пользователя научных данных Landsat 7 / Национальное управление по аэронавтике и исследованию космического пространства (НАСА). — 186 с.