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Remote Sensing Study of the Impact of Social-Economic Development on The Scale of Land Use in The Shaki District

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Abstract

The study investigates the changes in both the quantity and quality of land use in the Shaki district resulting from the increased level of social and economic development. Remote sensing was used to analyze the projects implemented under the State program 'Social and Economic Development of Regions,' assessing their impact on land use. The projects were categorized as either 'changing' or 'replacing,' based on their degree of impact, scale, and transformations between areas. The study also examined the population distribution by altitude zones and settlement levels. The satellite images were decoded and the land use areas were divided into classes. The level of land use between 2001 and 2020 was analyzed using the support vector machine (SVM) method to calculate the scale, difference, and regional growth rate of individual areas. The changes that occurred were identified and explained. Additionally, the transitions between categories were studied, the main changing and expanding areas were identified, and the increasing and decreasing tendencies between classes were examined.

Keywords *territorial planning, socio-economic development, remote sensing, SVM method, classification, Shaki district, transformation*

INTRODUCTION

Over the past century, the world's population growth and its impact on land have significantly increased (Ota and Eyasu 2020). As human activities on the earth's surface cause anthropogenic changes, there is a resulting change in land cover (Mahmood et al. 2014). These changes significantly affect the performance of various systems, such as energy, water, and soil balance. Moreover, the increasing pressure on limited natural resources, due to the increase in the number of population, leads to the change in land surface cover.

The impacts of land use on ecosystem sustainability are becoming a growing focus of global change studies. Studies have been carried out to date on change detection, urban environment planning or monitoring, natural disaster monitoring, land use and land cover (LULC) mapping, planning, resource management, site suitability analysis, and ecological or biological studies based on soil study and the measurement of anthropogenic influence.

In our republic, a number of factors influence the change of land use and land cover, including natural and social changes, intensive agricultural activity, temperature increase, overgrazing, growth of industrial areas, shrinking of glaciers, decrease and redistribution of water level of rivers and water basins, and decrease in rainfall. With the scientific and technical development, previously planned areas were carried out according to the use of natural resources, and in modern times, they are carried out in accordance with the possibilities of using the existing area based on geographic location information.

Previous studies on land cover in Azerbaijan have mainly focused on the use of supervised remote sensing maximum likelihood classification methods using Landsat 5 and

7 TM satellite images of 1998 and 1999 (Manakos and Brown 2014; Ismatova 2005). However, the results of the studies are not available for comparative analysis. Bayramov (2016) conducted a study on land use and changes in land resources in the Republic, mainly observing the increasing and decreasing trend of forest cover and greenery in 2014-2015 (Landsat 8).

Most of the conducted studies have focused on the change of the forest cover area and historical periods, and did not reflect the current situation or consider the perspective of social and economic development. As a result of the projects implemented in the "Social and economic development of regions" State program, relevant changes and transformations have occurred in the structure of land use in the research region. In the mountainous region, a decrease in the scale and change in the quality of usable land areas were recorded. The scientific novelty of this study lies in the analysis of the impact of State programs on territorial planning in the Sheki region, based on remote sensing and GIS technologies, and the changes they cause in the scale of land use. Using the method of decoding satellite images, the changes in the quantity of land use were monitored, and transformed areas were identified over the course of 20 years under the influence of State programs.

Features of the population location

The location of the population is unevenly distributed in the region due to the mountainous terrain. Thus, the distribution of the relief in the height zones, the location of farms and residential areas have been studied by other scientists at different times. For instance, scientists such as B.A. Budagov, R.Kh. Piriyev, M.A. Museyibov, N.H. Ayyubov, Sh.K. Demirgayayev, I.E. Mardanov, and Z.N. Eminov can be noted, who in their research gave the distribution of the population and analysed settlement by height in 6 altitude.

In the research region, the characteristics of the location of the population in the Sheki region, the distribution of the population by altitude zones were given in 6 categories, the number of population, settlements, administrative territorial areas and the villages belonging to them were calculated for each division. For this, the population census materials and the elevation model satellite image (DEM file) of the area were used. ArcGis 10.3 and Spatial analysis method were used.

Table 1. Location of settlements and population by altitude zones.

Altitude range	Area sq. km	Area share %	Number of settlements	Population (thousand people)	Share of population %
1-200	218,8	9,1%	4	14264	8
201-500	1313,3	54,8%	45	45938	27
501-1000	391	16,3%	23	103844	61
1001-1500	149,2	6,2%	3	6687	4

Source: Prepared by the author

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"Social and economic development of regions" State Programs

In order to improve the social welfare of the population in our republic, to adapt the level of social and economic development of the regions to the average development indicators of the city of Baku, the State program "Social and economic development of the regions" was adopted covering five years between 2004-2008, 2009-2013, 2014-2018 and 2019-2023. The program includes a plan of actions that takes into account the application to all regions and cities, including Sheki regionWithin the framework of the program, the measures implemented in Sheki region and the changes and substitutions in the structure of land use in the area as a result of it were analyzed. For this purpose, the projects carried out in different fields were reviewed.

Table 2. Summary of land use works in Shaki district.

Field	"Social economic development of regions" State Programs and their intervals			
	2004-2008	2009-2013	2014-2018	2019-2023
Industry and agriculture	112 ha mulberry garden	Providing loans to farmers for livestock development	City administrative lab	Shaki city hotel
	50 ha fruit garden	Construction of 3 granaries	State seed inspection	Slaughterhouse
	20 ha grape garden		Agrochemical laboratory	Warehouse
	Canning factory			Auxiliary building
	Shaki juices production LLC			Sorting station
	Construction materials combine			
Social infrastructure		Bridge construction	A psychiatric hospital	Medical station
	Ayrichay water lake	Road construction	Continuation of road construction	8 high school
	14 km su kanalı	Construction of gas pipelines	Agrolizing OJSC provided 175 pieces of agricultural equipment: 59 combines, 34 tractors, 2 excavators, 80 tractor-mounted equipment	
	Center for the rehabilitation of disabled people	Rehabilitation center	Continuation of gas pipeline construction	
	Building 3 schools	City hospital		
		Shaki equestrian sport base		
		The Youth Palace complex		
Forest		57,5 ha forest planting		
		33,5 ha forest sowing		
		5060 tree planting		

Source: Prepared by the author on the basis of measures implemented within the framework of the State programs "Social economic development of regions".

As a result of the measures implemented within the program, relevant changes in the use of land cover have occurred. These changes are mainly grouped into two categories, "changing fields" and "replacing fields". In addition to the measures mentioned in the state program, there are other projects, but here only the factors affecting the use of the territory have been addressed and analyzed. Thus, activities such as rebuilding and restoration of some enterprises and buildings on the territory in Sheki region, including the creation of new varieties in winemaking, replacement of technologies used in the field of sericulture with new ones, construction of telecommunication, utility lines, sewage systems, did not cause serious changes in land use, were not taken into account during evaluation.

Agriculture: In the first period of the adopted State program, in order to develop sericulture and cocooning in the region under the lines of "Sheki-Ipek" OJSC(Artunov N.B 2022), orchards were planted in Shaki city and Kayabaşı villages to create a raw material base for grape and fruit processing shops. In 2009-2013, preferential loans were given to farmers for the development of animal husbandry within the program. In the next State program, the development of drumming and increase of subsidies, investment in animal husbandry continued. In order to improve the material and technical base of agriculture, the Shaki city seed inspectorate and Agrochemical laboratory were built, and 172 pieces of equipment were given to the Agro-leasing center in this interval. Also, within this framework, the subsidies given to agricultural areas were increased and the process was improved.

Industry: Food and light industrial enterprises have been put into use within the framework of State programs for the development of industries(Pashayev N, and Artunov N, 2020).These are mainly the construction of a canning processing plant, a juice production enterprise, a warehouse, a sorting station and an auxiliary building for the improvement of the material and technical base of Azertutun OJSC and the expansion of the development of tobacco farming, a building materials combine, and warehouses for storing grain products.

Social infrastructure: In order to improve the social well-being of the population, drinking water and agricultural irrigation, a water channel, gas lines and highways were built and bridges were built from the Alijan river, Ayrichay reservoir, Psychiatry and city center hospital, rehabilitation and rehabilitation centers for the elderly, equestrian and youth palace complex , and 11 full secondary schools were commissioned.

Forestry: afforestation and forest seeding were carried out on the lands of the state forest fund, and tree plantations were carried out in the direction of greening the roadsides.

METHOD

Study area

The total area of Shaki district, located in the northwest of our republic, is 2488 km2 and it is the second largest district of Azerbaijan after Guba district. The Shaki district is surrounded by the Dagestan Republic of the Russian Federation from the north, Oguz from the east, Yevlakh from the south, and Gakh from the west (Fig 1).

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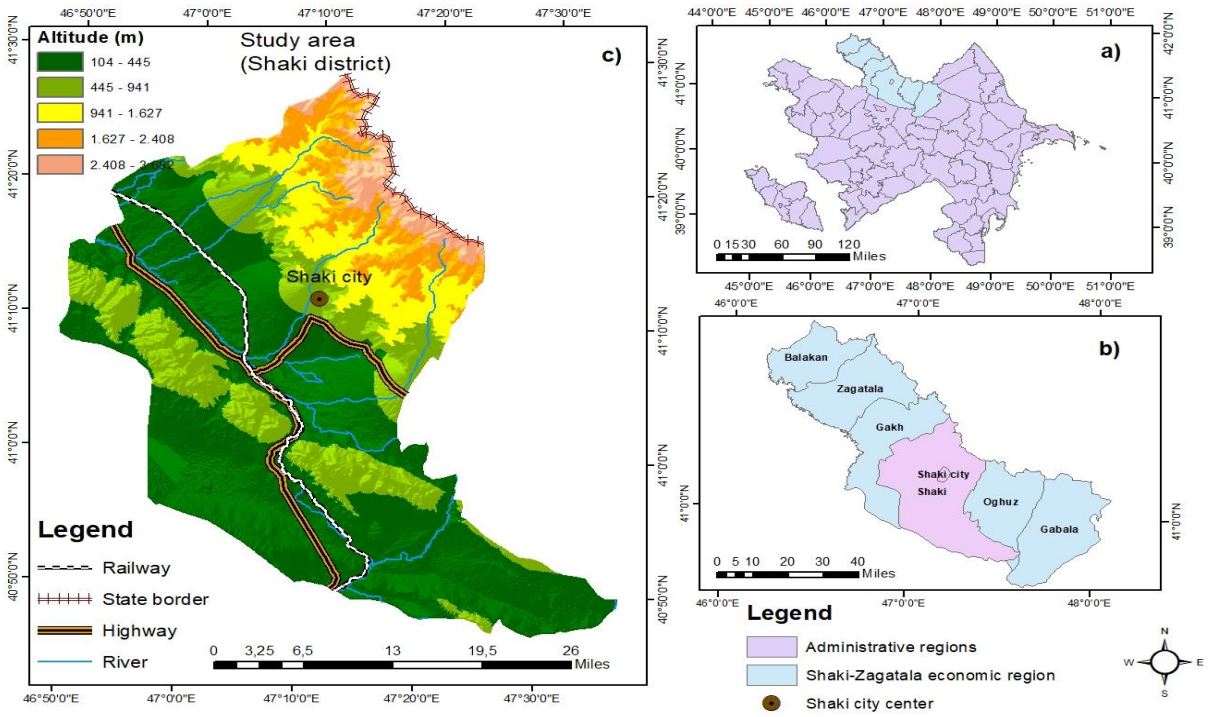

Figure 1. Study area: a) Administrative regions of Azerbaijan Republic, b) Shaki-Zagatala economic region, c) Shaki district

Data gathering and processing

Landsat 7 and 8 satellite images of 2001 and 2020, respectively, were used to determine the extent of land use in Shaki district (Table 3). The images obtained separately were first prepared uniformly by the mosaic method, and the research region was cut out from the area. The image quality enhancement was performed (Atmospheric correlation) and as a result, image quality was improved.

Name	Obtained	Platforma adı	Type	Band number	Cell size
Landsat 7	2001	Landast data collection	Orthophoto	7	30/30
Landsat 8	2020	Landast data collection	Orthophoto	12	30/30

Table 3. Satellite data used

The received satellite data were processed using supervised classification (SVM (support vector machine), a type of machine learning (ML) technology). At this time, a combination of 5,4,3 bands and image sharpening (Pansharping) with the histogram equalizer method were used. When classified by land use, grouping was done (Table 4).

Name	Description
Developed	*This includes residential areas of the population, social infrastructure areas, transport infrastructure and its units, industrial enterprises, agricultural production enterprises and farms.*
Forest	*Greenery, park areas, trees and bushes in backyards*
Bareland	*Areas classified as low productivity, areas with no vegetation or broken areas, areas temporarily formed due to the reduction of the flow area of rivers and not suitable for any agricultural area*
Cropland	*Plantation fields, orchards and vineyards, melon fields and backyard areas*
Water	*Rivers flowing through the area, artificial reservoirs and Acinohur lake*
Snow	*Areas with permanent snow cover in the highlands*
Pasture	*Foothills and non-agricultural areas*

Table 4. Grouping of land use

Remote Sensing

Remote sensing can significantly contribute to timely and accurate management of the agricultural sector, as it is convenient and suitable for collecting relevant data over large areas with high accuracy (Brisco, 2014). The management and monitoring of agricultural fields (Li X., & Shao X., 2013), the planning and spatial organization of industrial areas (Longbotham, et.al 2012), the optimization of social infrastructure and transport nodes have become easier with GIS systems(Huang, X., et.al, 2017). The use of the remote sensing method in the above-mentioned areas has gone beyond the regional scale and has started to be used to solve local problems as well.

With the improvement of the spatial resolution of remote sensing images, remote sensing image classification has gradually formed three parallel branches of classification at different levels: pixel-level, object-level, and image-level classification. (Cheng,G.,et.al,2020). The most widely used parametric classification is the maximum likelihood classification (MLC), which makes decision surfaces dependent on the mean and covariance of each class (Thakkar, A. K, vb , 2017). Image classification is an automated approach to classifying raster data from satellite imagery to aerial imagery and drone imagery(Senta A., and Šerić, L., 2021). This would typically involve evaluating several images and applying statistical rules to determine land cover identity for each pixel in the image (Swetanisha S., et, al, 2022). In this paper, supervised classification algorithms are applied for land use and land cover (LULC) classification. Satellite image classification is performed to prepare training and test data.

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RESULTS

Name	2001		Difference		2020	
	Area	%	(km2)	%	Area	%
Developed	210,6	9%	100,5	32%	311	13%
Forest	307,3	13%	116,7	28%	424,1	18%
Bare land	547,4	23%	-58,3	-12%	489,1	21%
Water	27,4	1%	14,5	53%	42	2%
Cropland	593,9	25%	13,9	2%	607,8	25%
Snow	119,2	5%	-16,4	-14%	102,8	4%
Pasture	578	24%	-170,9	-30%	407,1	17%
Total	2383,8	100%			2383,8	100%

Table 6. The results obtained after the classification of Shaki region

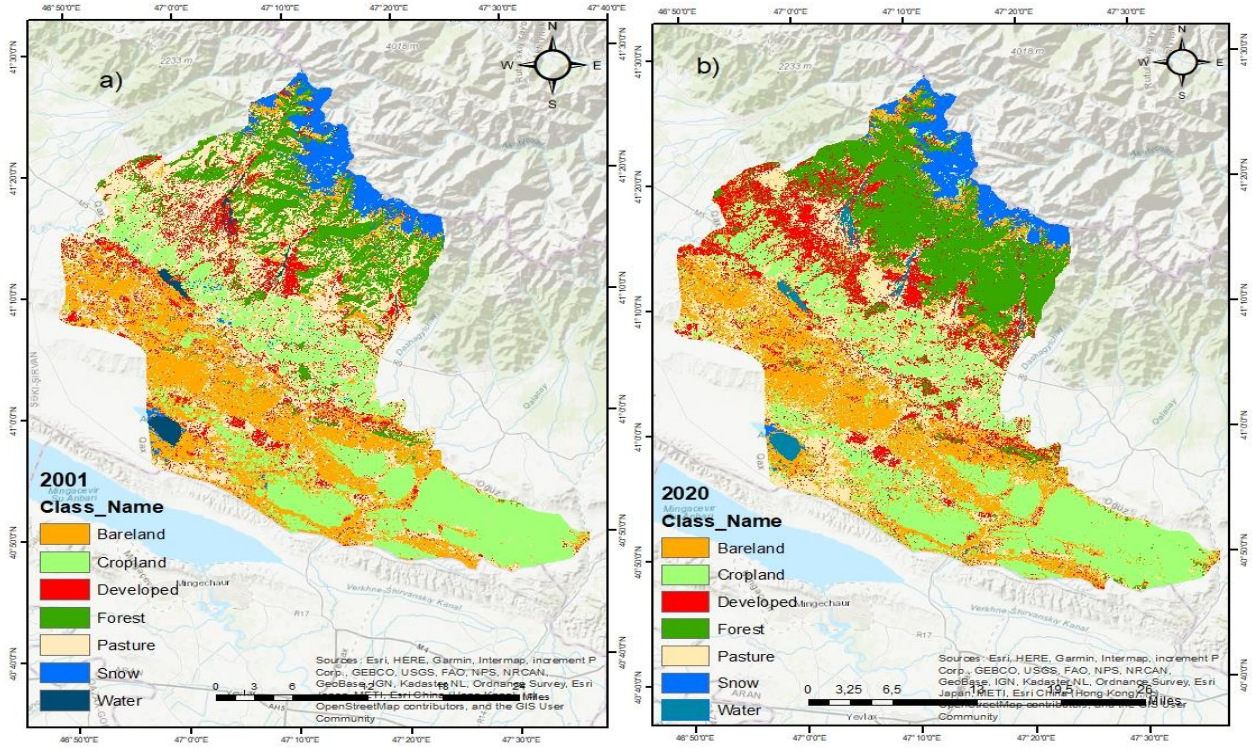

Figure 2. Results obtained after decoding satellite images: a) 2001 data, b) 2020 data

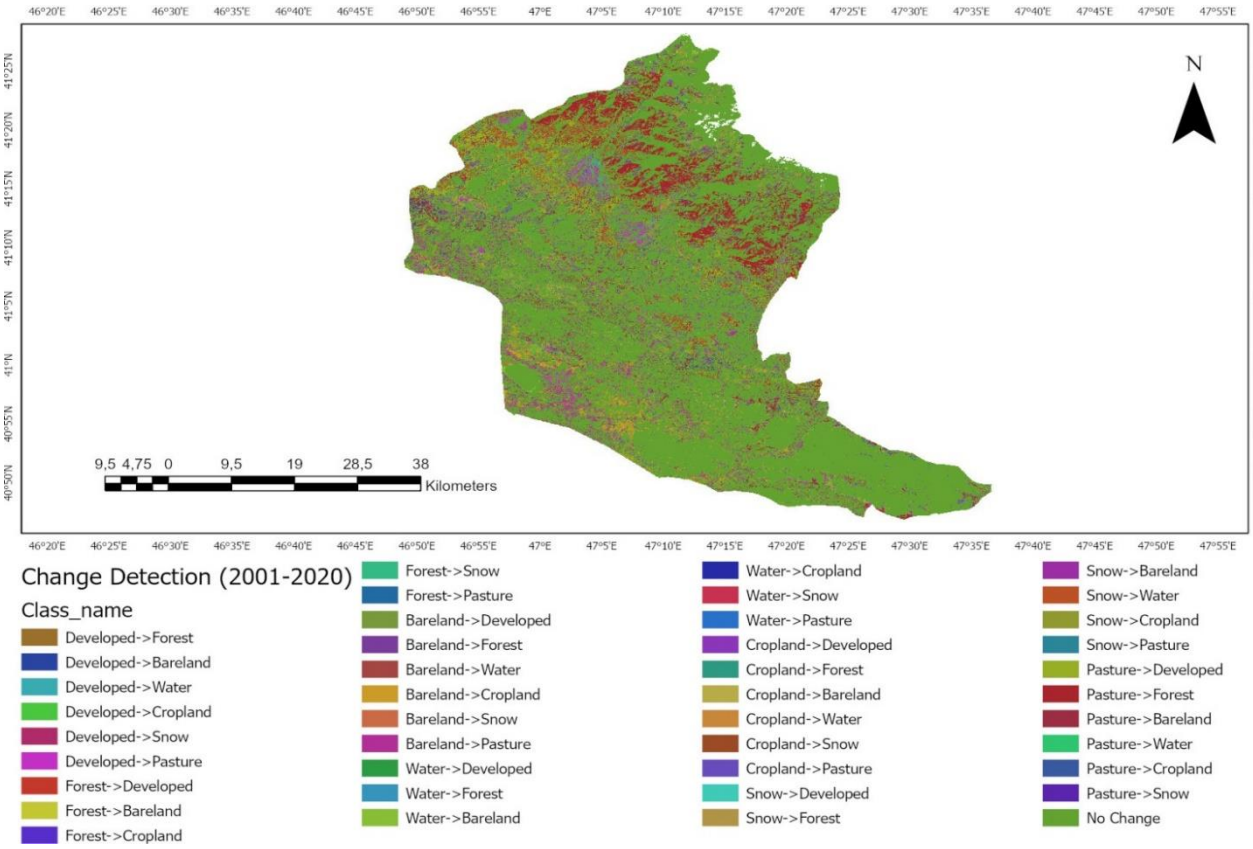

Fig 3. Stable and transforming areas by category (2001-2020)

From	To	Area(km2)
Bareland	Cropland	43,8
	Developed	16,2
	Forest	17,7
	Pasture	61
	Water	5,1
Cropland	Developed	13,3
	Bareland	15,4
	Pasture	17,7
	Water	5
Forest	Bareland	6,9
	Cropland	0,3
	Developed	40,5
	Pasture	2,3
Pasture	Bareland	47
	Cropland	7,5
	Developed	109,2
	Forest	137,7
Water	Bareland	1,44
No changes		1725,1

Table 7. Scale of mutually transformed areas between categories

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DISCUSSION

Land use changes

Although the processing of obtained satellite images reflects the general situation of spatial planning in the area, it cannot explain the reasons for its occurrence. For this, there is a need for a detailed explanation of the changes or transformations occurring in each category. Table 6 shows the results after classification. Let's take a look at the general indicators of land use by category during the years 2001-2020:

a) *Agriculture*- The share of agricultural areas in the use of land cover is quite high. So, if agriculture covered 25% of the total area or 593.9 km2 in 2001, this number was 607.8 km2 or 24.8% in 2020 (Fig 2). An increase of 2% or 13.9 km2 in the 20-year period is observed in the use of the area for agricultural purposes. The main reason is related to the increase of subsidies given for agricultural land in the region and the creation of industrial enterprises for the production of some agricultural products (the start of operation of the tobacco production enterprise for the development of tobacco and the expansion of its material and technical base, the creation of grain warehouses, the development of cocoon cultivation and the planting of sorghum trees, the planting of fruit orchards)(Artunov N. 2022) . In agriculture, it is observed that in different areas of crop cultivation, farmlands are replaced by orchards or vice versa.

b) *Developed territory*- In 2001, 9% (210.6 km2) of the territory of Sheki region was occupied by residential areas, while in 2020, this figure was 13% (311 km2). With the increase in the number of population, the creation of new industrial enterprises, and the improvement of the social infrastructure, the scale of land use is seen to increase. During the period 2001-2020, the growth was 100.5 km2 or 32%. The increase in the use of the area as a residential area has been noticed in the surrounding areas, including the city of Shaki, as well as in villages and towns. Along with the development of the city, there has been an increase in farming in the villages, the construction of residential apartments and the formation of other service areas.

c) *Bareland*-A decrease in the research area was observed in the total area of arid and barren areas. In 2001, 23% of the territory or 547.4 km2 were unusable areas, while in 2020 it was 489.1 km2 or 21%. During the period 2001-2020, arid areas are seen to have decreased by 58.3 km2 (12%). We see that these areas, which were created due to the destruction of bush areas and the cutting of trees, have started to recover with the increase of bushes in recent times.

d) *Forest*- An increase in forest reserves is observed in the category of forest reserves. So, if forest reserves covered 13% of the total area in 2001 or 307.3 km2, in 2020 it covered 18% or 424.1 km2. A 28% increase in the area of forest reserves and related greenery was recorded, which means 116.7 km2 area in a twenty-year period. The main reasons for the increase in the area of forests are the acceleration of the gasification process by the establishment of forests in the area and the laying of gas lines in the region starting from 2004. So, if earlier the population used forest firewood for heating purposes, now this problem has been replaced by gas, as a result, the rate of massive deforestation has decreased significantly.

e) *Snow area*- Areas of the district close to the Russian Federation are covered with snow and glaciers. Snow-covered areas in 2001 accounted for 5% of the area. However, in 2020, this number decreased to 4%. This is due to global climate changes, which has reduced snow cover by 14% or 16.4 km2 over twenty years.

f) *Water*- A significant increase in the change of water bodies in the region has been recorded. If in 2001, 27.4 km2 or 1% of the territory of the region was covered by water bodies, in 2020 this figure reached 2% or 42 km2. An increase of 53% and 14.5 km2 was recorded during the analyzed years. The main reason for this is the increase in water level in rivers due to the melting of snow and glaciers as a result of climate changes. Also, the low level of the water basin in the indicators of 2001 can be explained by the fact that the received satellite image does not reflect the peak times of the rivers. However, even when the second possibility is evaluated, it cannot explain such a difference. Therefore, initial assessment should be more accepted.

g) *Pastures*- Pastures, which are one of the important areas of agriculture, are the basis for the development of animal husbandry. However, it is observed that the pasture areas are decreasing in the region and this decrease is happening on a large scale. Thus, in 2001, 24% of the region's territory was covered by pastures and meadows, but in 2020, this indicator decreased to 17%. In general, during twenty years, the fields decreased by 170.9 km2 or 30%. The main reasons for the decrease in the area are the use of the area for agricultural purposes.

Interchangeable and transformable areas by Category

Figure 3 shows the transformations by categories. During the territorial planning, it was not taken into account during the analysis, since it was carried out only according to land use, since snow areas were classified as melting or otherwise. A large proportion of the areas classified as wasteland, including 30% agricultural and 42% are seen to be used as pastures. Most of the agricultural land has been converted into settlements or industrial facilities, pastures and wastelands, which account for 26, 34 and 30 percent, respectively. Forest reserves have been transformed into residential areas (81%) and arid areas (14%). It has been observed that the area of pastures decreases during territorial planning due to the increase in population and the expansion of settlements.. Thus, 36 percent of grasslands have been converted into human settlements, 16 percent into dry areas, and 46 percent into forest pastures (Table 7).

Regional growth rate

After classification, the following equation is used to determine the growth rate between land use categories by region:

$$Region\ growt\ rate\ = \frac{\text{Region area2} - \text{Region area1}}{Region\ area1} * 100\%$$

Here: Region area2 represents the indicator of the last year, and Region area1 represents the previous year.

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After applying the formula, the following results were obtained. The degree of growth in individual categories is characterized from -1 to 5.The white sand areas shown on the map (Figure 4) are the areas that have remained stable and unchanged over the years, covering 1725.1 km2.

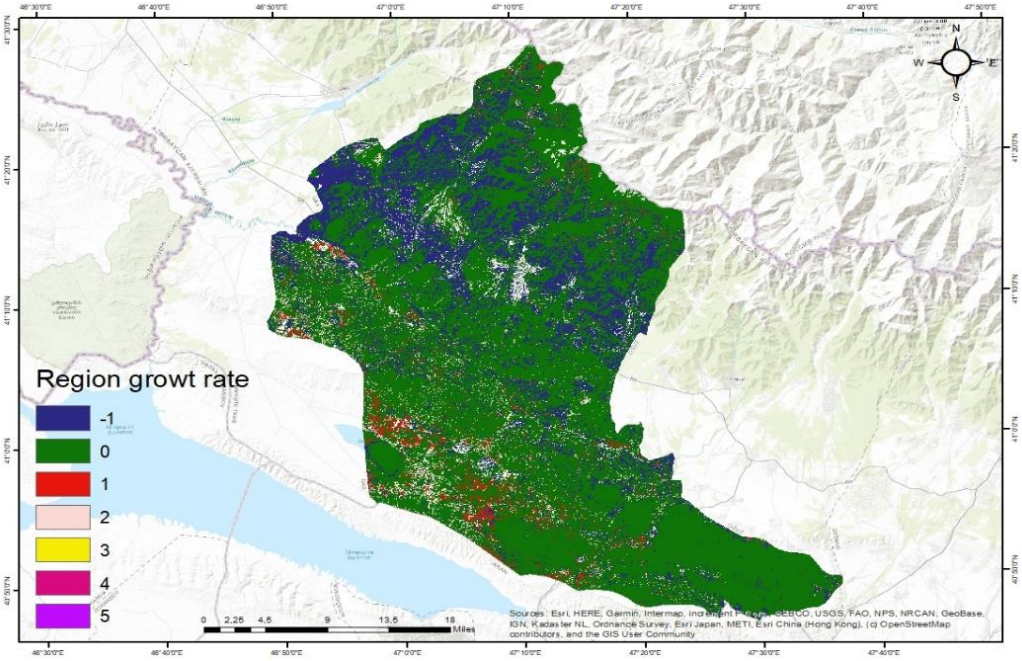

Figure 4. Region growth rate

CONCLUSION

As a result of our research, significant changes and replacements were determined in the structure of land use in the Shaki district between 2001 and 2020 as a result of the influence of the "Regional Social Economic Development" State program. With the rise of social and economic development, the tendency of the population to agricultural fields has increased, and the emergence of new trade and industrial fields has been determined. At the same time, after the land declarations held in the Republic, it was found that the share lands distributed among the population in the Sheki region are used independently of their purpose, not for agricultural purposes. Thus, it has been seen that agricultural areas are used for residential areas or industrial enterprises, pastures are used for cultivation, and useless and arid areas are used as pastures.

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