British Journal of Environmental Studies
ISSN: 2755-0982
DOI: 10.32996/bjes
Journal Homepage: www.al-kindipublisher.com/index.php/bjes

BJES
AL-KINDI CENTER FOR RESEARCH AND DEVELOPMENT

| RESEARCH ARTICLE

Evaluation of the Area of Clean Ice and Debris Ice Glaciers in Salang Area of Parwan Province using Remote Sensing Technology

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| ABSTRACT

The subject of my research paper is the Salang glaciers in Parwan province using GIS technology and remote sensing, the region has been researched by the mentioned technology, and within twenty years, from 1999 to 2019, the natural glaciers of the Salang area have been evaluated, and every five years a separate map has been arranged, the figures and data of each year have been calculated in separate tables. Since it is difficult to study the Salang glacier area closely, by using remote sensing technology, I have succeeded in evaluating its area, volume, and changes during the mentioned years. At first, it received its satellite images; later, it was corrected by the ENVI program, and the images were entered into the eCognation DEVELOPER and ArcGIS programs to reveal its bare and covered glacier areas.

| KEYWORDS

GIS, Remote Sensing, Glacier, Map, Salang, ENVI, eCognition

| ARTICLE INFORMATION

ACCEPTED: 12 December 2023 **PUBLISHED:** 01 January 2023 **DOI:** 10.32996/bjes.2024.4.1.1

1. Introduction

The subject of this research is the changes in the Salang glaciers of Parwan province in the last twenty years. The glaciers melt over time due to the emission of greenhouse gases such as carbon dioxide, methane, nitrogen dioxide, etc. (Hertzberg et al.,2009).

For this reason, I have to calculate the area and volume of the glaciers using remote sensing technology and different programs and check the extent of their melting because this type of research has not been done before in the mentioned area, and there is an urgent need to know the glaciers and prevent the destruction of the glaciers in this country.

The height limit of permanent snow is called the equilibrium line, which changes with latitude, the direction of the slope, the frequency of rainfall, and other local conditions such as warm winds and the time of precipitation (Barry,2006) (Goff& Butler,2016). Natural glaciers are ice blocks that are formed by the recrystallization of snow. Glaciers can move forward under the influence of gravity. Permanently, 7% of the land's surface is covered with snow. Moving seas and rivers of ice are known as natural glaciers.

There are many natural glaciers in the heart of the North Pole, the South Pole and the mountainous and high regions of the earth. Glaciers were more extensive in the past, so the regions that today include the temperate regions of the earth were covered by natural glaciers in the past glacial periods (Barry,2006). Glaciers have been an important factor in erosion, transportation, and sedimentation in different geological eras as well as now. The height limit of permanent snow is called the equilibrium line, which changes with latitude, slope direction, rainfall frequency and other local conditions such as warm winds and rainfall time. For example, this average limit reaches 600 meters above sea level in the polar and near polar regions, 2800 to 3100 meters in the alpine region, and 5400 to 5800 meters in the tropical regions. This limit of heat balance is located at an altitude of 3500 meters. Numerous glaciers have been seen in the world, which are in a state of decreasing and melting. Unfortunately, there is no information about Afghanistan's glaciers in general and especially about Salang glaciers in Parwan province in the global database of glacier monitoring. In this research, the satellite images of 1999 and 2019 were investigated, and the measurements were made on the LANDSAT satellite images (5,7,8) in a comparative way. The result of international efforts to evaluate the natural fluctuations of glaciers around the world has begun. However, there are few direct observations of natural glaciers in Afghanistan. In the Parwan province of Afghanistan, very little information on the fluctuation of natural glaciers has been reported so far, and the reason for this is the complex topography and the lack of field measurements. Due to the impassability of the road and the closed topography of Salang Parwan, the only scientific and practical method that makes it possible to research the mentioned glaciers is the use of GIS and remote Sensing technology.

Glaciers in Afghanistan represent a part of the sensitive area in the Asian continent; these glaciers have dire effects on sea surface waters, regional and local water resources, and natural hazards and have an important role in geopolitical stability (Klyachanov. et al.,1972). Due to the lack of sufficient information about Afghanistan's glaciers, we do not have the necessary information about the climate of Afghanistan's glaciers. As a result, the region lacks information about glaciers, glacier area, ice volume, height of balance line, advance and retreat of glaciers, feeding of glaciers, amount of erosion, and development of lakes (Harrison et al.,2006).

2. Literature Review

There are many studies about the changes of glaciers in the world, but little research has been done on the evaluation of Afghanistan's natural glaciers among the studies on the changes of glaciers in the Doda sub-basin area with 13 natural glaciers. The mentioned area was investigated by FCCs method using IRS LISS III bands 2, 3 and 4, and in total, with these methods, they found that from 1962 to 2001, about 18.16% of the glacier in the mentioned area decreased, and the volume of the glacier can also be obtained (Mehta et al.,2011) (Rai& Nathawat,2016).

Natural glaciers are mapped by remote sensing due to the problems of altitude and coldness. Studies in the Karakoram Mountains of Pakistan show that glaciers increase and decrease over several years, which is called El Nino. We also identified it in our studies using this phenomenon (Allan et al.,2020) (Minora et al.,2016).

Since some parts of the natural glaciers are covered, they should be evaluated by different methods in order to get the entire volume of the glaciers. This type of method is available by combining different bands (Sam et al.,2016).

3. Methodology

Since it is difficult and even impossible to evaluate closely with less equipment, we were able to solve and evaluate this problem through remote sensing technology. We did this using satellite images from 1999, 2004, 2009, 2014, and 2019; images can be downloaded from the United States Geological Survey online database. Later, we cut the satellite images according to the target area. Later, it is entered into a GIS program for data preparation; the Arc GIS program is one of the famous products of ESRI Company in America, which is used in the field of spatial information systems. With the help of this software, descriptive data can be used to create maps, tables and charts. In other words, ArcGIS is software that provides the possibility of creating a complete spatial information system. This program includes tools for programming, creating maps and managing them, supporting mobile and wireless systems, etc. This software provides users with the necessary tools for searching, analyzing data and displaying results with better quality.

In the GIS program, bands combine spatial images, and this band combination is different for Landsat 5, 7 and 8. In Landsat 5 and 7, we combine bands 1, 2, 3, 4, 5, and 7, and in Landsat 8, we combine bands 2, 3, 4, 5, 6, and 7 (Scheutz et al.,2009). Also, we cut the DEM of the area according to the scope of the project and calculated its slope; after that, we performed Composite Bands, Copy raster, Mosaic, and Clip operations in the GIS program.

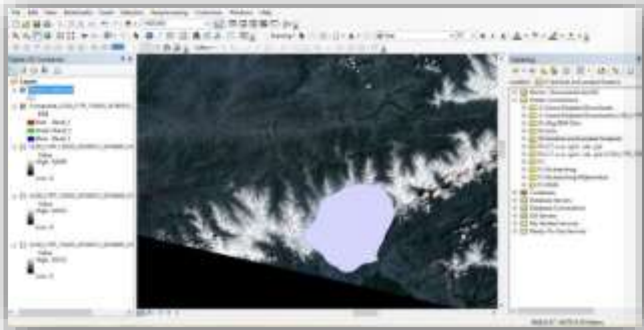


Figure 1. Satellite image of salang and salang boundary

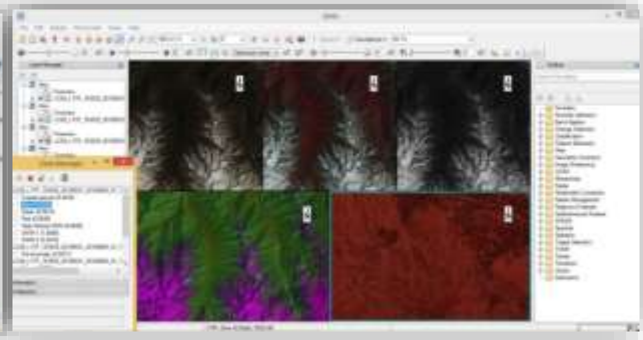


Figure 2. ENVI Environment

4. Results and Discussion

The prepared data was entered into the eCognition Developer program, which was launched in 2000. Later, this version was introduced to Professional 5 and in 2003, it was developed and introduced as eCognition™ Server, and now it is called eCognition Developer, which is very powerful for analyzing and analyzing images. This program is a powerful development environment for object-based image analysis. This is used in the field of earth sciences for the development of automatic analysis of remote sensing data. The mentioned program is designed based on the difference between colors and bands, and it can recognize the difference between colors and bands better, which forms the basis of remote sensing. In the mentioned program, three steps have been performed to identify the glacier area and the debris area (covered glaciers). First of all, we enter the data prepared in the ENVI program to eliminate the satellite gaps and fill it using the Landsat Gap file. SLOPE is entered into the eCognition program; at this stage, the analysis of satellite images is started by setting the algorithms in the eCognition Developer program. First, from the Edit Image layer mixing section, we consider (2, 4, and 5) for the Landsat 7 image and (3, 5, 6) for the Landsat 8 image to better display the glaciers. All similar pixels from the point of view of price or color similarity are included in one part, and later, by means of the Normalized Deference Snow Index (NDSI) NDSI= ([B2_Green]-[B5_SWI1])/([B2_Green]+[B5_SWI1]), the glacial areas are placed together under a polygon, and later, the agricultural areas are separated from the glacial areas by the NDVI index (Normalized Deference Vegetation Index) NDVI=([B4_NIR]-[B3_Red])/([B4_NIR]+[B3_Red]) and also the water areas, especially the water pond areas that are caused by the melting of natural glaciers, are made by the LWM ((Land Water Mark)) or Land Water Mark LWM=([B5_SWI1])/([B2_Green]+0.0001)*100(Scheutz et al.,2009).

Separated and also the areas of the glacier that are covered by sediments, which are referred to as Debris, are also separated, and in the second step, which is Classification, the noted areas, especially the Clean Ice Glacier areas and the Debris covered Glacier areas, are identified by the Classification operation, which is done by the specific indexes of the areas previously mentioned above, and in the third step, which is the Export Data stage or the data output stage, the final data is in the form of an export file. And re-enter the GIS program when the shape files are entered into the GIS program; using the tools in the program, I made the polygons in a fake color shape so that they assume the natural state. Calculations of figures (number of glaciers, number of areas covered by glaciers, area of glaciers and areas covered by glaciers, geographic coordinates of glaciers, Longitude, Latitude, Area Km2, absolute average height, Elevation-mean, average slope-mean, and volume of glaciers) Parwan province was made by special calculations, then the layout of the map was arranged and the characteristic signs, scale, etc. were arranged, and five maps were arranged from 1999 to 2019 of the Salang glacier areas of Parwan province, which show the changes of natural glaciers in the past 20 years.

Figure 3. salang district glacier

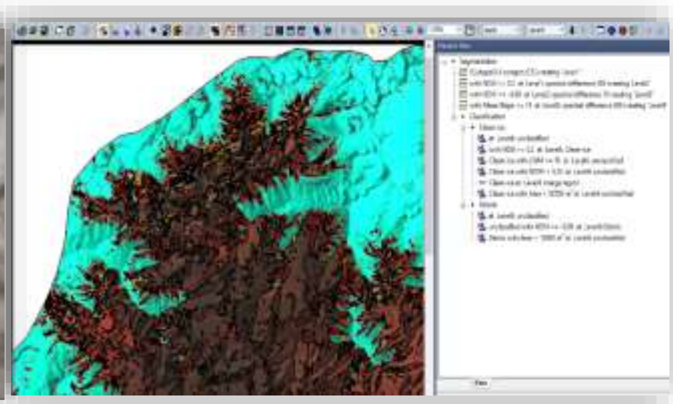


Figure 4. Segmentation in eCognation

As you can see in the pictures below, in 1999, the number and area of glaciers was more than in the previous years of 2004, which indicates the warming of the region during this period, which caused the melting of the glaciers. But after 2004, the number of glaciers and their area increased, which is proof of the cooling of the region during this period. This change increased until 2014, which reached its maximum this year. After 2014, the glaciers will melt, and their number and area will decrease until 2019.

This indicates the increase of greenhouse gases, which has caused the warming of the earth and the melting of the glacier (Hertzberg et al.,2017) (Vettoretti & Peltier,2011). Of course, it was mentioned that the El Nino phenomenon has also caused the decrease and increase of the glaciers in the mentioned area, and as a result of this phenomenon, the year 2014 has the highest number of glaciers.

Percentage	Area km2	Glacier
63%	102.4	2004
Increase	271.59	2009

4.1. Summary of evaluation results

4.1.1. The results of Salang glaciers between 1999 and 2004:

From 1999 to 2004, 56% of Salang Glacier has melted.

Table 1. Area of glacier in 1999 and 2004

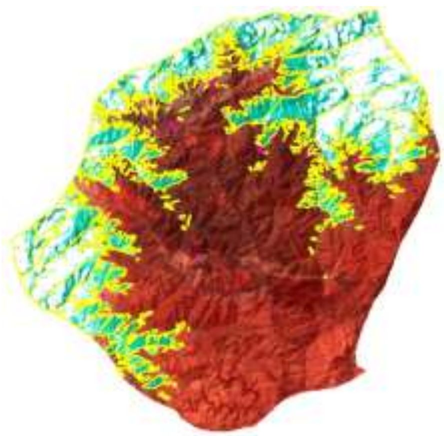


Figure 5. Map of Salang glaciers in Parwan province (1999)

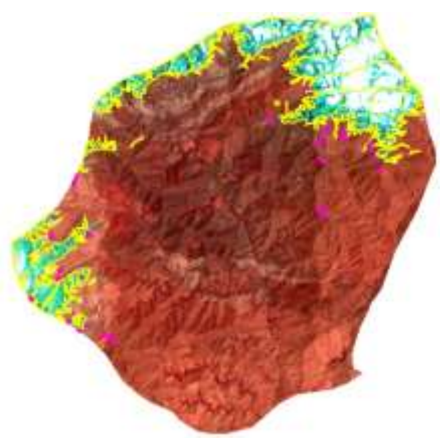


Figure 6. Map of Salang glaciers in Parwan province (2004)

Percentage	Area km2	Glacier
Decrease	230.20	1999
56%	102.4	2004

4.1.2. The results of Salang glaciers between 2004 and 2009:

From 2004 to 2009, based on the El Nino phenomenon, the glacier in 2009 increased by 63% from 2004, which caused climate changes and anomalies in the region every 2 to 7 years.

Table 2. Area of glacier in 2004 and 2009

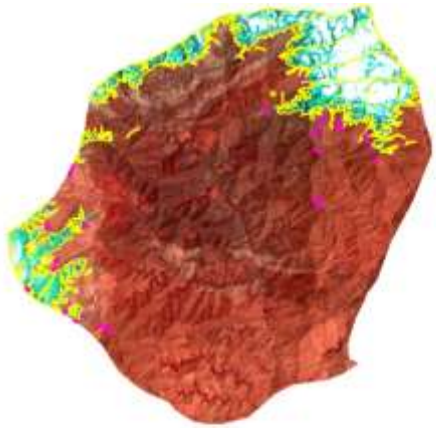


Figure 7. Map of Salang glaciers in Parwan province (2004)

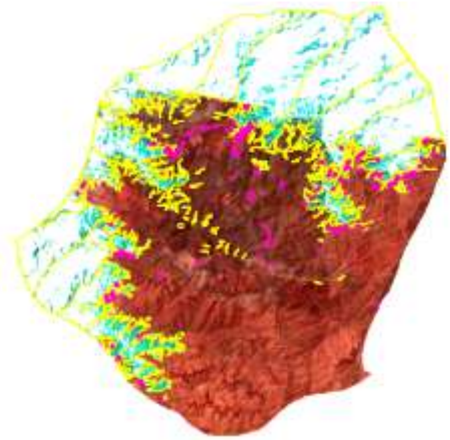


Figure 8. Map of Salang glaciers in Parwan province (2009)

4.1.3. The results of Salang glaciers between 2009 and 2014:

According to previous statements, from 2009 to 2014, an 11% increase in glaciers can be seen in Salang area.

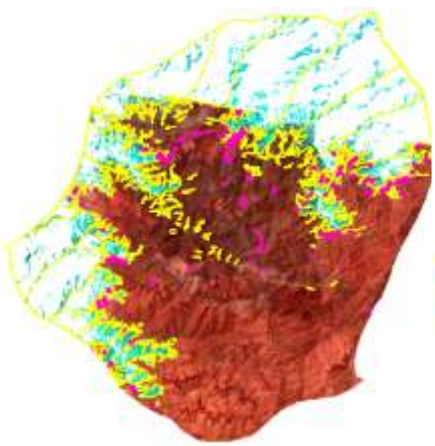


Figure 9. Map of Salang glaciers in Parwan province (2009)

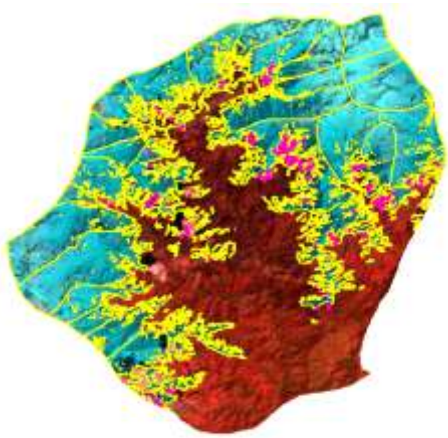


Figure 10. Map of Salang glaciers in Parwan province (2014)

Table 3. Area of glacier in 2009 and 2014

Percentage	Area km2	Glacier
11%	271.59	2009
Increase	342.66	2014

4.1.4. The results of Salang glaciers between 2014 and 2019:

As we know, the world is progressing, and in front of every progress, energy is needed, which causes the production of greenhouse gases in the environment as a result of burning all kinds of fossil energy; this process causes the earth to warm, the snow line to rise and the glaciers to melt. For this reason, 55% of natural glaciers have decreased in five years from 2014 to 2019, and if the production of greenhouse gases does not decrease, natural glaciers will decrease over time.

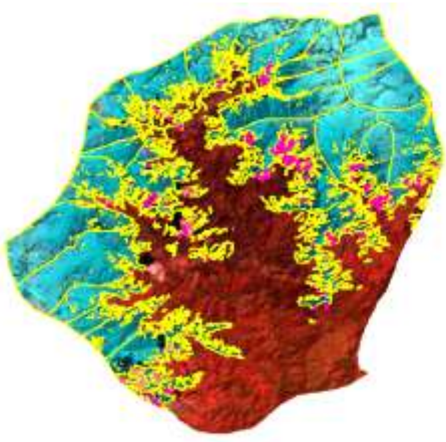


Figure 11. Map of Salang glaciers in Parwan province (2014)

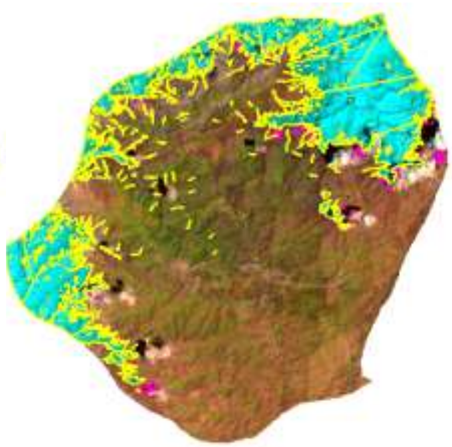


Figure 12. Map of Salang glaciers in Parwan province (2019)

Table 4. Area of glacier in 2009 and 2014

Percentage	Area km2	Glacier
Decrease	342.66	2014
55%	154.2	2019

4.1.5. Chart of Clean Ice Glacier Area(Km^2)

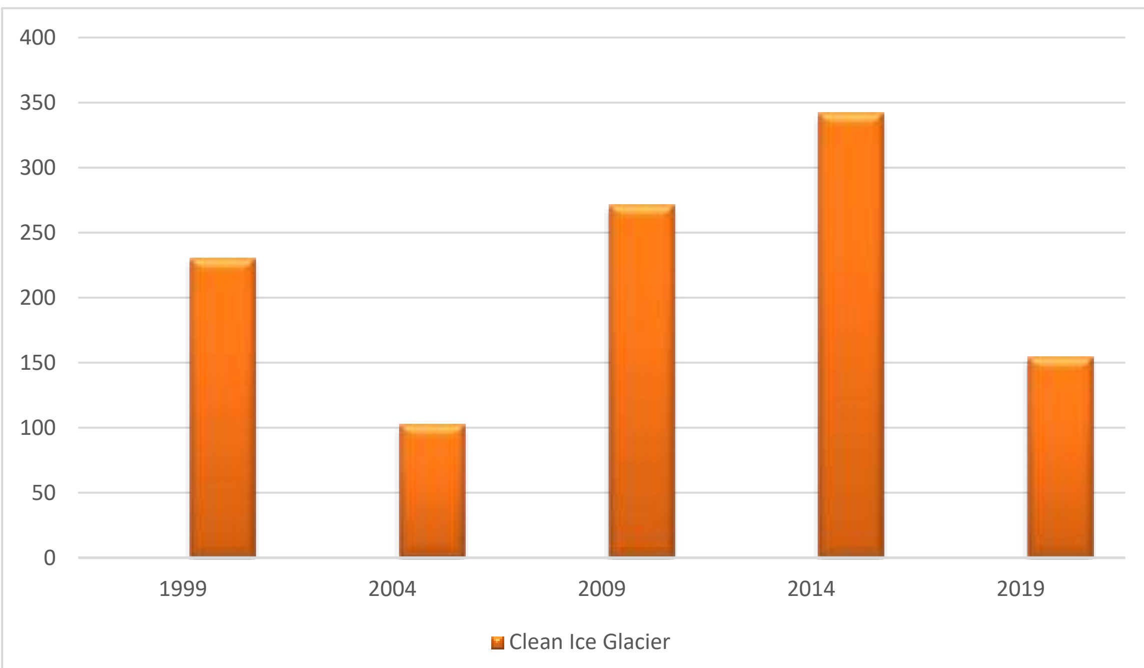
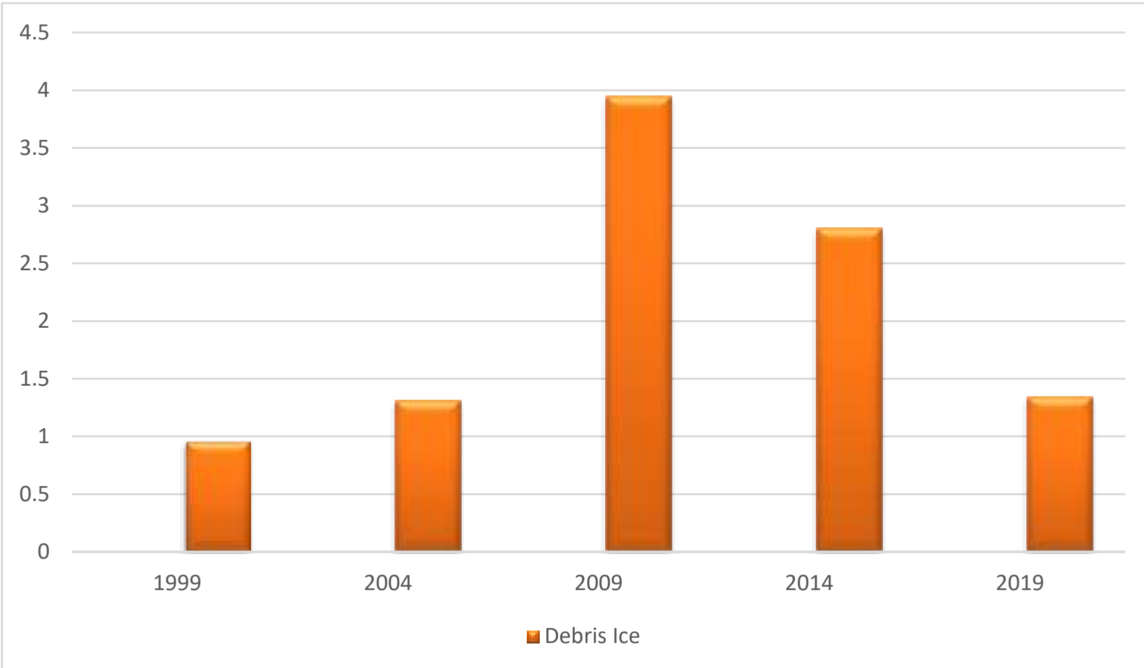


Figure 13. Chart of Clean Ice Glacier Area(Km^2)

4.1.6. Chart of Debris Ice Glacier Area (Km²)



5. Conclusion

Afghanistan's glaciers are located in mountainous areas and high levels; most of them are in the center and northeast of Afghanistan. Afghanistan's glaciers, most of which are located in the Wakhan Corridor of Badakhshan, belong to Asia's glaciers. It plays an important role in filling the seas. Unfortunately, there is little and insufficient information about their melting and melting fluctuations. As a result of the research on Salang glaciers in Parwan province, it can be seen that the glaciers have reduced considerably. As a result of the research, we found that Salang glaciers in Parwan province have significantly reduced the following parameters.

1- The thickness of the glaciers has melted over time, which has reduced their volume.

2- The area of the bare natural glaciers (Clean Ice) in 1999 was 230.2021 square kilometers, and the mentioned area in 2004 was 102.496 square kilometers, which shows the variation in the climate of this region, but in 2009, this area changed to 271.591 square kilometers. But in 2014, the mentioned area reached a maximum of 342.66 square kilometers due to snowfall and climate change. Later, until 2019, due to the use of fossil materials and the production of greenhouse gases, this figure will decrease dramatically to 154,243 square kilometers.

3- The area of covered natural glaciers (Debris) in Salang, Parwan Province, is changing like the open glaciers, which in 1999 was 0.9632 square kilometers; in 2004, the said area was 1.3082 square kilometers, but in 2009, it reached its maximum in the last few years to 3.946 square kilometers. It has decreased again, which was 2.8039 square kilometers in 2014 and 1.342 square kilometers in 2019.

4- The volume and number of natural glaciers have also decreased.

5- The Area and volume of the glacier in Salang (Debris and Clean Ice are listed in the table in the following order):

Table 4. Area and volume of glacier in salang

Estimated volume (Km ^{3})	Estimated volume (Km ^{3})	Debris glacierarea (km ^{2})	Clean Ice glacier area(km ^{2})	Year
0.00531	17.6767	0.9632	203.2021	1999
0.0112	8.026	1.3082	102.496	2004
0.0431	30.8284	3.946	271.591	2009
0.03474	33.9395	2.8039	342.662	2014
0.02384	14.9226	1.342	154.243	2019

Funding: This research received no external funding.
Conflicts of Interest: The authors declare no conflict of interest.
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