

Automatic Extraction of Glacial Outlines, Contours and Volume of Ice from Satellite Imageries (Use of Open Source GIS Software - QGIS)

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Abstract:

Remote Sensing and GIS are the two Geo-Spatial Technologies increasingly used in Geographic Research. The high cost of the software's used to apply these technologies to geographical data did not allow expansion of its use in India except in the projects which are financed by some funding agencies. Moreover, its use for individual research by teachers and students in absence of license access to these technologies was highly restricted. Even if a license is purchased by the educational institution, its maintenance cost further inhibits its use. The present paper highlights how QGIS, open source GIS software can be used to extract glaciers from satellite imageries. By adopting UBUNTU, an open source operating system and QGIS, an open source GIS software any department of Geography can establish a GIS laboratory where not only teachers but students may learn its applications and start using it in a big way. This will enable geography teachers, researchers, and students to use remote sensing and geographical information system in understanding, analyzing and highlighting the importance of various indicators of development.

Key words: GIS, QGIS, extraction of glaciers, contour drawing

I. INTRODUCTION

Remote Sensing and GIS are the two Geo-Spatial Technologies increasingly used in Geographic Research. The high cost of the software's used to apply these technologies to geographical data did not allow expansion of its use in India except in the projects which are financed by some funding agencies. Moreover, its use for individual research by teachers and students in absence of license access to these technologies was highly restricted. Even if a license is purchased by the educational institution, its maintenance cost further inhibits its use. The present paper highlights how QGIS, open source GIS software can be used to extract glaciers and draw contours from satellite imageries. By adopting UBUNTU, an open source operating system and QGIS, an open source GIS software any department of Geography can establish a GIS laboratory where not only teachers but students may learn its applications and start using it in a big way. This will enable geography teachers, researchers, and students to use remote sensing and geographical information system in **understanding, analyzing and highlighting the importance of various indicators of development.**

II. WATER IS ESSENTIAL ELEMENT OF LIFE

Without water there is no life. Earth is a unique planet because water is found here in various forms. Glaciers are - "A perennial mass of ice, and possibly firn and snow, originating on the land surface by the recrystallization of snow or other forms of solid precipitation and showing evidence of past or present flow" (Cogley et al. 2011). Glaciers are store houses of water and releases water slowly with increase in temperature. The delineation of glaciers is essential to estimate how much water is stored in glaciers. With the increasing average temperature of earth, glaciers are threatened to melt. Melting of glacier ice will led to increase in sea level. So it is again necessary to estimate the amount of water released after the melting of different glaciers. Glaciers are located in high altitudes and very rough topography. The atmospheric conditions in these regions is very hazardous. It is very difficult to reach there for physical surveying with instruments. Remote sensing and GIS together provides a way out to extract glacial outlines and estimates important parameter about these glaciers, which cannot be attempted physically. Such attempts have been made using licensed GIS software's, which involves higher costs. QGIS, an open source software is used to repeat the same exercise taught in IHCAP training organised by SBS(M) College of University of Delhi and the material provided during the training. In this paper only the exercise is tried, using QGIS, it is not possible to provide technicalities of the whole process, only the steps in QGIS will be given.

III. METHODOLOGY

The main exercise is to identify the snow from the surrounding terrain with the help of band ratioing. Then a threshold value is selected to classify the glaciers. Once the glaciers are classified we need to convert these raster data to vector data to have polygon in shape files.

3.1 Data Required:

To extract the glacier outlines, we need band 3 and band 5 satellite imageries of Landsat satellite, digital elevation models and QGIS software. The orthorectified satellite imageries are available from glovis.usgs.gov data browser.

3.2 The following are the steps required to be followed to get the results:

3.2.1 Download Landsat band 3 and band 5 imageries and DEM's of the same area.

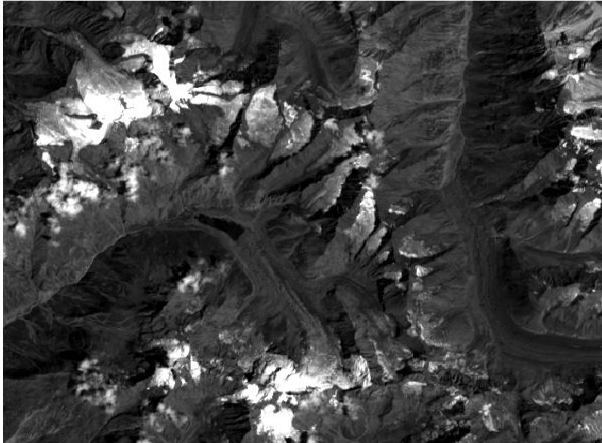


Fig. 1 Band 3 Landsat image



Fig. 2 Band 5 Landsat image

3.2.2 Add band 3 and 5 imageries as raster layer in QGIS

3.2.3 Open Raster Calculator from the Raster icon. Select the band 3 raster layer by double click. Add the division operator and select band 5 raster layer. The function will be in this form

"LE71470372000_08_B3_Clip@1" / "LE71470372000_08_B5_Clip@1". Specify the output raster file to save the processed output. Check the icon add result to project and press ok. A new layer of tiff format will be added to the project window. The resultant layer will have lesser variation of grey shades as compared to band 3 and 5 layers. The pixels are merged into either darker or lighter categories. Ice gives more reflectance, therefore, brighter pixels represent ice covered areas.

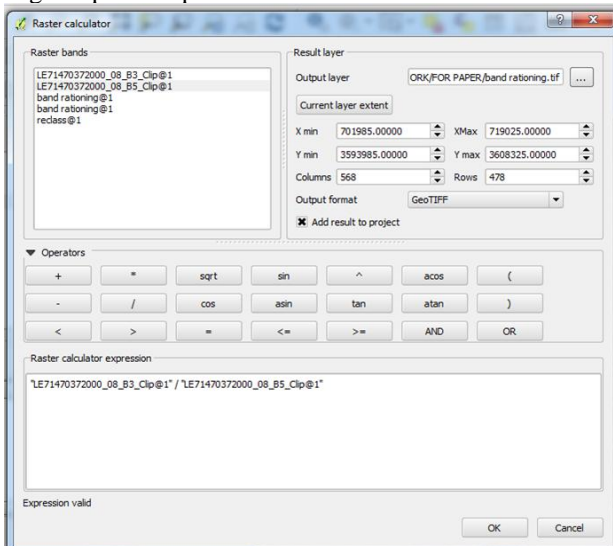


Fig. 3 Band Ratioing in Raster Calculator

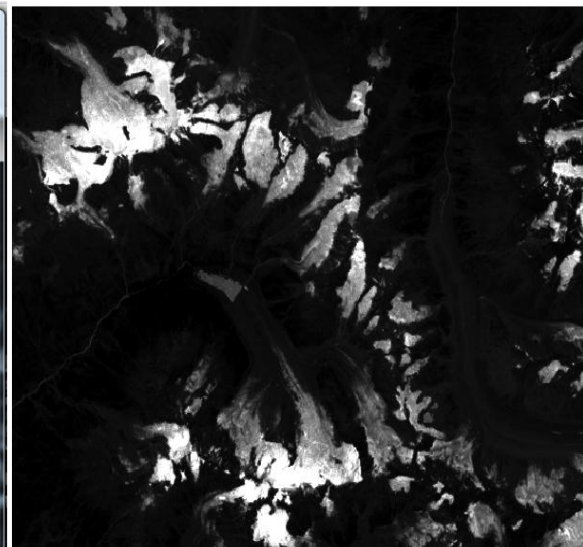


Fig. 4 Image after Band Ratioing

3.2.4 We need to remove the darker pixels, which are definitely not glaciers. This can be done by selecting a threshold value. One can check the reflectance values from properties of the layers. The values ranges between 29-190 in band 3 image, 10-94 in band 5 image and 0.64276 to 14.0602. It has been observed that pixel values between 1.8-2.2 can be considered as representing glacier ice.

3.2.5 This raster layer will be converted into vector layer using raster tool. The output file will have polygons with digital numbers (DN), in a shape file.

3.2.5 This can be further refined by opening the attribute table of the shape file. One can select and remove the DN numbers below and above a specified value.

3.2.6 The layer can be further improved in style of the property box. By graduated the number of classes can be further reduced. The final output will be polygons representing glacier outlines of the given area.

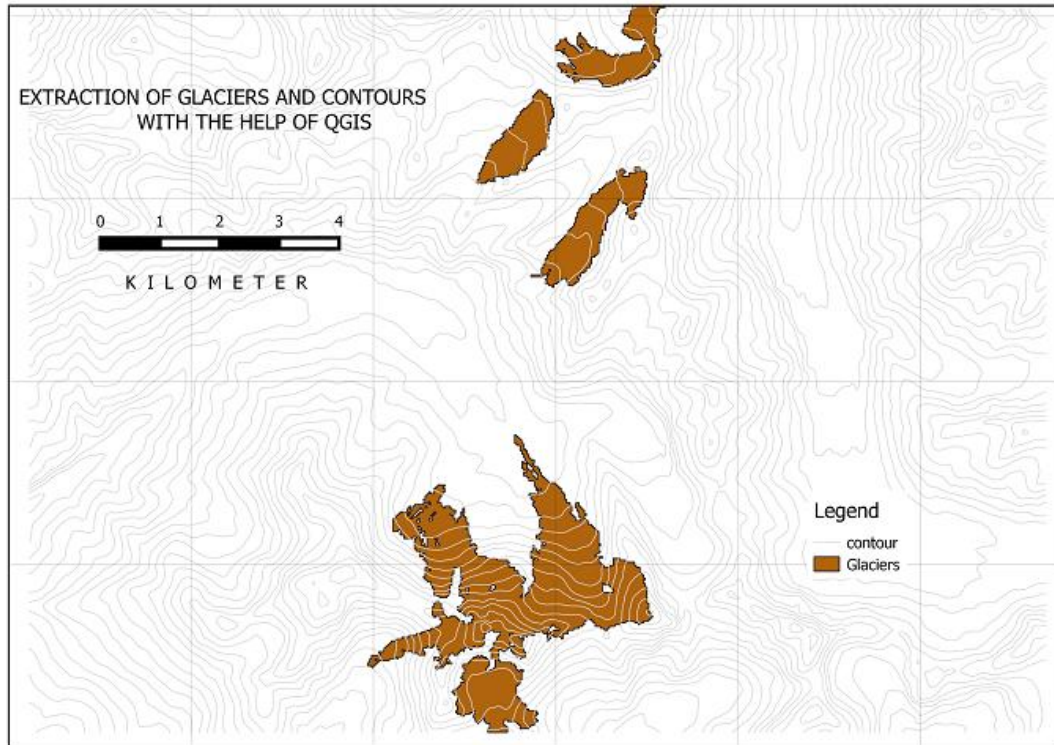


Fig. 5 Outlines of Four Selected Glaciers

IV. DRAWING OF CONTOURS

There is a plug-in named extraction in Raster Icon, by using this, contours can be drawn on a raster image. First, the raster layer is added to QGIS, then in Raster Icon → Extraction → Contour is selected. A new window of contour extraction will open. The raster layer is selected and the interval is assigned. A new file name may be suggested to save the exercise.

V. ESTIMATION OF ICE VOLUME IN A GLACIER

There are various methods used by different scholars to estimate the ice volume of a glacier ice. V–A scaling has been the most frequently used approach for ice volume estimations so far. Ice volume is calculated as a function of surface area, as large glaciers generally tend to be thicker. Area-related scaling techniques have been extensively applied for two reasons: first, their application is simple and fast. Once the scaling parameters are determined, glacier volumes can be quickly calculated for all glaciers with a known area. Secondly, area data had been measured and compiled long before digital terrain information became available (IHCAP Training Material). The general form of V–A scaling relation is $V = c A^\gamma$; where V is the volume of ice, c and γ are scaling parameters. The equation is used in the IHCAP Training. (IHCAP – Training Workshop on Applied Glaciology (Feb 2 – 5, 2016)). The scaling parameters used are given below:

$$V = c A^\gamma$$

where V is glacier volume, A is the Area of the polygon containing glacier ice,

c and γ are constants.

c	γ
0.2055	1.360

Source : Chen and Ohmura (1990)

With help of Zonal Statistics given in Raster Plugin, area of each polygon representing glaciers are calculated. This table may be exported to excel sheet and volume is calculated using the above suggested value in the given equation (Table 1).

Table 1: Calculation of Volume of Ice and Water of a Glacier

A	c	γ	A ratio power to y	$V = c A^\gamma$ (Kiloletre)
925200	0.2055	1.36	130041044.4	26723434.62
1189800	0.2055	1.36	183081554.7	37623259.5
1279800	0.2055	1.36	202168395.3	41545605.24
7705800	0.2055	1.36	2323122531	477401680

VI. CONCLUSION

The process of extracting glacier outlines , contours and volume of ice and water using open source GIS software-QGIS is easier than in the other GIS software's. The exercise can be attempted by saving the cost of software. The present paper is simply a repetition of the exercise taught in a training course, and the technical aspects of imageries, threshold values, reclassification values etc. are not explained. The author is highly indebted to all those who are involved in the training and used the same data for this exercise

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