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Using NDSI and Band Ratio Method Snow Cover Area Detection: A Case Study

Irshad. S. Shaikh
Research Scholar, Microwave and Imaging Spectroscopy Lab, Milya College, Beed.

Sharad. G. Gaikwad
Junior Geologist, Groundwater Surveys and Development Agency, Government of Maharashtra, India.

Kailash R. Aher
Groundwater Surveys and Development Agency, Government of Maharashtra, India.

Shafiyoddin B. Sayyed
HOD, Computer Science, Microwave and Imaging Spectroscopy Lab, Milya College, Beed.

Irshad.I. kureshi
Assistant Professor, Geology Department, Deogiri College Chh. Sambhajinagar, India.

Sanjay S. Patile
Regional Water Testing Lab (G.S.D.A), Government of Maharashtra, India.

Anjum Z. Shaikh
Assistant Professor, Dept. of CS, IT and Animation, Deogiri College Chh. Sambhajinagar.

Imran.D.sayad
Assistant Professor, S.E.S. College, Sakherkheda taluka, Sindkhed Raja, Dist.Buldhana, India.

Rushikesh S. Bhalerao
Assistant Geologist, Groundwater Surveys and Development Agency, Government of Maharashtra, India.

Abstract - Glaciers are a main source of water during summer in Himalayan areas. Corresponding to the historical studies, glacier is directly affected by climate change. It is important to identify change in snow cover area (Glacier area) to identify change in glacier. Remote sensing and GIS technology are used to monitor Snow covered area. This paper focuses on Sentinel-2B data of trisul glacier which is a part of Indian Himalayas to identify glacier. These multispectral images were extracted from USGS Earth Explorer. The sentinel-2B data are processed using Semi automated Classification Plugin (SCP) of QGIS tool. Snow covered area is identified by using two automated methods: Normalized Difference Snow Index (NDSI) and Band Ratio. For NDSI reflectance of visible, shortwave band is used. For Band Ratio reflectance of near infrared, shortwave infrared band is used. It is challenging to detect snow covered area from the satellite as snow covered area and cloud area have same white colure i.e. same reflectance. In this paper, represents experiments on two methods for snow area extraction on satellite images.

Keywords: Glacier, Band Ratio, Geospatial, NDSI, QGIS.

I. INTRODUCTION

A term geospatial achieve more popularity in a recent time and it defines collective data, related method, also. Geospatial data play a key role in analysing and visualizing spatial data. The important challenge nowadays is to understand, to handle and to model the data if there are too many or too few of them. Significant problems arise while dealing with large databases or a long period of observation

[1]. Information retrieval methods and algorithms used

Remote sensing to analyse geospatial data which is a part of geospatial analysis [2].

Remote sensing is an important part of geospatial technology that is used for environmental impact assessment process. Geospatial tool issued in many applications like air, water, land, etc., resource monitoring, and change detection.

A change in climate is a main reason of natural disasters which is observed by using geospatial data. Out of many phenomenon's, glaciers are directly affected by climate change. Glaciers are one amongst the foremost landforms

That represent the frozen sort of water on earth. Glacier out line are vital for various application inside glaciology. This contains glacier area change analysis [3], [4], [5], determining glacier velocity [6], [7], [8], volume modification estimations [9] and input and validation information in glacier modeling [10], [11].

II. RELATEDWORK

Till date, many methods are adopted for glacier detection such as NDSI and band Ratio. It is used to analyse visual content in snow processes. The standard technique to estimate environmental snow is to physically observe the snow cover. It is monitor with in a

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network of ground based Meteorological stations. Snow literature delivers particular Information about seasonal snow cover. Although, the spatial scale of this data is insufficient. In 19th and 20th centuries, Snow Water Equivalent (SWE) and Snow Covered Area (SCA) were keen about field assessment [14]. In 20th century, the complete global scales measured effectively by SCA and SWE. It uses images of active and passive satellites [15].

Haq et.al [16] is proposed a study on glacier monitoring using satellite images. In this paper, multispectral Landsat images taken as a source images and generate outputimages. The results of glacier mass balance were attained using Accumulation Area Ratio (AAR) and Band ratio method. The research work has shown an overall reduction in glacier area during the study period. Overall, this paper discusses in context of decrease in glaciers amount in a particular study period. Kulkarni et.al [13] has suggested their research work related to

monitoring snow cover by spectral reflectance to develop Normalized Difference Snow Index (NDSI). This proposed idea is based on the low reflectance in the SWIR region and high reflectance of a win specific visible region.

In development of NDSI and Band Ratio method reflectance value is used. The study is focused on snow covered area identification.

The Normalised Difference Snow Index (NDSI) is essential for detecting snow cover in various environments and is key for managing water resources and assessing avalanche risks. It utilizes unique spectral characteristics of snow and ice to distinguish them from other surface features.

METHODOLOGY

The classification and change detection approach used to determine snow cover changes with the aid of unsupervised classification methods is presented in Fig. 3. Firstly, Landsat satellite images were subjected to image preprocessing (geometric, radiometric, and atmospheric correction) processes according to the study flowchart. Then, atmospherically corrected Landsat satellite images were used to obtain snow cover areas using three different unsupervised classification methods (R/SWIR, NIR/SWIR, and NDSI). Finally, comparative analysis of the classification methods was performed and the snow cover area change was evaluated.

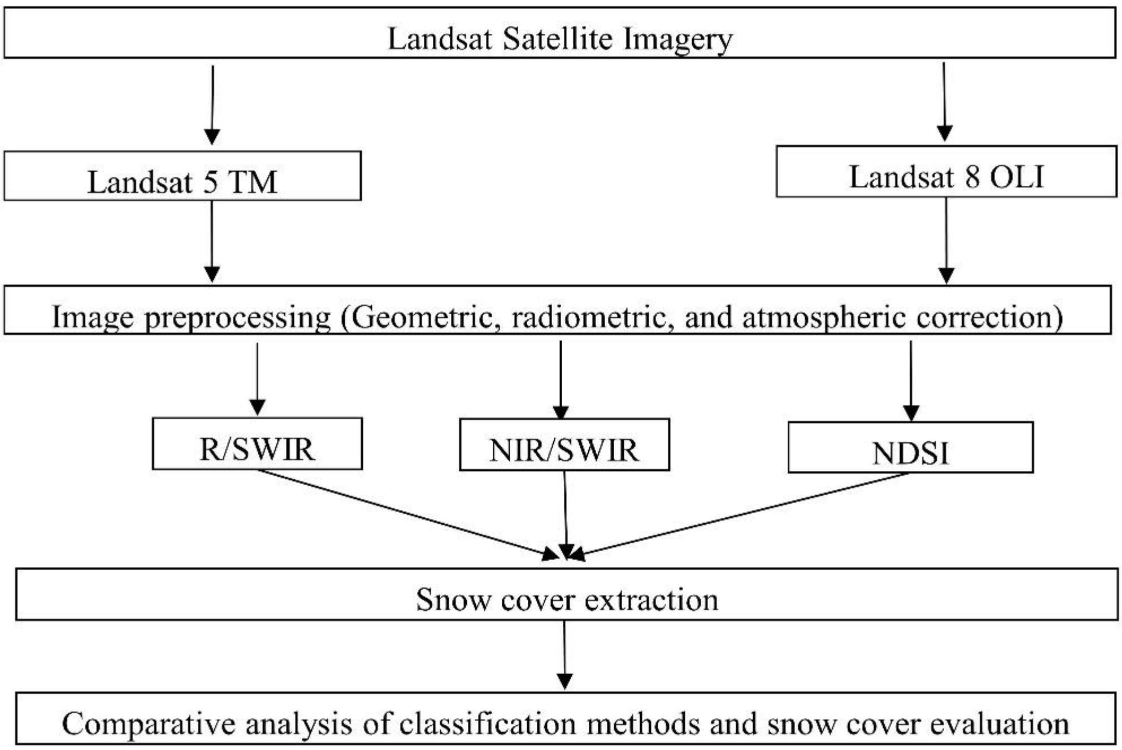

Fig: Flowchart of study

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Image Processing

Initially, a study area was created from the peak to the mountain's slopes. The study area boundaries were used for all satellite data. Geometric correction, one of the image pre-processing stages, aims to align and rectify the image data to represent the geographic features and spatial relationships accurately. This process is carried out using ground control points (GCPs), which are known coordinates located at the same geographic position in both the reference image and the image to be transformed. These GCPs are evenly distributed across the image [29]. The geometric correction process resulted in a root mean square error (RMSE) value of 0.1 pixels in this study.

In change detection studies, it is significant to prefer satellite images with identical spatial and radiometric resolution to reduce errors caused by factors such as variations in sun angle, seasonal differences, or the satellite's position when using images from different years. Therefore, radiometric correction should be performed. This was achieved by transforming pixel brightness values of satellite images to spectral radiance values. Later, Spectral radiance values were processed using the FLAASH atmospheric correction in ENVI 5.3 software. This approach was implemented to effectively eradicate influences from reflected energy.

In this study, three different unsupervised image classification methods (R/SWIR, NIR/SWIR, and NDSI) were used to investigate which method would determine the snow cover most accurately.

Red/Shortwave Infrared Band Ratio

The Red / Shortwave infrared (R/SWIR) band ratio is an effective unsupervised classification method used to determine snow cover. This ratio is calculated by comparing the reflectance values of the red (R) and shortwave infrared (SWIR) bands. The formula is as Equation 1 follows

$$\text{Band Ratio}_1 = \frac{R}{SWIR} \qquad (1)$$

The reflectance values in Landsat 5 TM bands 3 and 4 are denoted as R and SWIR. In Landsat 8 OLI, Band 4 and 5 correspond to R and SWIR because of the spectral bandwidth match. Snow shows high reflectance in the R band and low reflectance in the short-wave infrared. Therefore, this ratio is an effective tool for determining snow cover

Near Infrared/Shortwave Infrared band ratio

The Near infrared / shortwave infrared (NIR/SWIR) band ratio is another effective unsupervised classification method for determining snow cover. This ratio is calculated by comparing the reflectance values of the near-infrared (NIR) and short-wave infrared (SWIR) bands. The formula is as Equation 2 follows

$$\text{Band Ratio}_2 = \frac{NIR}{SWIR} \qquad (2)$$

NIR and SWIR denote the reflectance values in Landsat 5 TM bands 4 and 5. Because of the spectral bandwidth match, the values for bands 5 and 6 correspond to NIR and SWIR in Landsat 8 OLI. Snow shows high reflectance in the NIR band and low reflectance in the SWIR band. This feature helps to distinguish snow cover from other surface types. Wang, Wang [16] used this method for snow cover mapping in dense coniferous forests. They emphasized that this method is one of the most effective methods used in snow cover mapping studies.

Normalized Difference Snow Index

Normalized Difference Snow Index (NDSI) is one of the important unsupervised classification methods used to determine snow cover areas thanks to the wide-area observations provided by remote sensing data. NDSI is calculated with the reflectance values of the green band (G) and SWIR bands. The formula is as Equation 3 follows

$$\text{NDSI} = \frac{(G-SWIR)}{(G+SWIR)} \qquad (3)$$

Normalized Difference Snow Index (NDSI) Purpose: To identify and map snow-covered areas. Snow reflects visible light strongly but absorbs shortwave infrared light, which NDSI exploits to differentiate snow from clouds and other surfaces. Formula:\(NDSI=\frac{(\text{Green}-\text{Shortwave\ Infrared})}{(\text{Green}+\text{Shortwave\ Infrared})}\)It uses the reflectance values from the green (visible) and shortwave infrared (SWIR) bands of a satellite image. Applications: Hazard mitigation, water resource management, weather forecasting, and climate change research.

$$\circ\ NDSI = \frac{(\text{Green} - \text{Shortwave Infrared})}{(\text{Green} + \text{Shortwave Infrared})} \qquad (4)$$

Other "NDSI" acronyms

Normalized Difference Salinity Index: Used in remote sensing to estimate salinity levels in water bodies by analysing red and near-infrared light reflectance.

Normalized Difference Soil Index: Used to map soil properties.

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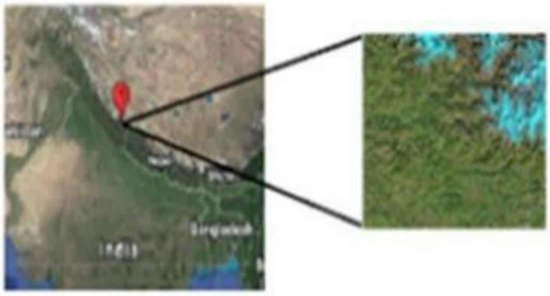

Fig. 1: study area shown as the coverage of sentinel-2B in

Uttarakhand, Trisul (Path Row: 145-039)

STUDYAREA

The area used for this study is located in Bageshwar, Uttarakhand, India bounded between 30°18′46 N and79°46′38E. Trisul is in a mountain area with a group of glaciers. The prominence of Trisul glacier is 1616 m long, and elevation of the Trisul is 7120m. The location of the research area is shown in the above Fig.

METHODOLOGY

The main use is to detect the snow from the neighbouring land with the help of band ratio and normalised difference.

Snow index. Then, for accurate glacier classification threshold

Value is chosen.

A. Software Used

To detect a snow accurately from the image Quantum Geographic Systems (QGIS) is mostly used. It is a free and open source tool that supports analysis and processing of geospatial information, and visualization. This kind of GIS gives user the flexibility of using different layers above each other. The QGIS 3.22 version is used in this paper for experimental simulations.

B. Data Required

In this paper, operations are evaluated on standard dataset ‘sentinel-2B’. The satellite images are available from https://earthexplorer.usgs.gov website which is freely available. The experiments are first listed and evaluated in QGIS using NDSI and Band Ratio. During experiment different bands of satellite image was used. The detail of bands is mentioned in Table 1.

Table I: Specification of images used in study

Sensor	Spectral Bands	Spectral Result	Swath Width (km)	Date of acquisition
MSI (Multispectral Image)	Band 4 – Red	10	31	23 November 2017
	Band8 –NIR	10	106	
	Band11 –SWIR	20	91	

EXPERIMENT

To find glaciers using NDSI and Band Ratio, following satellite Sentinel band 4, band 8 and band 11images are used to get output.

Fig. 2: band 3 sentinelimage

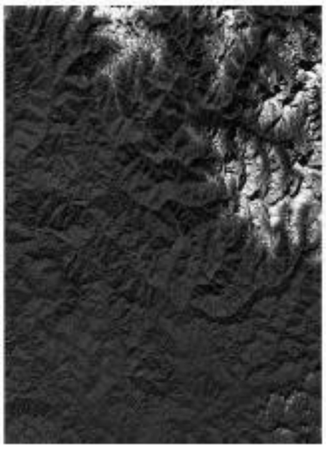

Fig.3:band8 sentinel image

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Fig. 4: band 11 sentinelimage

Fig. 5: NDSIoutput image

Fig. 6: NDSI output after applied threshold value

These three images of band 4, band 8 and band 11 are added into raster layer of QGIS. After that using raster calculator NDSI and Band Ratio is calculated.

Normalized Differential Snow Index (NDSI)

In a mountain area, snow mapping is difficult because of cloud cover and shadows

This problem can be solved not fully but partially using the Normalised Differential Snow Index (NDSI). Snow of NDSI is reflective in the visible part more and absorptive in the short-wave infrared. IN normalisation, all values are between -1 and 1. NDSI was calculated using the following formula:

$$NDSI = \frac{\text{Reflactance of GREEN} - \text{Reflactance of SWIR}}{\text{Reflactance of GREEN} + \text{Reflactance of SWIR}}$$

Area of snow/ice cover area is highlighted using GREEN and SWIR band which is applied in NDSI. In the below image indicates area of snow/ ice cover as positive value.

White area indicates snow/ice cover area. QGIS is used for applying above formula with threshold value to classify snow area.

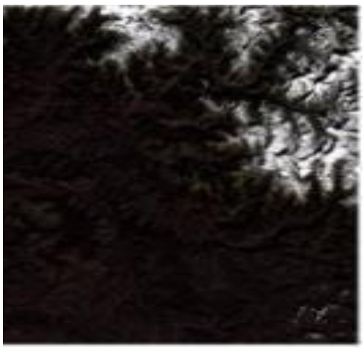

Fig. 7: NDSI modified colour image

In image bright area represent area office covered because a bright pixel indicates ice covered region. A dark pixel does not represent glaciers. By selecting a threshold value, dark pixels can be removed.Kulkarnietal. Explain threshold value for detecting snow is above 0.4 [13]. Band 4 image pixels value range is between 1 and 0.0158. Band 11 image pixels value between 1 and 0.0001. The output image pixel value range is between 0.736286 and 0.998055. From the observation, an estimation of NDSI between -1 and 1 [17] represents glacier ice. A better understanding is accomplished by exploring the histogram of NDSI method is given beneath:

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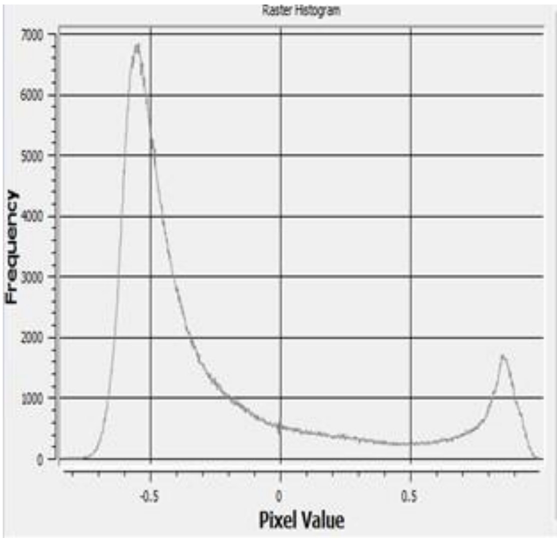

Fig. 8. : Histogram of NDSI method output image

From this raster histogram analysis, it can be considered that the calculation is done correctly due to the pixel values lying between -1 and 1. In this histogram, strong negative pixel values of NDSI indicate cloud-free pixels. The range of cloud value pixels is between -0.1 and +0.2. Under 0.20 pixel values are considered 'non-snow' pixels as considered and high pixel values are considered as snow pixels.

Band Ratio

Using remote sensing methods mapping area of snow covered is a challenging task. The reason for that is a glacier surface has a same reflectance as cloudy area into visible to

near infrared area. Subsequently, at some point, NDSI is not utilised effectively for snow mapping. Thus, for glacier mapping, another method was produced that is band ratio. It is a semi-automated technique used in glacier study. The two groups of bands are used Near Infrared (NIR) and Short Wave Infrared (SWIR). These two bands discriminate snow/ice surface accurately in a shadow area [18].The interpretation of image is done effortlessly by using near infrared and visible band data that is main advantage of these two bands [19]. Following formula is used to estimate band ratio for snow/ice cover area highlighting

$$\text{Band Ratio} = \frac{\text{NIR}}{\text{SWIR}} \quad (5)$$

$$\text{Band Ratio} = \frac{\text{Band 8}}{\text{Band11}} \quad (6)$$

Fig. 9. Band Ratio output image

Fig. 10. NDSI output image after applied threshold value

Fig. 11. Band Ratio modified colour image

Spectral response is high for snow in band 8 while band 11 has low. Dark brown represent Vegetation while bright white represent snow area in above Figure 11 see clearly. Output of image before applying threshold and after threshold is also clearly show in Figure 9 and Figure 10. Mapping clean snow/ ice threshold of band ratio is a best

Approach and it performs better than NDSI. QGIS tool is used to calculate band ratio image. Band 8 image pixels value range is between 0.22 and 0.837.Band11image pixels value between 0.015 and 0.410. Output image pixel value range is between 0.167 and0.975.

As Discussed for NDSI histogram, for Band Ratio histogram is explored in Fig.12. In raster histogram pixel value range is between 0.167 and 0.975. The range of cloud value pixels are between -0.1 and +0.2 range. Under 0.20 pixels value are 'non snow' pixels as considered and high pixels are considered as snow pixels.

Capitalize only the first word in a paper title, except for proper nouns and element symbols. For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation[8].

CONCLUSION

The research work demonstrates that sentinel data are useful in extracting snow cover area because of its resolution and spatial quality. In comparison with visible band and near infrared band, snow is more reflected in infrared band. Thus, in this paper two methods are computed that includes NDSI and Band ratio. This is used to compute snow mask from image. This threshold of both methods is helpful to get accurate snow cover area with less shadow effect in image. Finally we summarize that both methods NDSI and Band ratio provides as an aid to the analysis of snow from image.

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Declarations

Competing interests

The authors declare no competing interests.

REFERENCES

[1] Ahmadianfar I, Shirvani- Hosseini S, He J, Samadi- Koucheksaraee A, Yaseen ZM (2022) An improved adaptive neuro fuzzy inference system model using conjoined metaheuristic algorithms for electrical conductivity prediction. Sci Rep 12:4934. https://doi.org/10.1038/s4 1598-022-08875-w

[2] Araji MT, Waqas A, Ali R (2024) Utilizing deep learning towards real-time snow cover detection and energy loss Estimation for solar modules. Appl Energy 375:124201. h t t p s : / / d o i . o r g / 1 0 . 1 0 1 6 / j . a p e n e r g y . 2 0 2 4 . 1 2 4 2 0 1

[3] Arslan AN, Akyürek Z (2019) Special issue on remote sensing of snow and its applications. Geosciences 9:277. https://doi.org/10.3390/ge osciences9060277

[4] Aydar E, Şen E, Sarıkaya MA, Kuzucuoğlu C (2019) In the footsteps of Strabon: Mount Erciyes Volcano—

[5] The roof of central Anatolia and Sultansazliği basin. In: Kuzucuoğlu C, Çiner A, Kazancı N (eds) Landscapes and landforms of Turkey. Springer International Publishing, Cham, pp 565–576.

[6] Bar S, Parida BR, Pandey AC (2020) Landsat-8 and Sentinel-2 based forest fire burn area mapping using machine learning algorithms on GEE cloud platform over Uttarakhand, Western himalaya. Remote Sens Applications: Soc Environ 18:100324. https://doi.org/10.1016/j.rs ase.2020.100324https://doi.org/10.1016/j.rsase.2020.100324

[7] Benesty J, Chen J, Huang Y, Cohen I (2009) Pearson correlation coefficient. In: Cohen I, Huang Y, Chen J,

[8] Benesty J (eds) Noise reduction in speech processing. Springer, Berlin Heidelberg, Berlin, Heidelberg, pp 1–4

[9] Bormann KJ, Brown RD, Derksen C, Painter TH (2018) Estimating snow-cover trends from space. Nat Clim Change 8:924–928. https://doi.org/10.1038/s41558-018-0318-3

[10] Burns P, Nolin A (2014) Using atmospherically-corrected Landsat imagery to measure glacier area change in the cordillera Blanca, Peru from 1987 to 2010. Remote Sens Environ 140:165–178. h t t p s : / / d o i . o r g / 10 . 1 0 1 6 / j . r s e . 2 0 1 3 . 0 8 . 0 2 6

[11] Gaur MK, Goyal R, Saha D, Singh N, Shekhar S, Kumar A, Benesty J, Chen J, Huang Y, Cohen I (2009) Pearson correlation coefficient. In: Cohen I, Huang Y, Chen J, Benesty J (eds) Noise reduction in speech processing. Springer, Berlin Heidelberg, Berlin, Heidelberg, pp 1–4

[12] Bormann KJ, Brown RD, Derksen C, Painter TH (2018) Estimating snow- cover trends from space. Nat Clim Change 8:924–928. https://doi.org/10.1038/s4 1558-018-0318-3.

[13] Burns P, Nolin A (2014) Using atmospherically-corrected Landsat imagery to measure glacier area changein the cordillera Blanca, Peru from 1987 to 2010. Remote Sens Environ 140:165–178. h t t p s : / / d o i . o r g / 10 . 1 0 1 6 / j . r s e . 2 0 1 3 . 0 8 . 0 2 6

[14] Gaur MK, Goyal R, Saha D, Singh N, Shekhar S, Kumar A, Chauhan JS (2022) The Estimation of snow cover distribution using satellite data in the cold arid leh region of Indian himalaya. Pol J Environ Stud 31:63–73. https://doi.org/10.15244/pjoes/135606

[15] Gunen MA (2022) Performance comparison of deep learning and machine learning methods in determining wetland water areas using EuroSAT dataset. Environ Sci Pollut Res 29:21092–21106. h t t p s : / / d o i . o r g / 10 . 1 0 0 7 / s 1 1 3 5 6 - 0 2 1 - 1 7 1 7 7 - z

[16] Hicks A, Notaroš BM (2019) Method for classification of snowflakes based on images by a Multi-Angle snowflake camera using convolutional neural networks. J Atmos Ocean Technol 36:2267–2282. h t t p s: // d o i. o r g / 1 0. 1 1 7 5 / j t e c h - d - 1 9 - 0 0 5 5. 1

[17] Ihlen V, Zanter K (2019) Landsat 8 (L8) data users handbook. h t t p s : / / w w w . u s g s . g o v / m e d i a / fil e s / l a n d s a t - 8 - d a t a - u s e r s - h a n d b o o k. Accessed 6 May 2024.

[18] Jun S, Lansey KE (2023) Convolutional neural network for burst detection in smart water distribution systems. Water Resour Manage 37:3729–3743. https://doi.org/10.1007/s1 1269-023-03524-x.

[19] Kesikoglu MH (2024) Evaluating Spatial resolution enhancement on impervious surface detection using support vector machine. Res Des 1:33–42. h t t p s : / / d o i . o r g / 1 0 . 1 7 5 1 5 / r e d e 2 0 2 4 - 0 0 3 b u 1 1 1 1 r s

[20] Kesikoglu MH, Atasever UH, Özkan C (2016) The usage of Rusboost boosting method for classification ofimpervious surfaces. Int Arch Photogramm Remote Sens Spat Inf Sci XLI- B7:981–985. h t t p s : / / d o i . o r g/ 1 0 . 5 1 9 4 / i s p r s - a r c h i v e s - x l i - b 7 - 9 8 1 - 2 0 1 6

[21] Kesikoglu MH, Ozkan C, Kaynak T (2021) The impact of impervious surface, vegetation, and soil areas on land surface temperatures in a semi-arid region using Landsat satellite images enriched with Ndaisi method data. Environ Monit Assess 193:143. https://doi.org/10.1007/s10661-021-08916-3

[22] Kulkarni AV, Rathore BP, Singh SK, Ajai (2010) Distribution of seasonal snow cover in central and Western himalaya. Ann Glaciol 51:123–128. https://doi.org/10.3189/172756410791386445

[23] LeCun Y, Bengio Y, Hinton GE (2015) Deep Learn Nat 521:436–444. https://doi.org/10.1038/nature14539

[24] Lee C-Y, Gallagher PW, Tu Z (2016) Generalizing pooling functions in convolutional neural networks: Mixed, gated, and tree. 19th International Conference on Artificial intelligence and statistics, pp 464–472

[25] Lillesand T, Kiefer RW, Chipman J (2015) Remote sensing and image interpretation. Wiley Module F (2009) Atmospheric correction module: Quac and flaash user's guide. h t t p s : / / w w w . n v 5 g e o s p a t i a l s o f t w a r e . c o m / p o r t a l s / 0 / p d f s / e n v i / fl a a s h m o d u l e . p d f. Accessed 23 May 2024

[26] Nagajothi V, Priya MG, Sharma P (2019) Snow cover Estimation of Western Himalayas using Sentinel- 2 high Spatial resolution data. Indian J Ecol 46:88– 93.

[27] Paul F, Kääb A (2005) Perspectives on the production of a glacier inventory from multispectral satellite data in Arctic Canada: Cumberland Peninsula, Baffin Island. Ann Glaciol 42:59–66. h t t p s : / / d o i . o r g / 1 0 . 3 1 8 9/ 1 7 2 7 5 6 4 0 5 7 8 1 8 1 3 0 8 7

[28] Pellikka P, Rees WG (2009) Remote sensing of glaciers: techniques for topographic, Spatial and thematic mapping of glaciers. CRC Racoviteanu AE, Arnaud Y, Williams MW, Ordonez J (2008) Decadal changes in glacier parameters in the cordillera Blanca, Peru, derived from remote sensing. J Glaciol 54:499–510. h t t p s : / / d o i . o r g / 1 0 . 3 1 8 9 / 00 2 2 1 4 3 0 8 7 8 5 8 3 6 9 2 2

[29] Samadi-Koucheksaraee A, Chu X (2024) Development of a novel modeling framework based on weighted kernel extreme learning machine and ridge regression for streamflow forecasting. Sci Rep 14:30910.
https://doi.org/10.1038/s41598-024-81779-z

[30] Samadi-koucheksaraee A, Ahmadianfar I, Bozorg- Haddad O, Asghari-pari SA (2019) Gradient evolution optimization algorithm to optimize reservoir operation systems. Water Resour Manage 33:603–625.
https://doi.org/10.1007/s1 1269-018-2122-2

[31] Sara U, Akter M, Uddin MS (2019) Image quality assessment through FSIM, SSIM, MSE and PSNR—a comparative study. J Comput Commun 7:8–18. https://doi.org/10.4236/jcc .2019.73002

[32] Sarıkaya M, Çiner A, Zreda M (2003) Late quaternary glacial deposits of the Erciyes volcano. Yerbilimleri. Sellami EM, Rhinane H (2023) A new approach for mapping land Use / land cover using Google Earth engine: A comparison of composition images. The international archives of the photogrammetry remote

[33] sensing and Spatial information sciences XLVIII-4/W6-2022. 343–349. h t t p s : / / d o i . o r g / 1 0 . 5 1 9 4 / i s p r s - a r c h i v e s - x l v i i i - 4 - w 6 - 2 0 2 2 - 3 4 3 - 2 0 2 3

[34] Siewe SS (2007) Change detection analysis of the landuse and landcover of the fort Cobb reservoir watershed.
Oklahoma State University

[35] Sood V, Singh S, Taloor AK, Prashar S, Kaur R (2020) Monitoring and mapping of snow cover variability using topographically derived NDSI model over North Indian Himalayas during the period 2008–19.
Appl Comput Geosci 8:100040.
https://doi.org/10.1016/j.acags.2020.100040

[36] Tercan E, Atasever UH (2021) Effectiveness of autoencoder for lake area extraction from high-resolution RGB imagery: an experimental study. Environ Sci Pollut Res 28:31084–31096. h t t p s : / / d o i . o r g / 1 0 . 1 0 0 7 / s 1 1 3 5 6 - 0 2 1 - 1 2 8 9 3 - y

[37] Turan SC, Cengiz MA (2022) Ensemble learning algorithms. J Sci Arts 22:459–470. h t t p s : / / d o i . o r g / 1 0 . 4 6 9 3 9 / j . s c i . a r t s - 2 2 . 2 - a 1 8

[38] Wang Y, Su J, Zhai X, Meng F, Liu C (2022) Snow coverage mapping by learning from Sentinel-2 satellitemultispectral images via machine learning algorithms. Remote Sens 14:782.
h ttp s : / / d o i . o r g / 1 0 . 3 3 9 0 / rs 1 4 0 3 0 7 8 2

[39] Xu Y, Liu Y, Jiang Z, Yang X, Wang X, Zhang Y, Qin Y (2022) Improved convolutional neural network and its application in Non-Periodical runoff prediction. Water Resour Manage 36:6149–6168. h t t p s : / / d o i . org / 1 0 . 1 0 0 7 / s 1 1 2 6 9 - 0 2 2 - 0 3 3 4 6 - 3

[40] 1.Kanevski, M., A. Pozdnukhov, and V. Timonin,"Machine learning Algorithms for geospatial data. Applications and software tools", International Congress on Environmental Modelling and Software,(2008), Vol. 4, pp. 320-327,2008.

[41] Kumar, Uttam,"Algorithms For Geospatial Analysis Using Multi-Resolution Remote Sensing Data.",PhD diss., G25135,2014.

[42] Nuth,Christopher,JackKohler,MaxKönig,AngelavonDeschwanden, Jon Ove Methlie Hagen et al., "Decadal changes from a multitemporal glacier inventory of Svalbard.", The Cryosphere ,Vol. 7, No.5, pp. 1603-1621,2013.

[43] Bajracharya, SamjwalRatna, Sudan Bikash Maharjan, and FinuShrestha,"The status and decadal change of glaciers inBhutan from the 1980s to 2010 based on satellite data.", Annals ofGlaciology, Vol. 55, No. 66, pp. 159-166, 2014.

[44] 5. Shangguan, Donghui, Shiyin Liu, Yongjian Ding, Lizong Wu, Wei Dengetal., "GlacierchangesintheKoshiRiverbasin,centralHimalaya, from 1976 to 2009, derived from remote-sensing imagery.", Annals of Glaciology, Vol. 55, No. 66, pp. 61-68,2014.

[45] Berthier, Etienne, H. Vadon, David Baratoux, Yves Arnaud, C. Vincent etal.,"Surfacemotionofmountainglaciersderivedfromsatelliteoptical imagery.", Remote Sensing of Environment, Vol. 95, No. 1, pp. 14-28, 2005.

[46] Kääb, A,"Combination of SRTM3 and repeat ASTER data for Deriving alpineglacierflowvelocitiesintheBhutanHimalaya.",RemoteSensing of Environment, Vol. 94, No. 4, pp. 463-474,2005.

[47] Luckman, Adrian, Duncan J. Quincey, and D. Benn, "Quantification of Everest region glacier velocities between 1992 and 2002, using satellite radar interferometry and feature tracking.", Journal of Glaciology, Vol. 55, No. 192, pp. 596-606,2009.

[48] Berthier,Etienne,EricSchiefer,GarryKCClarke,BrianMenounos,and FrédériqueRémy,"Contribution of Alaskan glaciers to sea-level rise derived from satellite imagery.", Nature Geoscience, Vol. 3, No. 2, pp. 92,2010.

[49] Gardelle, Julie, Etienne Berthier, Yves Arnaud, and A. Kaab,"Regionwide glacier mass balances over the Pamir-Karakoram-Himalaya during 1999-2011 (vol 7, pg 1263, 2013).", The Cryosphere, Vol. 7, No. 6,pp. 1885-1886,2013.

[50] Rees,H.Gwyn,andDavidN.Collins.,"Regionaldifferencesinresponse of flow in glacier fed Himalayan rivers to climatic warming.", Hydrological Processes: An International Journal, Vol. 20, No. 10, pp. 2157-2169,2006.

[51] Racoviteanu, Adina E., Richard Armstrong, and Mark W. Williams., "Evaluation of an ice ablation model to estimate the contribution of melting glacier ice to annual discharge in the Nepal Himalaya.", Water Resources Research, Vol. 49, No. 9, pp. 5117-5133,2013.

[52] Based spectral reflectance to develop NDSI method for the snow cover 1- 2, pp. 73 80,2002.
Brown, Ross D., and Barry E. Goodison.,"Interannual variability in reconstructed Canadian snow cover, 1915 1992.", Journal of Climate, Vol.9, No. 6, pp. 1299-1318,1996.

[53] Frei, Allan, Marco Tedesco, ShihyanLee, James Foster, Dorothy K. Hall et al.,"A review of global satellite-derived snow products." , Advances in Space Research, Vol. 50, No. 8, pp. 1007 1029,2012.

[54] Haq, M. Anul, Kamal Jain,
India User Conference, pp. 1-8,2011.

[55] Atif, Iqra, Muhammad Ahsan Mahboob, and JavedIqbal,"Snow cover area change assessment in 2003 and 2013 using MODIS data of the Upper Indus Basin, Pakistan." Journal of Himalayan Earth Sciences,Vol. 48, No. 2, pp. 117,2015

[56] Hall, D. K., J. P. Ormsby, R. A. Bindschadler, and
reflectance zones on glaciers using Landsat
Annals of Glaciology, Vol. 9, pp. 1 5,1987.

[57] Soft Computing and Engineering (IJSCE), Vol. 1, No. 6, pp. 2231-2307,2012.