Jurnal Kejuruteraan 31(2) 2019: 215-220
https://doi.org/10.17576/jkukm-2019-31(2)-05

Glacier Mapping with Object based Image Analysis Method, Case Study of Mount Everest Region

Dhval Thanki[a*], Dippal Israni[a] & Ashwin Makwana[a]
[a]*U and P U. Patel Department of Computer Engineering,*
[a]*Chandubhai S. Patel Institute of Technology,*
[a]*Charotar University of Science and Technology, CHARUSAT*
**Corresponding author: dhaval.thanki07@gmail.com*

Received 22 February 2019, Received in revised form 7 April 2019
Accepted 17 July 2019, Available online 31 October 2019

ABSTRACT

Substantial progress in Geoinformatics System in recent years leads to the research in monitoring and mapping of glaciers. Monitoring glacier in the mountain region with traditional manual method is very crucial and time-consuming. Glaciers are melting because of global warming. Melting of glaciers can causes calamities like rising in sea level, glacial lake outburst, avalanches etc. Glacier monitoring using multi-temporal data for objects on the surface of the glacier is hard to classify. This paper gives an insight into the importance of Geo-spatial data and object-based image analysis method for satellite image processing. The object-based image analysis benefits more compared to traditional pixel-based image analysis as it is more robust and noise removing more image features etc. Spectral data with multiple bands is the backbone of surveying and monitoring of glacier. In this paper case study of Mount Everest region (27 48° 32N, 86 54° 47E) is represented. The remotely sensed image needs to be taken in a cloud-free environment. Object-based image classification is done in recognition tool. Also, the step by step methodology of object-based classification, segmentation and post-classification possibilities are discussed. Finally, the paper presents several representations of indexes. The integration of indexes is useful for accurately classifying the different part of terrain, lake, vegetation and glacier.

Keywords: Glacier Mapping; Object Based Image Analysis; Classification: Geographic information system; Geo-spatial

INTRODUCTION

Geo-Spatial data refers to the data which contains information about latitude and longitude of any location, size and shape of the earthly object, address etc. Remote sensing technology and expansion of geo-spatial data are very useful in efficient planning and strategic decision-making system (Alkathiri et al. 2017). For extracting pattern from Spatial data, it requires complex data pre-processing like radiometric and geometric transformation, feature extraction, classification and various post-processing techniques. The importance of spatial data mining is also growing with the increasing amount of geo-spatial datasets (Bogorny et al. 2010).

There are many applications of Geo-Spatial data, it can be useful in the classification of environmental data, monitoring of environmental changes, pattern recognition, land cover and land use classification, change detection using satellite images, finding crime pattern, traffic control and many others (Kanevski et al. 2008). Remotely sensed imagery with high resolution and multiple bands from satellite are used in study of land cover and land use classification in urban area or areas that are unable to reach.

The huge collection of spatial data hides the interesting patterns which is hard to find by traditional systems and data-mining. Thus, new techniques are needed to analyse spatial data for extracting interesting data, and useful patterns (Bogorny et al. 2010). Machine Learning algorithms are helpful in prediction, classification and segmentation techniques of object detection. There are many applications of machine learning algorithms like Support vector machine and k-Nearest Neighbour are useful in human gait recognition with implementing Locally Linear Embedded (Sahak et al. 2018). Complexity increases with numbers of band increase in satellite image which is known as curse of dimensionality (Kanevski et al. 2008). There are many challenges that arise while dealing with spatial data like interpolation, risk Mapping, uncertainties in modelling and prediction etc.

Geo-graphic information system (GIS) will help us to solve more environment related problems like weather forecasting, disaster prediction and monitoring global climate. Due to the global warming glaciers are melting fast and because of that sea level will increase, so monitoring glacial change is necessary. This article will focus on glacier monitoring and change detection. Specially we are focusing on the Mt. Everest region which covers wet snow, glacier lakes debris covered snow and many other glacial entity

Mountain glaciers are a natural source of fresh water and plays a major role in global climate (Kanevski et al. 2008). Therefore, it is important to study glacial dynamics and monitor change in the glacier. With help of remote sensing satellites capturing glacier movement is easy as compared to traditional methods which requires manpower and on field study, land surveys etc. Traditional methods are time consuming and dangerous.

There are two approaches for remotely sensed image analysis pixel based and object-based image analysis. Nijhwan et al. (2016) demonstrated the image analysis methods for glacier change detection (Gore et al. 2017). In comparison with the traditional pixel-based method, object-based analysis method is more accurate and also easily applicable (Nijhwan et al. 2016). Possibilities of post-processing after classification is a major advantage of object base image analysis over pixel base image analysis. Object base method is able to classify automatically between glacier ice, debris covered ice, and surface with water and also include vegetation in different classes (Nijhwan et al. 2016), Object base misses the small objects located on glacier, however pixel based separates every pixel in different class with compare to object-based approach it can accurately classify small objects on glacier. Pixel based approach has low computational time, also it covers all the detail precisely.

Classification of remotely sensed multispectral images is done at the pixel level. The pixel-based method uses the spectral band information for classification. It is based on variability of reflectance standards in each band it classifies each and every pixel (Rastner et al. 2014). Advancement in computer processing piloted the Object-based approach in image analysis (Lillwsand 2006). For accurate classification Object-based approach focuses on spectral characteristics, processing spatial information with radio-metric correction and finding shape, texture, and relationships between the various objects (Blaschke 2010). In the object-based approach, there are three main steps in processing, segmentation, and classification. At the classification level, there are several supervised machine learning algorithms like Support Vector Machine (SVM), Random Forest, K-Nearest Neighbour for supervised classification, K-means for unsupervised clasification and Regression Tree (CART) etc.

METHODOLOGY

SYSTEM DIAGRAM

In Object base image analysis method after radio-metric and geo-metric correction, Segmentation is crucial which converts group of pixels into vector objects. And accuracy of classification also depends on the segmentation. Spectral difference segmentation is used for acquiring accurate vector objects from pixels. Spectral segmentation uses the spectral mean threshold values for segmentation. In classification step derived vector classes will be classified based on the shape, size and other spectral properties. In this paper we will discuss all the steps of Object base Image analysis with comparing to our test region. After classification process results and sample both can be exported for further accuracy assessment process. Following Figure 1 represents the steps of object base image analysis. It is required to follow all the steps to acquire accurate classified image.

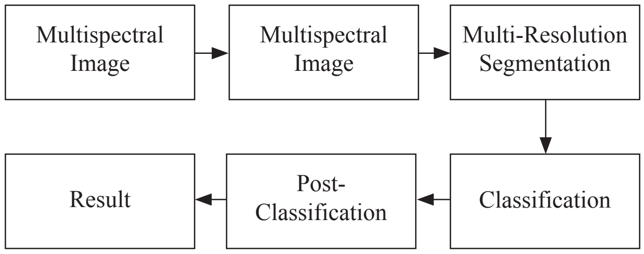

FIGURE 1. Steps of Object Based Image Analysis Method

For spectral classification with object-based image Analysis approach, Multi band images from sentinel-2, Landsat ETM+, Landsat TM and ASTER are useful, for topographic information, Digital Elevation Model (DEMs) is used. Due to its post processing possibilities no any additional inputs are required. Datasets can be divided in classes before processing. Every pixel needs to be divided into classes using threshold value, divided classes used as input to the classifiers (Nijhwan et al. 2016). Dataset images are available on USGS Earth Explorer. Dataset images were taken on 11th of September 2018. Input images needs to be in Visible and Infra-red Range of spectrum. Total 5 images from different band and same location were taken as input, Three Visible bands and 2 Infra-red bands were used to calculate various band ratio.

PRE-PROCESSING

Pre-processing step will be helpful in removing the noisy data from image or calculating the parameter which are helpful in image classification. There are two types of methods to pre-process image, radiometric and geometric. Radiometric correction will be used to enhance image parameters and geometric correction will be used for Realtime mapping of image with location. For Glacier study parameters are like slope, hill-shade are used to identify glacial objects. By calculating the statistics of input image noisy data can be removed. To remove dark object from images and to avoid dark shadows of mountains there are radiometric pre-processing method called Dark Object Subtractions. By calculating reflectance, performing normalization on image and calculating band ratio of multi band input image a such type of illumination can be avoided. On the surface of glacier there are five main entities which can be seen on spectrum of multiple sensors from satellite. These five entities are Snow, ice, water, rock, and vegetation.

For extracting snow from other surrounding, there is Normalised difference snow index (NDSI) which extract snow. NDSI uses the visible green band and Short-Wave Infrared (SWIR) band from the spectrum. It assures the whether the target captured is snow. For vegetation and water bodies there is normalised index respectively Soil Adjusted vegetation index (SAVI) and Normalised difference water Index (NDWI). In calculation of both index visible (VIS) band and Near Infrared band (NIR) requires. SAVI can be calculated with Near Infrared and visible red band from spectrum. Water index can be counted with visible red band and Near infrared band.

$$\text{NDSI} = \frac{Green - SWIR}{Green + SWIR} \quad (1)$$

$$\text{SAVI} = \frac{NIR - Red}{NIR + Red} \quad (2)$$

$$\text{NDWI} = \frac{NIR - SWIR}{NIR + SWIR} \quad (3)$$

SEGMENTATION

Segmentation is the merging of an image's pixels based on similarity into spatially continuous and separate regions (Blaschke et al. 2010). Multi-Resolution segmentation is widely used for object-based image analysis as it will fulfils all the essential requirements before classification. Multi-Resolution Algorithm for segmentation is based on texture and utilising fractal algorithms. In multi resolution algorithm, the merging decision can be taken based on local similarity criteria that describes the similarity of adjacent objects in image. A "merging cost" is allocated to each possible merge. These costs show the *degree of fitting*. For a possible merge the *degree of fitting* is evaluated and the merge is fulfilled. When there are no more possible merges the procedure stops (Blaschke et al. 2010).

For Multi resolution segmentation of pixels there are more method such as Spectral Angle Mapper and Maximum Likelihood Classifiers. here Spectral Correlation Mapper (SCM) can eliminate correlation which does not hold positive values with maintaining characteristics values of SAM. After merging all pixel based on similarity it creates object and the scale of object can be changed. Change in scale of objects will affect the classification accuracy. Scale parameter holds the actual object size from image. We can also define the weighting based on bands of input datasets. For test region scale, shape and smoothness needs to be defined. For Everest test region Scale factor is 20 and smoothness 0.5 taken. Executing segmentation process on any image is slow. But the process of segmentation and classification needs to be fast in times of disaster, crucial support and dealing with risk, so solution of this problem is Simple linear iterative clustering (SLIC) (Ovidiu 2017).

Spectral difference segmentation is merging algorithm which merges the vector objects based on Spectral mean Threshold value.

All the Parameters which are taken as input for Multi-resolution segmentation. They all are given in Table 1.

TABLE 1. Input Parameters for Multi-Resolution Segmentation

Region	Scale	Shape Parameter	Spectral Difference
Mt. Everest (Himalaya)	80 > 100	0.8 > 0.9	95

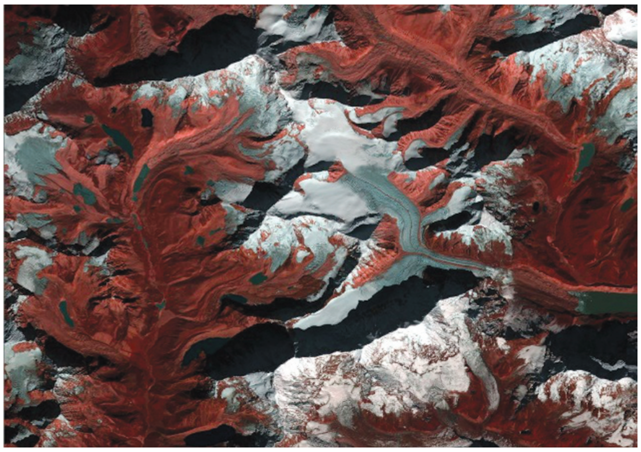

FIGURE 2. This image is Sentinel-2a image of Mt. Everest Region in Near Infra-red band

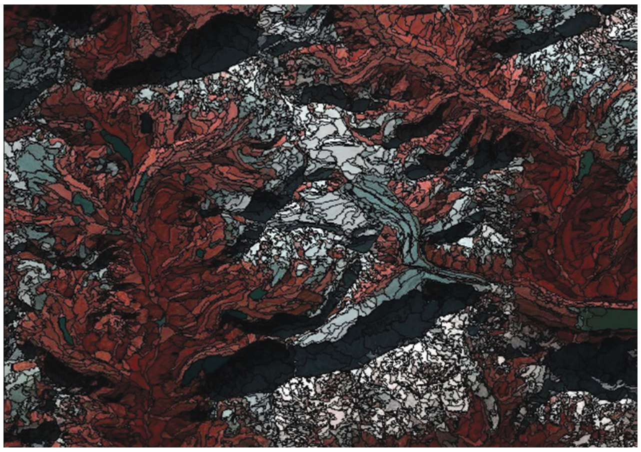

FIGURE 3. Image After Performing Multi Resolution segmentation with scale parameter of 90 and shape of 0.85

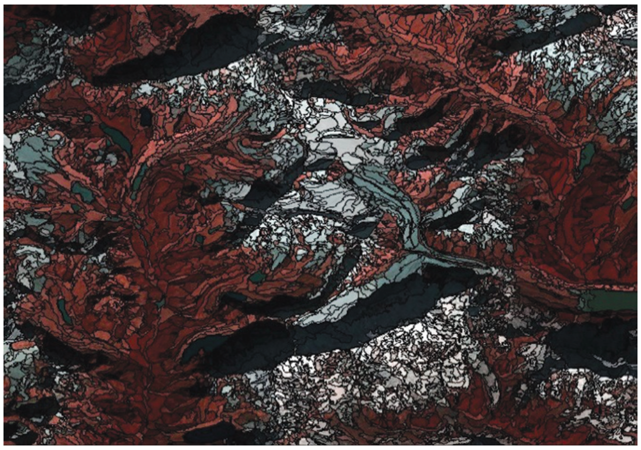

FIGURE 4. Image After Performing Spectral Difference Segmentation with max value of 95

CLASSIFICATION

Threshold values are used for classification for different classes, different threshold values are generated, and based on that threshold value classification will be done (Rastner et al. 2014). Object are assigned to the classes as per the ratio band, Objects with ratio of VIS/SWIR are allocated to "Snow and Ice" and it will exceed the mean value of threshold (Rastner et al. 2014). Threshold values are generated for particular class based on that threshold value object classification will be done. Machine Learning algorithms are used as classifiers in classification of high-resolution image (Dave et al. 2018). There are several algorithms like Support Vector Machine, Decision Tree, Naïve Bayes, K-Nearest Neighbour which are helpful in classification of glacial object. For classification setting tuning parameter and training sample both are very important for accuracy (Qian et al. 2014). In classification there are two approach, layer based and object based. In Object-based classification various objects are created from selecting sample size segments. Classification can be done using either rule-based procedure or using machine learning algorithms based on training samples (Ruiliang et al. 2011). Intent of classification is to process the whole segmented image with input of sample size and classifying pixels and segments into respected category (Purohit et al. 2017).

In this case study we have performed k-NN classification algorithm on our dataset, k-NN is one of the simplest instance-based machine learning algorithms. Object will be classified based on the majority of their votes of neighbours. Neighbours can be taken as set of objects, no other explicit training is required. For training purpose of k-NN only feature vectors with class labels are required. We have performed layer wise classification and there are four class snow, lake, vegetation, and soil. In layer-based classification accuracy of classified image is depends upon number of training sample taken for algorithm training. Thus, maximum training samples are taken for class snow because there are various types of snow, for achieving more accuracy for particular class manual sample insertion is needed. Training phase of k-NN algorithm consist of feature vectors and class labels. Here four class labels are assigned to the four classes snow, water, vegetation, soil. Colour assigned to the class labels are white for class snow 24 samples, dark blue for water 7 sample, green for vegetation, dark grey for soil 25 sample taken. All the training samples created manually by selecting Region of Interest (ROI) for different classes. After selecting training sample area source and numbers of value for k needs to be define. Executing classification on segmented images will provide objects which are assigned to the classes divided based on training samples. To the classification algorithm as a sample of various glacial entity will be assigned based on NDWI, NDSI and SAVI, based on these parameters after assigning class label like snow, water and Soil with vegetation classification with K-Nearest Neighbour will be executed. Class colour difference can be easily seen glacier as light grey and shadow cover glacier as dark grey.

TABLE 2. Sample size selected for Layer based classification

Class	Sample
Snow	24
Soil	25
Water	7

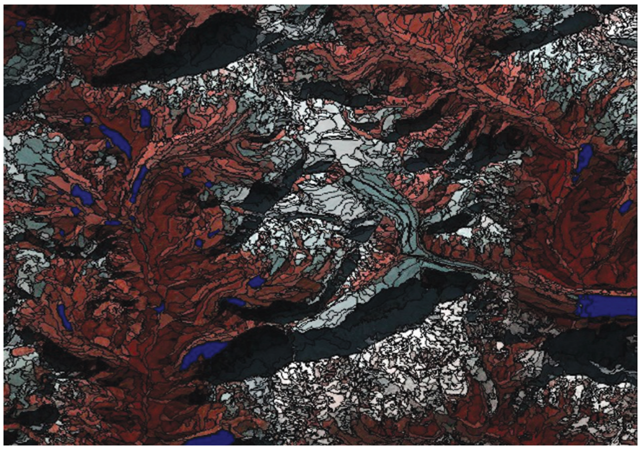

FIGURE 5. Class Water assign based on NDWI

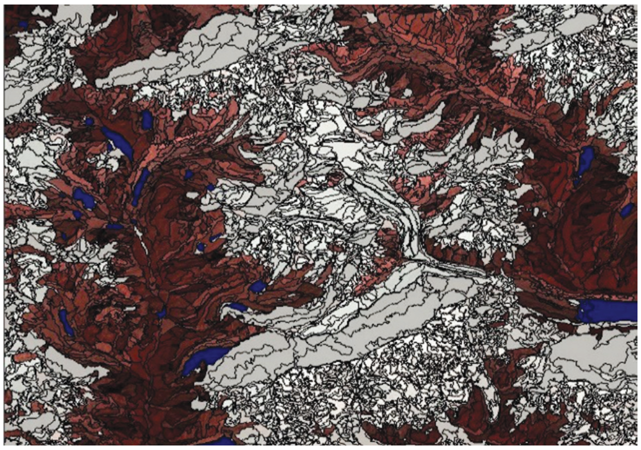

FIGURE 6. Class Snow assign based on NDSI

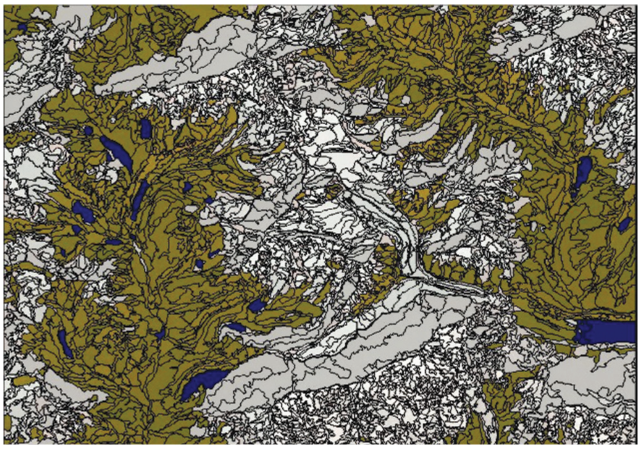

FIGURE 7. Class Soil assign based on SAVI

POST-CLASSIFICATION

Post-classification possibilities are the main advantage of object-based image analysis method. Post-classification is used to eliminate commission and omission types of error from classified image. It also has ability to merge all classified objects based on similarity of objects. Glacial objects that includes debris-covered, super-glacial lakes and other glacial entity would not be the part of mapping but they must be included, for this kind of distinctions post classification capabilities can be applied. It also generates one kind of loophole in process to classify un-classified objects by reducing threshold for appropriate input data (Rastner et al. 2014). post-classification capabilities manage neighborhood relationships and merging with neighbor classes. It eliminates dependency on additional inputs like Digital elevation Model (DEM). Also, it can export rule set classification.

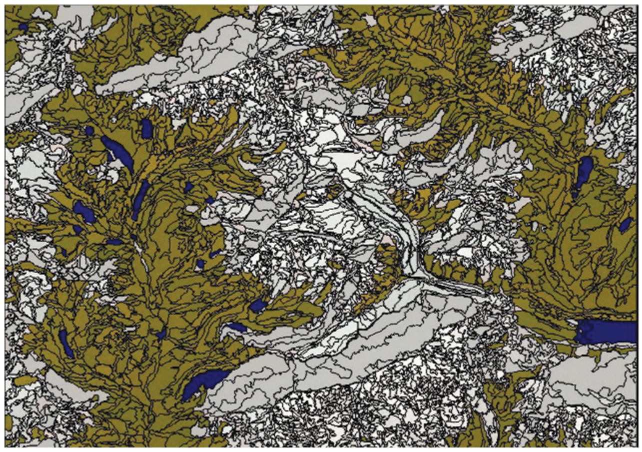

FIGURE 8. Image after merging all assigned classes to their respective sample size

RESULT AND DISCUSSION

After merging all the classified classes in output image, there is lake in blue color, glacier in white color and soil with vegetation in dark yellow. Also, we get the all three-band type of image SAVI, NDSI and NDWI. By combining all three images we can easily classify the glacial objects. Image containing SAVI will give soil and vegetation index, from same procedure we will get snow and water and after classifying all the other class soil can be classified. But there are heavy dependencies on segmentation step which is critical So choosing shape, compact factor and scale is very important as per the requirement. PBIA only outperforms OBIA in terms of identifying objects with single pixel size and processing time, object base method takes more processing time because of segmentation. Finally, we compared the Object based Classification with band ratio parameter with normal, Pixel base classification and object base classification (Rastner et al. 2014). Results we acquire were much better in band ratio methods. Error matrix was created for accuracy assessment and object-based technique produced the highest values of kappa coefficient and overall accuracy.

TABLE 3. Comparison of Object-base and Pixel-Base method in Mt. Everest Region

Methods	Overall Accuracy
Pixel Base Image Analysis	0.766
Object Base Image Analysis	0.885
Object Base Image Analysis with K-NN	0.933

CONCLUSION

This paper represented the Pixel based and Object based approaches that are well developed for satellite image classification. This paper also showcases the standard methods to investigate object-based approach on Mt. Everest region. Object based image analysis has surpassed pixel-based image analysis method in mountain regions. Results mentioned in this paper showcases that object-based method have performed well on multispectral sentinel images. In classification approach there are lots of well-established combination will give accurate results. Newly developed combinations need to be tested. Variation between ground and image illumination must be taken care of at pre-processing step. Performing radiometric correction is also challenging because of availability of data. Hyper-spectral data is also enriched with information. Also, it could provide the advantages to classification after understanding of various process and phenomena. It will give visual interpretation to the data beyond the human ability to see. Using object base image analysis method for regions which has more uncertain conditions is more efficient and accurate than pixel base method or any other traditional method. There are also Hyperspectral satellite images which has rich amount of data. It can be harvest by various machine learning algorithm and image processing techniques.

ACKNOWLEDGMENT

The authors would like to thank CHARUSAT Space Research and Technology Center (CSRTC) for providing required resources to carry out research work.

REFERENCES

Alkathiri, M., Abdul, J. & Potdar, M.B. 2017. Kluster: Application of k-means clustering to multidimensional GEO-spatial data. *International Conference on IEEE, Information, Communication, Instrumentation and Control (ICICIC) 2017*, 210.

Blaschke, T. 2001. What's wrong with pixels? Some recent developments interfacing remote sensing and GIS. *Interfacing Remote Sensing and Gis* 6: 12-17.

Blaschke, T. 2010. Object based image analysis for remote sensing. *ISPRS Journal of Photogrammetry and Remote Sensing* 65(1): 2-16.

Blaschke, T., Burnett, C. & Pekkarinen, A. 2004. *Image segmentation methods for object-based analysis and classification*. Chapter 12. Remote sensing image analysis: Including the spatial domain. Kluwer Academic Publishers.

Bogorny, V. & Shashi S. 2010. Spatial and spatio-temporal data mining. Data Mining (ICDM). *10th International Conference on IEEE International Conference on Data Mining 2010*, 1217.

Csillik, O. 2017. Fast segmentation and classification of very high resolution remote sensing data using SLIC superpixels. *Remote Sensing* 9(3): 243.

Dave, M., Ganatra, A. & Israni, D. 2017. Evaluating classifiers and feature detectors for image classification bovw model: a survey. *International Journal of Computer Engineering & Applications* 12: 1-7.

Gore, A., Mani, S. Hari, R.P.R., Shekhar, C. & Ganju, A. 2017. Glacier surface characteristics derivation and monitoring using Hyperspectral datasets: a case study of Gepang Gath glacier, Western Himalaya. *Geocarto International* 34(1): 23-42.

Kanevski, M., Pozdnukhov, A. & Timonin, V. 2008. Machine learning algorithms for geospatial data. Applications and software tools. *International Congress on Environmental Modelling and Software* 53: 320-327.

Lillesand, T., Ralph, W. & Chipman, J. 2006. *Remote Sensing and Image Interpretation*. New York, NY, USA: Wiley.

Nijhawan, R., Garg, P. & Thakur, P. 2016. A comparison of classification techniques for glacier change detection using multispectral images. *Perspectives in Science* 8: 377-380.

Pu, R., Landry, S. & Yu, Q. 2011. Object-based urban detailed land cover classification with high spatial resolution IKONOS imagery. *International Journal of Remote Sensing* 32(12): 3285-3308.

Purohit, N. & Israni, D. 2017. Vehicle classification and surveillance using machine learning technique. *International Conference on Recent Trends in Electronics, Information & Communication Technology* 2017: 910-914.

Qian, Y., Zhou, W. Yan, J., Li, W. & Han, L. 2015. Comparing machine learning classifiers for object-based land cover classification using very high resolution imagery. *Remote Sensing* 7(1) : 153-168.

Rastner, P., Bolch, T. & Paul, F. 2014. A comparison of pixel-and object-based glacier classification with optical satellite images. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 7(3): 853-862.

Sahak, R., Tahir, N.M., Yassin, A.L.M. & Kamaruzaman, F.H. 2018. Kinect-based human gait recognition using locally linear embedded and support vector machine. *Jurnal Kejuruteraan* 30(2): 235-247.