MINI REVIEW

Need of Harnessing Potential of Lichenometry for Glacier Retreat Studies in the Indian Himalayan Region

Kapil Bisht[1*], Poonam Mehta[1], Shashi Upadhyay[1], Yogesh Joshi[2]

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Abstract

In the present study an attempt has been made to attract the attention of the geologists, glaciologists and lichenologists of the world towards Himalaya. The Himalaya houses tremendous amount of eternal ice, and hence, is considered as the 'Third Pole' of earth. In the Asian Continent the Himalaya attains a very specific place and is considered as the 'Water Tower' of Asia. During recent decades the ice stored in the glaciers of Himalaya has shrunk considerably under the influence of global warming. Most of the Himalayan glaciers could not get desired field investigations due to their remoteness and unfavorable climate and are studied mostly through remote sensing based applications. In the present study, an attempt has been made to encourage the researchers to adapt lichenometry as a tool to investigate the retreat of Himalayan glaciers.

Keywords: Glacier, Indian Himalayan Region, Lichenometry, Radiocarbon.

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Introduction

The Indian Himalayan Region (IHR) comprising 12 states (Arunachal Pradesh, Assam, Himachal Pradesh, Jammu and Kashmir, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, Uttarakhand and West Bengal) of India is spread over an area of 5.3 lakh km^2 which is about 16% of country's total geographical area. It forms an arc of 2500 km length between the Indus and Brahmaputra river systems over latitudes 26°20′-35°40′ and longitudes 74°50′-95°40′. Out of the 12 Himalayan states glacier are present only in 05 states viz. Arunachal Pradesh, Himachal Pradesh, Jammu and Kashmir, Sikkim and Uttarakhand. Among the 05 states comprise 9575 glaciers which collectively cover an area of 37466 km^2 (Raina and Srivastava, 2008). About 2000 km^3 volume of ice stored in these glaciers is the perennial source of fresh water for millions of people across the country. During recent decades the Himalayan glaciers have faced rapid retreat due to warming climate and change in precipitation regime. Most of the Himalayan glaciers have retreated since the mid-19th century (Bhambri and Bolch, 2009) and have gained attention of public and scientists from across the globe (Bolch *et al.*, 2012). The Himalaya has lost about 13% of glaciated area during the last 4-5 decades (Kulkarni and Karyakarte, 2014). Studies have suggested that glaciers in the Himalaya are retreating; however, the rate of retreat is a matter of debate because the retreat rates are different for different regions (Bahuguna *et al.*, 2014). Lichenometric dating of receded moraines of glaciers can be used to estimate the recession rates of glaciers and hence in understating the temporal and spatial fluctuations (recession and advancement) of glaciers.

Lichenometry, which uses lichens to estimate the age of the substrate on which it grows, is the most frequently used technique by geologists for dating rock surface and moraine ridge on recent glacier forelands in polar and alpine regions. Lichenometry is used to estimate late-Holocene chronological events and is particularly useful in arctic-alpine environments above the tree line which are generally devoid of trees and dominated by lichens. The lichens in these environments grow very slowly and have great longevity (Armstrong, 2004), and in this region lack of suitable organic material makes other dating techniques (*e.g.*, dendrochronology and radiocarbon dating) less suitable or not possible. With various characteristics like slow growth rates, long life span , lesser requirement of nutrients , and presence of specific adaptations lichens become suitable to survive in the harsh environments on Earth (Honegger, 1998). The morphological and physiological adaptations aided with ability to change the ecological behaviour enable lichens to tolerate dessert, polar and chemically rich habitats (Armstrong, 2017).

Lichenometry is based on the fact that if the relationship between the size and age of lichens is known, then the age of a surface on which the lichens are present can be estimated from the size of the lichens (Innes, 1985). If the 'Colonization Delay' (time taken by lichen to appear on the exposed rock surface, after its exposure to environment and sunlight) and the annual growth rate of lichen is known, then the minimum date of exposure of substrate can be obtained by measuring the diameter of the largest lichen on that substrate. During the process of glacier retreat the heaps of moraines are left, which on exposure to environment and sunlight get colonized by lichens. Lichenometry can be performed via two approaches:

[1]G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora-263643, Uttarakhand, India

[2]Department of Botany, University of Rajasthan, Jaipur-302004, Rajasthan, India

***Corresponding author:** Dr. Kapil Bisht, G.B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora-263643, Uttarakhand, India; Mobile: +91-9627694404; Email: kapilkannu@gmail.com

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Indirect Lichenometry

In indirect approach, substrates of known age are required and then lichen measurements are taken on that surface (Mottershead, 1980). A correlation is established between the size of the lichen and the surface age, based on lichen measurements from surfaces of known age (Matthews, 1994). A growth curve is then constructed from the lichen sizes from surfaces of known age. In India several surfaces of known age can be found having lichens on them, like stone monuments, grave yards, churches, exposed rocks near glacial snouts that have been dated etc.

Direct Lichenometry

In direct approach measurements of lichen growth (either radial or diameter) are taken for a longer period of time. It takes several years of measurement to assess the growth rate of a particular species on a specific substrate. Growth rates of lichens may be influenced by the texture, chemical composition and microclimatic conditions of the substrate. Same lichen species can show different growth rates on different substrates. After measuring a number of lichen thalli including both smaller and large thalli a growth curve is constructed. Relatively few studies have adopted the direct approach, largely because of practical difficulties associated with the slow-growing crustose lichens that are most commonly used for dating purposes. The crustose lichens grow a few mm over the period of one decade; it becomes unfeasible to measure the growth of lichens for this much of time period. The variability in growth rates of lichens were reviewed by Bradwell and Armstrong (2007) for 13 studies. They found considerable variability in the estimated mean annual diameter growth rates of the *Rhizocarpon* subg. *Rhizocarpon* ranging from 0.08 to 1.47 mm/year. Trenbirth and Matthews (2010) monitored the diameter over 25 years for 2,795 individuals of the *Rhizocarpon* subg. *Rhizocarpon* at 47 sites on 18 glacier forelands in southern Norway. The mean annual growth rate for the 47 sites ranged from 0.43 mm/year to 0.87 mm/year. This clearly indicates that the growth rates of even a particular lichen species are not same.

Whatever the means of performing lichenometry (*i.e.*, direct or indirect) and whatever the species being used, a person can use any of the following techniques to measure lichen diameter in field for getting accurate/relative date of the exposure of the surface.

Longest Axis Measurement of the Largest Lichens

The longest axis is measured from edge to edge along the maximum diameter of the largest lichen thallus on the surface. Sometimes there is a disadvantage of this method *i.e*. on rocks where there is a good population of lichens, the thalli may overlap each other and sometimes two or several thalli can be measured as a single thallus, which can give wrong results. So the role of hypothallus is significant in delimiting the single thallus from the neighboring ones. In some studies (McCarroll, 1994) this methodology was applied. Only five or ten largest thalli measurements are necessary to estimate the age of the target surface (Innes, 1985). The measurements are generally done with ruler or tape. The measurement can also be taken on transparent sheets by directly putting the sheet over the thallus to trace the outline and then it can be measured in the laboratory.

Mean of Largest Lichens in Single Substratum

The mean of the largest lichens diameter on one substratum is assumed as the largest orbicular growth of the lichen. Few studies (Bull *et al*., 1994) have utilized the mean of the largest individual thalli at a large number of sites (defined as individual boulders); assuring that a sample of the largest lichens best characterize the lichen population. As with the use of the single largest thallus, use of the mean of largest thalli emphasizes rapid colonization and optimal microenvironments.

Size-Frequency Measurement

This method involves the measurement of very large number of lichen thalli; these measurements are used to estimate the largest thalli with maximum ages of subpopulations of lichens in the data set. This approach was applied in several studies (Benedict, 1967; Smirnova and Nikonov, 1990; Winchester and Harrison, 1994).

Percentage Cover

When lichens start colonizing the bare exposed surface, in due course of time the whole surface gets covered with many individuals of different lichen species. Percentage cover is the proportion of area of the surface covered by lichens of it. This technique allows for the inclusion of coalesced thalli in the data set that would otherwise be ignored by other techniques.

Development of Dating Curve

A 'dating curve' that is the back bone of any lichenometric investigation can be plotted against age of the surface on which the particular lichen grows. There must be a distinct positive correlation of pattern of size of thallus with the approximate age of the exposed surface.

Photographic Method

Benedict (2008) described the photographic method to monitor lichen growth. Photographs are taken over a period of time. Then with the help of Adobe Photoshop the photographs are adjusted in a way that the millimeter scale included in each photograph can be reproduced at the actual size of lichen thallus. Original and repeat photographs are viewed side by side to ensure measurements were made in the same locations. Distances are measured in pixels.

Area Measurement of Lichen Thallus

Lichen growth rates can also be calculated by measuring the area of the thallus. Rydzak (1961) traced the outlines of thalli on plastic sheets and then retraced these at a later date. The surface area of each traced thallus can be measured by a planimeter; the procedure is repeated in the next period of measurement and the increment can be calculated in mm^2.

Although lichenometry was developed in 1950s (Beschel, 1950), in India it was started in 2001. In IHR first lichenometric dating of glacial moraines was conducted on Gangotri Glacier of Uttarakhand. Study conducted by Srivastava *et al*. (2001) using lichen species *Rhizocarpon sublisidum*, *Rinodina oreina* and *Xanthoria elegans* showed the age of exposure of three moraines of Gangotri Glacier as 1782 AD, 1849 AD and 1865 AD. Awasthi *et al*. (2004) used lichen *Dimelaena oreina* for estimating

Fig. 1: Lichenometric exercise conducted on Milam Glacier moraine of Uttarakhand.

the age of moraines in Gangotri Glacier by monitoring lichen growth for three years and calculated the age of moraines as 1881 AD and 1897 AD. Chaujar (2009) studied impact of climate change on Himalayan glaciers based on the dating of lichens. He showed that the age of the largest lichen on the loop of moraine of Chorabari Glacier of Uttarakhand was 258 years. It showed the period when the Chorabari Glacier started receding from the point of its maximum advancement. Joshi and Upreti (2010) used *Rhizocarpon geographicum* to estimate the retreat of Pindari Glacier. They calibrated approximate age of the surface exposed at a distance of 1 km from the glacier snout ranged from 550 to 600 years. Bajpai *et al*. (2016) studied retreat of Kupup and Thangu area of eastern Himalaya in Sikkim and Thajiwas Glacier in Ganderbal district of north western Himalaya of Jammu and Kashmir with the help of *Rhizocarpon geographicum.* The Thajiwas glacier showed vertical retreat of 200 m in 279 years, while in Thangu and Kupup area of eastern Himalaya the vertical retreat was estimated 200 m in 100 and 91 years respectively. They observed faster recession rates in eastern Himalayan (20 mm/century) than the north-western Himalaya region (18.5 mm/century). Bisht (2018) focused on glaciers of Kumaun Himalaya for estimating their rate of recession with the help of lichenometry. Bisht *et al*. (2018a) conducted lichenometric studies on Milam Glacier in Uttarakhand using the lichen *Dimelaena oreina* and showed that the Milam Glacier has receded 1450 m in last 70 years with an average recession rate of about 20 m/year (Fig. 1). Bisht *et al*. (2018b) performed lichenometry on moraines of Adi Kailash Glacier of Uttarakhand with lichen species *Rusavskia elegans* and revealed that the glacier has receded 470 m during the last 41.37 years with an average recession rate of 11.36 m/year. Recently, Bisht *et al*. (2019) discussed the problem of cairns (how cairns affect the efficacy of lichenometric dating) in Himalayan region and suggested some control measures to overcome this issue.

The first and foremost lichenometric measurement method is to measure the diameter of the imaginary engraved circle within a lichen thallus. Since, the lichen growth rates are very crucial for any lichenometric study, it is very important to use a digital caliper instead of the normal ruler for diameter measurements of lichen thalli (Bisht *et al*. 2020). Because most of the lichens which are preferred for lichenometric studies are very slow growing; they grow with the rate of a few millimeters per year. In this case it is not possible to calculate their actual annual growth with the help of a normal ruler.

Conclusion

Most of the glaciers in IHR are very difficult to approach and due to remoteness and harsh climatic condition, working with sophisticated equipments in glaciers becomes unfeasible. To carry heavy and sophisticated equipments to glaciers is a difficult task and there is also a risk of theft and vandalism. In this context lichenometry becomes very crucial to study glacial chronology because it provides a quick, inexpensive and reliable method for rapidly dating the moraines; it is easy to perform, does not require any sophisticated equipment, is free from the risk of theft and vandalism and does not harm nature and natural resources. Looking at the number of glaciers and number of lichenometric studies done (only a few which can be counted on finger tips), it is reasonable to say that there is a wide scope for lichenometry to be applied on glaciers of IHR.

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