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# Climate change, alpine treeline dynamics and associated terminology: focus on northwestern Indian Himalaya

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**Abstract:** The study of alpine treeline as a climate marker may be used as an important indicator in mountain ecosystem dynamics. However, the terms, yardsticks and methods usually applied worldwide are not comparable among various studies. An appraisal of the relevant literature with special reference to the work by Panigrahy *et al.* (2010) in northwestern Indian Himalaya to promote and advocate adopting uniform pattern and interdisciplinary observations is attempted. It is observed that the terminological variability and the resultant confusion, variable definition of tree and treeline and their relative validation at the ground, remain major impediment in developing standardized and quantitative assessment protocols of treeline dynamics as a precise climate change response. This situation has resulted in generating differential reliability in treeline study from local to the global level. In order to address this issue ecologically compatible terminology and UNESCO standard sampling methodology has been proposed. It is also concluded that treeline dynamics is more related to the deflected snow precipitation system rather than global warming in the Himalaya.

**Resumen:** Elestudio del límite arbóreo alpinocomo un marcador climáticopuede ser usado como un indicador importante en la dinámica de ecosistemasde montaña. Sin embargo, lostérminos, las varas de medición y los métodos aplicados usualmente en todo el mundono son comparablesentre estudios. Aquí se intenta evaluar la literaturarelevante,haciendo especial referencia al trabajo de Panigrahy *et al.* (2010) en los Himalaya del noroeste de la India, a fin de promover que se hagan observaciones interdisciplinarias y abogar por la adopción de una patrón uniforme. La variabilidad terminológicay la confusión resultante, la definición variable de árbol y de límite arbóreo y suvalidaciónrelativa sobre el terreno, continúan siendo un impedimento-fuertepara el desarrollo de protocolosestandarizadosyde evaluaciones cuantitativasde la dinámica del límite arbóreo como una respuesta climática precisa. Esta situación ha resultado en la generación de una confiabilidad diferencial en el estudio del límite arbóreodesde el nivel local hasta el mundial. A fin de atender este asuntose proponeuna terminología ecológicamente compatible y una metodología estándar de muestro como la de la UNESCO. Asimismo, se concluye que la dinámica del límite arbóreo está más relacionada con el sistemadesviado de precipitación de nieve que con el calentamiento global en los Himalaya.

**Resumo:** O estudo da linha-de-árvores alpina como um marcador do clima pode ser usado como um indicador importante na dinâmica do ecossistema de montanha. No entanto, os termos, pontos de referência e métodos usualmente aplicadas em todo o mundo não são comparáveis entre os vários estudos. Faz-se, assim, uma avaliação da literatura relevante, com especial referência ao trabalho de Panigrahy *et al.* (2010) no noroeste do Himalaia indiano, para promover e defender a adopção de um padrão uniforme e observações interdisciplinares. Observa-se que a variabilidade terminológica ea confusão daí resultante, definição variável de árvore e linha-de-árvores e sua validação relativa no solo, permanecem como o grande obstáculo

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ao desenvolvimento de protocolos de avaliação quantitativa padronizadosdadinâmica da linha-de-árvores como uma resposta precisa da mudança climática. Desta situação resultou a geração de uma fiabilidade diferencial no estudo linha-de-árvoresdonível local ao global. A fim de resolver esta questão,propõe-se terminologia ecológicacompatível ea metodologia de amostragem padrão UNESCO.Concluiu-setambém que a dinâmica da linha-de-árvores está mais relacionada com sistema de precipitação deflectida daneve do que do aquecimento global nos Himalaias.

**Key words:** Alpine treeline, biosphere reserves, Chorabari-Dokriani glacier, climate marker, timberline, treeline dynamics, treeline-global warming, treeline terminology.

The article by Panigrahy *et al.* (2010) is an outcome of the important attempt to study the treeline change in high altitude region of north-western Indian Himalaya. The study is significant as the area falls under a part of Nanda Devi Biosphere Reserve (NDBR). NDBR is one of the 16 Biosphere Reserves of India to protect natural habitat. It is also a part of the World Network of Biosphere Reserves based on the Man and Biosphere Programme of United Nations Educational, Scientific and Cultural Organization (UNESCO).

Panigrahy *et al.* (2010) have used the term "timberline" to denote the ecological identity of upper altitudinal limit of tree growth in mountain ecosystem. The term timberline actually refers to the highest limit for the commercial timber species only and "treeline" represents the elevation above which no tree exists and hence the two terms do not have exactly the same meaning. A perusal of treeline research literature such as Alftine & Malanson (2004); Arno & Hammerly (1984); Bake & Moseley (2007); Georg Miehe *et al.* (2007); Grabherr *et al.* (1994); Hassl & Baker (1997); Hoch & Korner (2003) and Jobbagy & Jackson (2000) revealed that the terminological confusion, difference in the definition of tree and treeline and their validation at the ground, lack of uniformly accepted method and technique for precise field work and observation, lack of data on anthropogenic contribution, etc., remain main hindrances in the development of associated knowledge on treeline and this situation has ultimately generated differential reliability in treeline study at local, regional and global level.

The synonyms, such as, treeline, alpine treeline, timberline, and forestline and ecotonal vegetation and upper treeline, etc., are frequently used worldwide by various workers to describe the uppermost limit of forest trees and their associated ecological identity on high mountains. In my opinion only "alpine treeline" should be used, as this term is more ecologically appropriate for forest trees at highest mountain elevation and reflects the science behind the principle and objective of study. As treeline sometime may occur even in non alpine regions such as coastal and desert treelines, the term is bound to have a loose implied meaning and the purpose of the study may become less appropriate. Therefore, there is a need to use the term alpine treeline instead. The species representing alpine treeline may be or may not be of timber size and value and hence the term "timberline" neither reflects ecological identity nor conveys meaning in true sense. The term "forestline" means all species other than the trees and hence creates confusion among the species to be considered for treeline study. The "ecotonal zone" in fact refers to the transitional boundary of highest mountain vegetation and consists of herbs, shrubs and trees. Moreover, it may characterize more than one elevation at upper and lower border line and cannot be an expression of climatic conditions prevailing exactly at treeline even within an ecotonal area. The term, therefore, deviates from the ecological principle and does not justify the spirit of treeline study. The term "upper treeline" creates utopian existence of a lower line, which has no ecological relevance with respect to the objective of the study. Thus the term "alpine treeline" may be considered most agreeable as one of the climate markers in mountain ecosystem. Further, the term "line" with tree-line does not represent a pencil drawn line, it rather refers to a boundary or a particular zone/ area having nearly similar micro-climatic conditions. And depending on its local drivers and other associated factors it may some time represent different elevations in the same mountain valley. For example, under similar climatic domain of NDBR region in Bhagirathi river watershed (Dokriani glacier valley) at Tela hill top, alpine treeline shows spatial existence at the elevation of 3880 m asl but near the glacier snout it is reported at the elevation of 3960 m asl. Factors such as wind velocity, high gradient, livestock grazing and difficult accessibility are identified as the main local drivers.

In the methodology part, Panigrahy *et al.* (2010) have not described any quantitative yardstick for tree height limit, and method for altitudinal identification and delineation to demarcate tree and non-tree flora in treeline vicinity. In order to develop uniform pattern in treeline study, globally recognized and UNESCO standard sampling method and associated field practices are needed to be adopted for preliminary demarcation of tree and non-tree flora (Mueller-Dombois & Ellenberg 1974) with prescribed benchmark of minimum tree height of 5 meter. The tree height benchmark may be further refined to 3 meter (Korner 1998, 1999; Korner & Paulsen 2004) to facilitate future monitoring of treeline dynamics with shorter time intervals.

During my study in and around Dokriani and Chorabari glaciers in upper catchment of rivers Bhagirathi and Mandakini in Garhwal Himalaya, which are a part of same climatic domain as NDBR, it was observed that at the alpine treeline altitude dwarf plants , such as, junipers, spruces and other species, especially *Rhododendron companulatum, R. anthopogon, Sorbus acuparia, S. foliolosa* and *Lonicera obobata* followed by *Betula utilis*, grow as frontline invader species assuming a shrub/tree habit. These plants remain buried under the winter snow for a period of about four-five months. After snow melt they form a thick vegetation carpet of a similar green colour, and are hardly differentiable at the level of habit (requisite height) on the basis of tonal variation perceived in remote sensing data. The assessment of trees of requisite benchmark height and their spatial delineation is a primary condition to enable us to quantitatively differentiate between treeline flora and rest of the species. It is generally done precisely through random ground check at certain sampling sites, because even the alpine treeline species such as *Rhododendron companulatum, R. anthopogon, Sorbus acuparia, S. foliolosa* remain shrubby and below the prescribed height in early stage. Hence, they cannot be considered under the treeline flora during assessment time. Without the prescribed and quantified definition of tree with respect to height, studies on treeline reflect variability in the perception of researchers and lack uniformity in methodology. Further, Normalized Difference Vegetation Index (NDVI) method used in the aforesaid study (Panigrahy *et al.* 2010) helps in the assessment of vegetation density but is hardly used to delineate trees according to prescribed yardstick in treeline vicinity.

Panigrahy *et al.* (2010) also attributed the treeline ingression towards higher altitudes to global warming related rise in temperature. However, recent study conducted in the western Indian Himalaya region (which also includes NDBR area) suggests that global warming impact is hardly discernible in instrumental recording as well as in natural archives. Results based on observational records and reconstructions of tree rings suggest a pre-monsoon temperature cooling during the later part of the 20th century. A rapid decrease in minimum temperatures at rates which are around three times higher than the rate of increase in maximum temperature found in local climate records indicates that western Himalaya defy global warming (Yadav *et al.* 2004). The study carried out in Dokriani glacier reveals that there is hardly any increasing trend in air temperature reported instrumentally so far and contrary to warming perception, a decrease in glacial snout recession has occurred from 17 - 18 m year$^{-1}$ found during the years 1991-2000 to 16.6 m year$^{-1}$ recorded for the years 2001-2007 (Dobhal & Mehta 2010). General slowdown in the rate of glacial retreat has also been reported during late nineties and in the decade of year 2000 in the Himalayan region (Bali *et al.* 2010; Raina 2009). Logically, the presumed warming in high altitude ecosystem should also have been reflected by more and more annual glacial water discharge but study conducted between the years 2000-2006 melt season (10 May to 20 October) at Gangotri glacier suggests more or less a decreasing trend and even no significant difference was observed in day and night water discharge (Singh *et al.* 2010). The northwestern Himalayan rivers such as Beas, Chenab, Ravi and Satluj also have not witnessed increasing trend of overall water discharge (Bhutiyani *et al.* 2008). My visual reconnaissance experience gathered during the past 20 years suggest that due to change in monsoon pattern, (i) critical level of moisture is not available during snow precipitation season and (ii) occasional torrential rainfall is also accelerating existing snow melt in high altitude region, especially in the northwestern part of Indian Himalaya. The monsoonal deflection finally results into low or negative snow/ice mass balance periodically and perpetually generates considerable snow-uncovered area. Recently, change in monsoonal trend has been established and it is revealed that summer monsoon circulation in general, over India during the period of years 1951-2004 has weakened (Dash *et al*. 2009) and it may well be mainly attributed to the low snow precipitation in Himalayan region. Therefore, irrespective of warming, alpine area not covered by permanent snow cover is being encroached and occupied by vegetation and accordingly alpine treeline is rapidly expanding in the area, which otherwise restricted the plant growth due to snow cover.

Considering the above facts related to high altitude Himalayan ecosystem, it can be presumed that ground realities are in variance with the phenomenon of global warming and invasion of the treeline in erstwhile snow and glacier regime, towards the higher altitudes is more related to the deflected snow precipitation system than the global warming impact in the Himalayan region.

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