Timberline of Sikkim Himalaya in changing environment: Geographical influence on distribution and conservation priorities

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ABSTRACT

The Himalayan region presents the highest timberline in the Northern hemisphere which is sensitive to changes (climatic and anthropogenic). The present study analyzes timberline and topographical influences of mountainous terrain along altitudinal gradient in eastern Himalayan region. To analyze these influences watershed approach was adopted and timberline mapping was carried out using different satellite images to analyze the impact of resolution at large scale mapping. In situations, where difficult topography poses challenges to auto-extraction of features, use of visual interpretation and associated knowledge is more appropriate. Thus visual interpretation was employed. Total length of timberline mapped (at 30meter (m) resolution) was 828Kilometers (km) in the state of Sikkim, however only 5% increase was observed mapping on finer scale (5.8m resolution). Thus, for regional or state level mapping medium resolution is efficient. In Sikkim, timberline at rare locations descends below 3200m above mean sea level (amsl) (negligible but present), however occurs in a considerable span of elevation (2.2 km) from 2600 to 4800m amsl. Presence of timberline is more visible from 3200m onwards which rarely reaches upto 4800m. More than half (56.8%) of the total timberline in the state exists in the narrow range (400m) elevation zone 3600-4000m amsl, which emphasizes most favorable environment for occurrence of timberline in eastern Himalayan region. Nearly one fourth (24.7%) extends above 4000m and only less than 1% above 4400m. Trees prefer moderate slopes thus 71% timberline is on the slopes less than 35 degrees ($<35^{o}$). Mostly the timberline was observed on warmer aspects (66%). Occurrence at island habitats (summit trap) without scope to escape from threats of global warming makes timberline and species vulnerable. Topography of a watershed plays an important role in occurrence of natural timberline and various locations in different watersheds are critical for timberline conservation; an entity important for human sustenance, wildlife ecology, and species range shift.

1. Introduction

The Indian Himalayan region (IHR) is one of the youngest and highest mountain range in the world. IHR is a representative of vast range of landscapes, which not only have a unique patterns but also exhibit many contrasting features. The Himalayas have a profound significance on the lives of local communities residing in this region because of the resources present despite tough and rugged terrain. The high altitude limit of forests, commonly referred to as treeline, timberline or forest line, represents one of the most obvious vegetation boundaries (Christian Kdrner and Jens Paulsen, 2004). The treeline represents an ecological transition zone between fundamentally different low land and high altitude ecosystem (Mani, 1978), it is not an abrupt physical line, rather it is a boundary or transition zone, but viewed from a distance, the emotional transition looks quite abrupt and is customarily regarded as a line (Peili Shi and Ning Wu, 2013).The timberline ecotone area is considered to be among the most prominent vegetation zones in high mountain areas. The upper limit of natural forests with a steep gradient and increasing at and fragmentation and stubtedness is sometimes called the treeline ecotone or timberline ecotone. A tree is defined as an upright woody plant with a dominant above-ground stem that reaches a height of at least 3m, with its crown closely coupled to prevailing atmospheric conditions (Körner 1998). Therefore, the treeline is defined here as the altitude above which any trees is lower than 3m (Körner 2012b). The timberline ecotone is a broad area of 50 to 100 m below the treeline to the line bounding the full forest. The timberline, since the timberline and treeline are coupled boundaries; the fundamental mechanisms causing their general position should be similar (Körner 1998).

The recent developments in remote sensing techniques have provided new opportunities in mapping. Remote sensing technology a better choice over ground based study and successfully used to advancement of timberline mapping. Using of remote sensing techniques for study of rugged and inaccessible terrains such as Himalayas is especially helpful in identifying timberline ecotone and timberline boundaries. Timberline ecotone is important and

sensitive component of landscape and need spatial monitoring for its response to global climate change. In this study, present position of timberline at different resolution was mapped.

2. Study area

In the Indian Himalayan Region (IHR), the state of Sikkim has been selected for understanding the geographical influence on the state's timberline and impact of the changing Himalayan environment on the treeline. Regional scale mapping of timberline has been attempted in Sikkim, where high altitude timberline occurs. The geographical area of Sikkim 7,096 Km² (~0.21% of the country).It is situated in northeastern part of India and share international boundaries with China in its north and east, Bhutan in its east and Nepal in its west. Its lies on 27.5330°N latitude and 88.5122°E longitude. Almost 35% of the state is covered by the Khangchendzonga National Park.

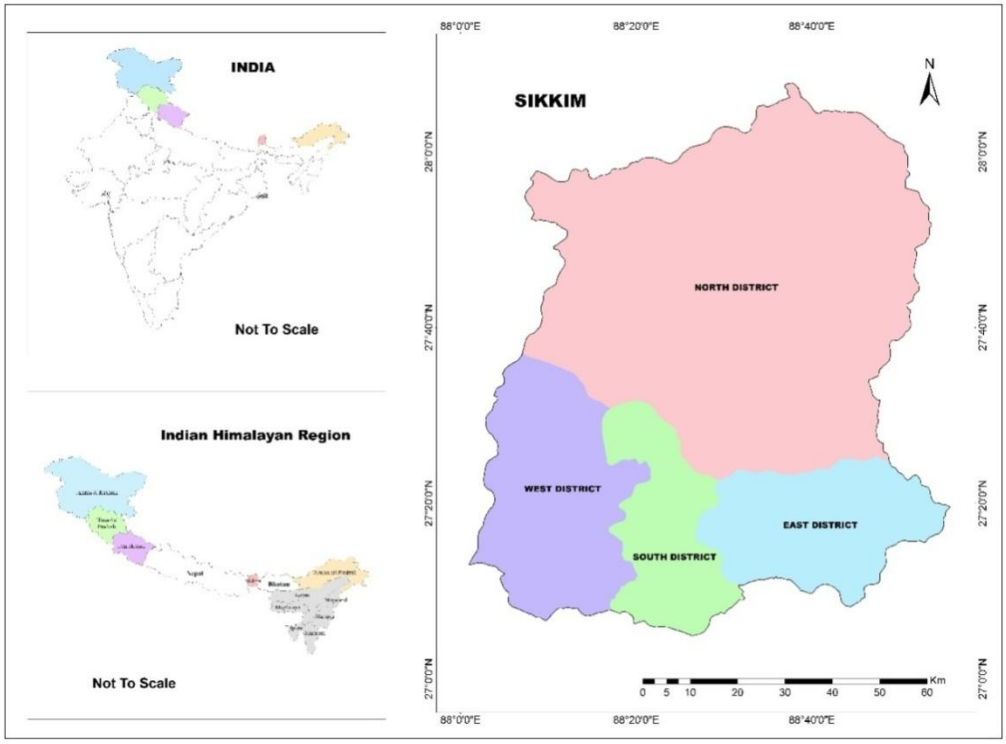

Fig 1. Location map of Studied State - Sikkim

3. Methodology

3.1 Data Acquisition- Preprocessed two different multispectral imagery (Landsat 30m and LISS IV 5.8m spatial resolution, 2015) obtained from United States Geological Survey (USGS) and National Remote Sensing Center (NRSC) was used for timberline mapping. These images were level georeferenced, orthorectified and projected in UTM WGS 1984 zone 45 coordinate system. Imagery was subset to fit the study area by using Erdas Imagine 16 (image processing software), Digital Elevation Model (DEM) 30m resolution, was also obtain from USGS website.DEM models were generally used for assigning elevation to digitize timberline. All the digitize timberline was resample of 30m resolution.

3.2 Method-Timberline was manually delineated by interactive interpretation procedure (following the tonal, texture, size, shadow, shape, contextual, association, pattern of the forest edge and uppermost patch of trees). Digital Elevation Model was used to assign the elevation of timberline. Timberline mapping for Sikkim state was carried out by using Landsat and LISS IV (for refinement) satellite images 2015 having spatial resolution of 30m and 5.8m. In situations where difficult topography poses challenges to auto extraction of features, use of human interpretation and local knowledge is more appropriate, thus visual interpretation method was adopted supported by ground truthing in different watersheds. Topography controls the overall presence of timberline hence various attribute i.e., slope, aspect and elevation were developed for entire state of Sikkim with the help of Digital Elevation model (DEM). DEM was used to assign the elevation of timberline, eight watershed's timberline was selected and their elevation and aspect were extracted from merging timberline with the DEM. During analysis it was realized that watershed has also influent in controlling vegetation

(barriers and pathways) on a given landscape hence different watersheds were also derived from the DEM. Timberline in the present case does not mean that at every spot of this line a tree is present but certainly the presence of upper limit of trees on this line is as high as 99% of the total length described for an area. Hence it can be fairly considered as upper timberline in the region.

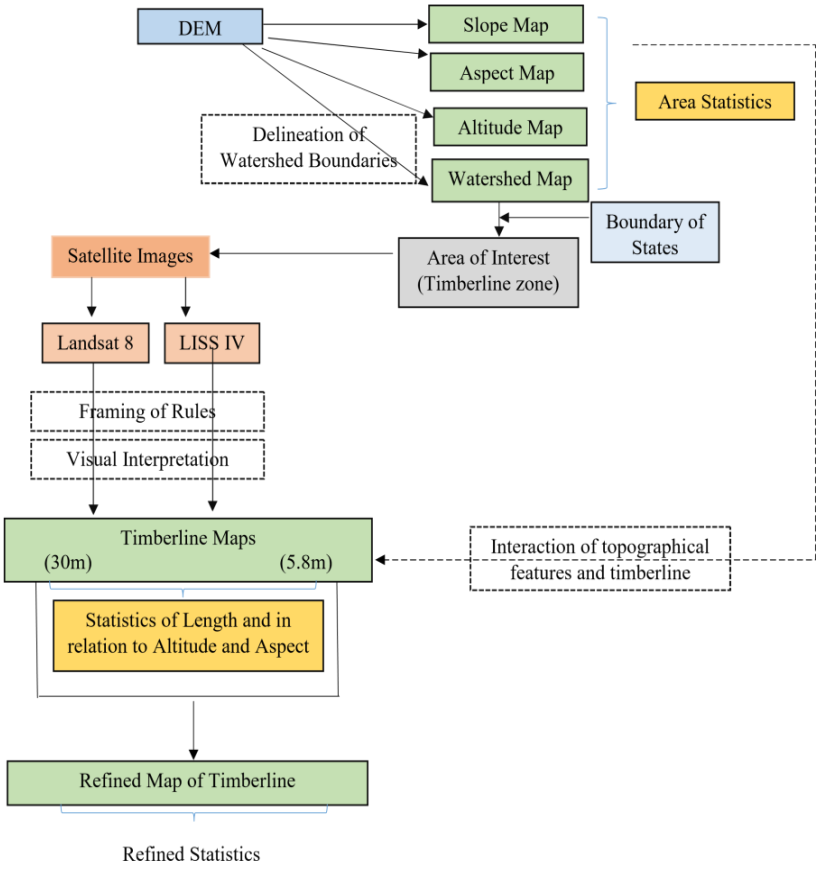

Fig 2. Schematic representation of methodology for Timberline Mapping

4. Results

4.1 At resolution 30: Timberline in the year 2015 (derived from 30m resolution of Landsat 8) is presented in. Total length of this line is approx 828 km in the state. In rare locations of the state, high altitude timberline may occur between 2600m and 3200m amsl altitude (negligible but present). Presence of timberline is more visible from 3200m onwards and scarcely reaches up to 4800m. 4400m and above altitude contributes minimal portion of timberline (3.4%). More than half (51.6%) of the total timberline of the state occurs between 3800m and 4200m altitude, and 27.8% of timberline is present in between 3400m and 3800m.Further, segmentation of total timberline into major watersheds of the state reveals that timberline also occur in the areas which do not culminate in the permanent snowline, e.g., Timberline in Lower Rangit and Rangpo Chhu watersheds where elevation is high and timberline forms an island type of habitat, particularly in the former. Presence of timberline, e.g., Upper Tista watershed is the largest watershed in the state and predominantly has high elevations but this contributes only 19.6% of the total timberline while Upper Rangit watershed, with more areas in mid or low elevations, have similar proportion of timberline (19.7%) in the state. These attribute revel that in a few rare locations presence of timberline may descend upto 2600m. It is apparent from uncommon pattern in the watersheds that mountainous topography has major role in occurrence of timberline at a particular watershed or area. For example, the island type occurrence of high altitude region in Lower Rangit restricts majority of timberline between 3000m and 3600m (83.7% of total of watershed) while elevation extends beyond 4000m. In Upper Rangit watershed elevation reaches to highest point but maximum timberline (82.3%) falls in between 3600m and 4400m. It can be deducted that elevation zone of 3600m to 4200m in the mountainous landscape of Sikkim State is more favorable for occurrence of timberline, however upper and lower presence of timberline is apparent in many locations. Proportionate distribution of timberline in different watersheds of the state is depicted in Fig 3 Peak occurrence of timberline in all the watersheds found between altitudinal zone of 3600m and 4000m, suggesting a most favorable environment for timberline in eastern Himalayan region.

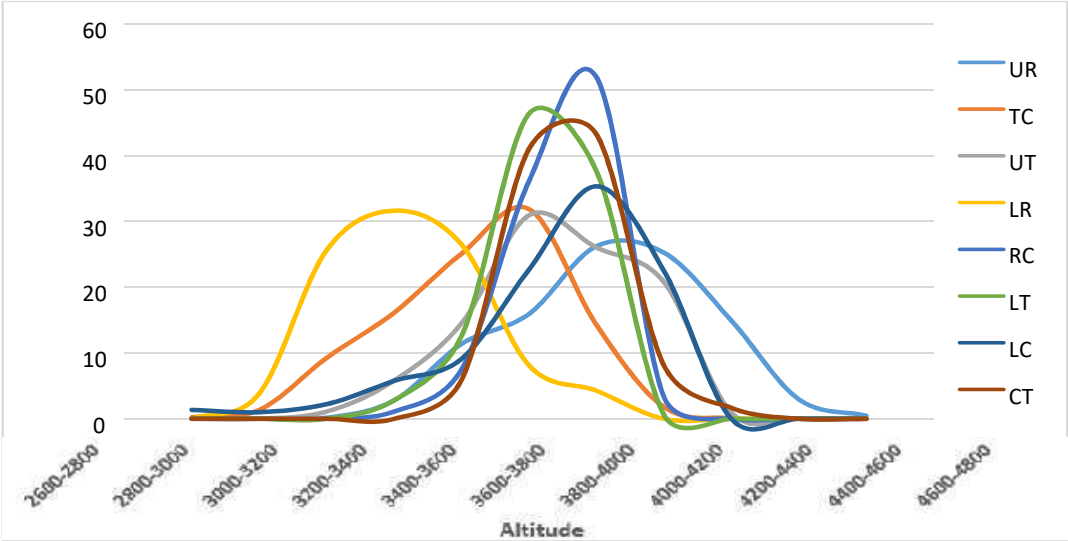

Fig 3. Distribution of Timberline in different Watershed of Sikkim

4.2 At resolution of 5.8m: To refine the mapping and see the influence of satellite resolution, timberline was derived for the same year of 2015 by using LISS IV (5.8m resolution), due to high resolution, length of timberline increased by 39km but the total increase was 4.7%. Hence, high resolution image adds only less than 5% to the accuracy; however positional difference may be greater. Distribution of refined timberline in different watershed of the Sikkim is given in Table 6 which reveals that except for two watersheds (Central Tista and Rangpo Chhu) there was gain in the length of timberline. Distribution of refined timberline in different altitudinal zones of a watershed. Depending upon the topographical limitations within a watershed variation in occurrence of timberline may range widely between 2600m and 4600m in the state. However, full expression of timberline varies between the watersheds; maximum timberline occurs in an altitudinal zone of 3600-4000m altitudes. Proportionate distribution of refined timberline in different watersheds of the state is depicted in Fig 4. Similar to previous resolution of Landsat, peak occurrence of timberline in majority of the watersheds lies between altitudinal zone of 3600m and 4000m, further proving this zone most favourable environment for timberline in eastern Himalayan region.

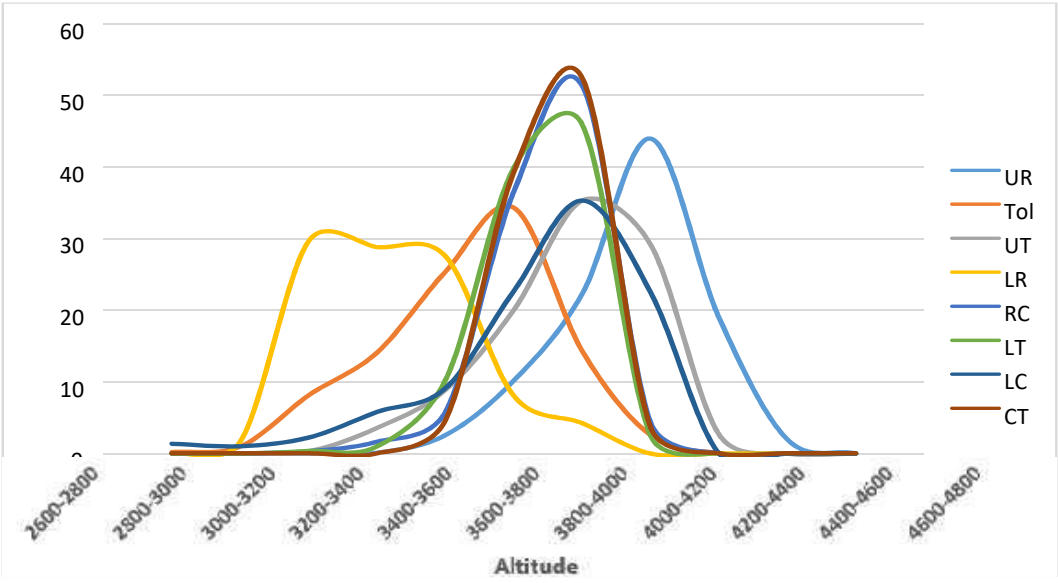

Fig 4.Percent distribution of Timberline along different altitude in different Sub-watershed LISS IV

4.3 Comparison between two resolutions: Proportionate distribution of refined timberline in different watersheds of the state is depicted in Fig 4. Similar to previous results (obtained using 30m resolution of

Landsat image) peak occurrence of timberline in majority of the watersheds lies between altitudinal zone of 3600m and 4000m, further emphasizing this zone is most favourable environment for occurrence of timberline in eastern Himalayan region.

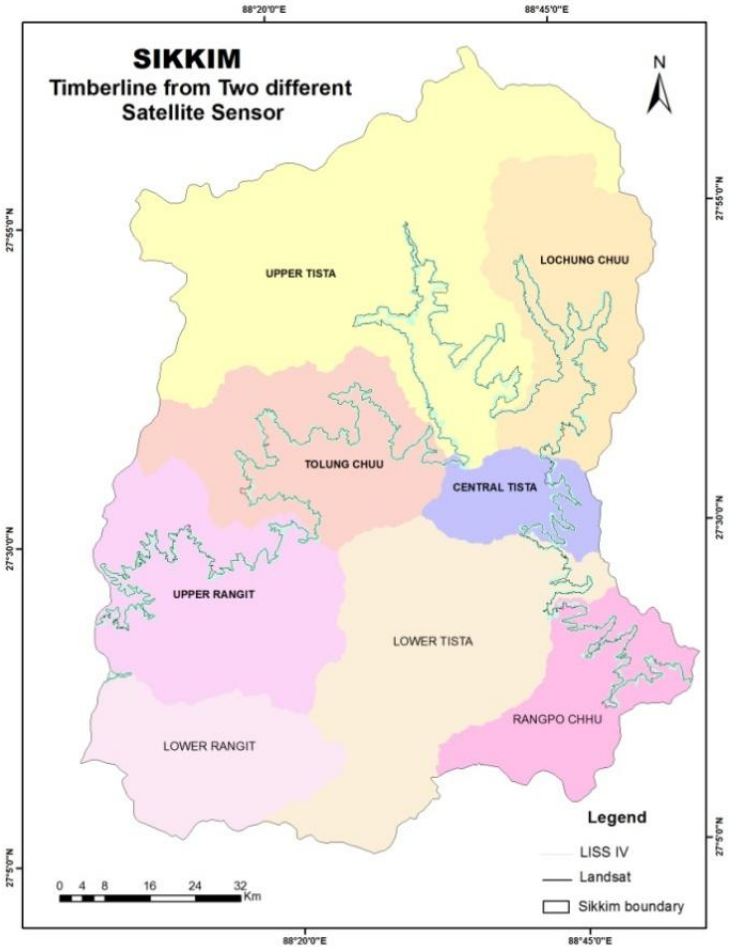

Fig 5.Timberline(s) from two different resolutions in Sikkim

Fig 5 depicts difference in two timberlines (black colour – 30m; and Cyan colour – 5.8m resolution). Noticeable differences are present in some locations. Altitudinal distribution of both the resolutions is given in Fig 6.

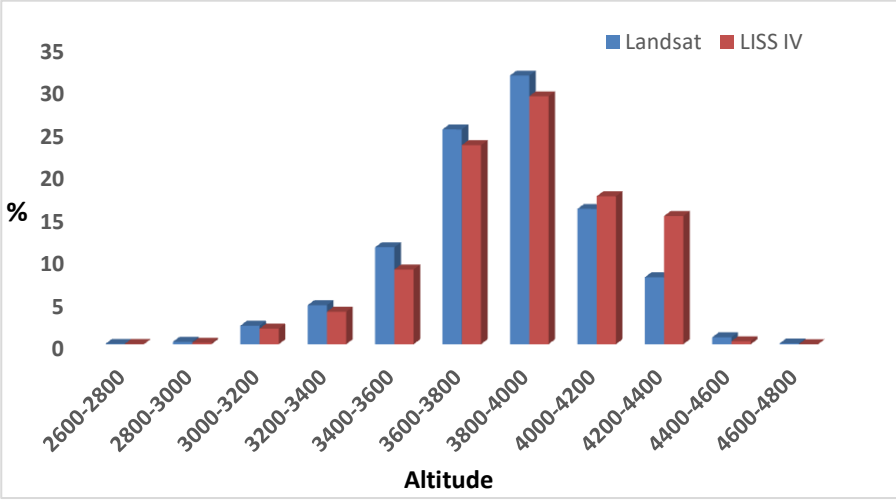

Fig 6. Differences in timberline of Sikkim State drawn at two resolutions

In dense or sparse trees occurring between 3400m and 3800m high resolution improved the curvature of timberline and total length decreased considerably in this elevation zone. Nearly one fourth (24.7%) extends above 4000m and only less than 1% above 4400m. Trees prefer moderate slopes thus 71% timberline is on the slopes <35o. Largely of the timberline was on warmer aspects (66%).Enhancement in the length of timberline was observed at both ends of altitudinal gradient.

5. Conclusion

Topography of a watershed plays an important role in occurrence of the natural timberline, thus the great heterogeneity in elevation, but maximum timberline occurs between altitudinal zone between 3400m and 4400 m amsl. Segmentation of total timberline into major watersheds of the state reveals that timberline also occur in the areas which do not culminate in the permanent snowline. Incorporation of topographic information from the region will help to identify where timberline would advanced in future in response to rising temperature. Geomorphological factors are most important factors structuring the timberline ecotone of Sikkim watersheds and having large area in high altitudes does not reflect the maximum presence of timberline.

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