Topographical influences on high altitude forest line in the Indian Central Himalaya: Case of Pindari Glacier Valley

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Abstract

High altitudes of the Himalaya have been realized to more prone towards temperature increase due to global temperature rise while decrease in temperature limits the plant growth there. Altitudes in high mountains do not support tree growth beyond an elevation and termination of continuum of forests is often termed as forest line/timberline. This is a dynamic state which is influenced by local topography and geography on which a very little knowledge exists for the Himalayan region. This study focuses on the mapping of timberline, using high resolution satellite images, in a glaciated valley (Pindari Valley covering an area of 397.35 km2) having three glaciers (three valleys) in the Indian Central Himalaya. Three valleys exhibit a variation of ~1 km in highest elevation (3050-3970m amsl) of timberline which shows a buffering range for temperature escape for the tree species of timberline. Impact of robust topography will limit this expansion and limit of forest growth as apparent by the fact that about 62% of the area does not have vegetation (snow, glacier, rivers, rock, etc.) in an elevational zone of 4 km (2000-6600m amsl). Presently, vegetation (alpine, forest, and shrubs) are limited to 38% of the area. Timberline also varies considerably (570-700m) in three sub-watersheds of Pindar valley. Expansion of tree vegetation is further limited by the availability of soil and suitable habitat as apparent from fragmented occurrence of alpine meadows (203 fragments of <1ha in size). Globally observed evidences, a gradual shifting of timberline towards higher altitudes as an impact of global warming, may not hold true in some Himalayan situations where influence of local topography within valleys is more prominent even buffer capacity of species is present to absorb impacts of climate change.

1. Introduction

The treeline represents an ecological transition zone between fundamentally different low land and high-altitude ecosystem (Mani, 1978). The high-altitude limits of forests, commonly known as treeline and forest line. In highlands, upper altitudinal limit of forests commonly forms treeline (sometimes also referred as forest line), and represents one of the clearly visible vegetation boundaries (Korner, 1998; Holtmeier, 2009). The treeline lying between montane forests and alpine vegetation, the alpine treeline is a particularly conspicuous boundary. The Himalayan region presents the highest timberlines and treelines in the world and the most diverse in terms of treeline tree species of *Abies spp, Picea spp, Rhododendron spp, Juniperus spp and Betula spp*. In Himalayan region, the topography is an important for local conditions, including microclimate, soil, temperature and the disturbances of the region (Barder and ruijten, 2008).

Alpine life zones lie between the altitudinal tree line, and its substitutes, and the altitudinal limits of life, or the snow line. The alpine zone, above the tree line, in the Himalaya is lined up as an archipelago on the high mountains at the southern periphery of the high central Asia separated from each other by deeply incised transverse valleys (Miene, 1997). The alpine region usually begins at 3000 m amsl and the snow-line at 5000 m (Mani 1978). The region which lies between the altitudes of 3000- 5000 m amsl is locally known as 'Bugiyal' (alpine pasture) throughout the Central Himalayan region. Treeline in the Himalayan region varies from place to place, as in the western part of the Himalayas it is roughly at about 3600 m, however, it descends as low as 2550m in Gilgit or is as high as 5000 m in Thalle La in the Karakorum ranges (Singh *et al.,* 2012).

As the need for environmental planning and management becomes important, an accompanying call for land cover information emerges in parallel. Land cover and land use mapping is a product of the development of remote sensing, initially through aerial photography (Colwell, 1960). Land cover varies at a range of spatial scales from local to global, and at temporal frequencies of days to millennia, it is one of the earliest applications of remote sensing technology. Remote sensing is an important tool to study alpine treeline and changes in the recent past because of its capability for viewing wider areas (Singh et al., 2012). This ‘viewing’ of large areas repeatedly is necessary for acquiring information about land cover and it has been perhaps the most widely studied problem employing satellite data, beginning with Landsat1. Most of the studies using high resolution data (i.e. 20–100 m) are methodological in nature, exploring various information extraction techniques and applying these over limited areas (Cihlar, 2000). Treeline shift response to climate change can be monitored using images from remote sensing satellites, which helps to overcome the difficulties posed to direct observation by the poorly accessible Himalayan terrain (Rawat, 2012). Alpine plant species have been found to shift to higher elevations, although the shifting rate varies with species and their sensitivity to climate. However, treeline dynamics appear to be more related to changes in snow precipitation than to global warming (Negi, 2012). Remote sensing investigations by Singh et al. (2012) indicated that the treeline shifted 388 ± 80 m upwards in the Uttarakhand Himalayas between 1970 and 2006. A study using repeat photography and supplementary measurements in the eastern Himalayas (northwest Yunnan) also indicated glacier recession and an advance in the treeline (Baker and Moseley, 2007).

The recent developments in remote sensing techniques have provided new opportunities in mapping. Satellite images are available for detailed land use and land cover mapping over large areas at fine spatial resolutions. This study focuses on the mapping of timberline, using high resolution satellite images, in a glaciated valley having three glaciers (three valleys) in the Indian Central Himalaya.

2. Study Area

The study area i.e., Pindar valley covering an area of 397.35 km^2 (Fig.1). The area is confined in the higher reaches of Pindari catchment, and includes three primary contributing rivers originating from Pindari glacier, Sundardhuga glacier and Kaphani glacier, to the southeast of famous peaks of Nanda Devi, and Nanda Kot. The Pindari glacier flows towards south direction and gives rise to the Pindar river. At Dwali, Pindar river meets with Kaphani river and forms a violent course. Further downwards confluence below the village Khati witnesses merge of rivulet from Sunderdhunga glacier into Pindar river.

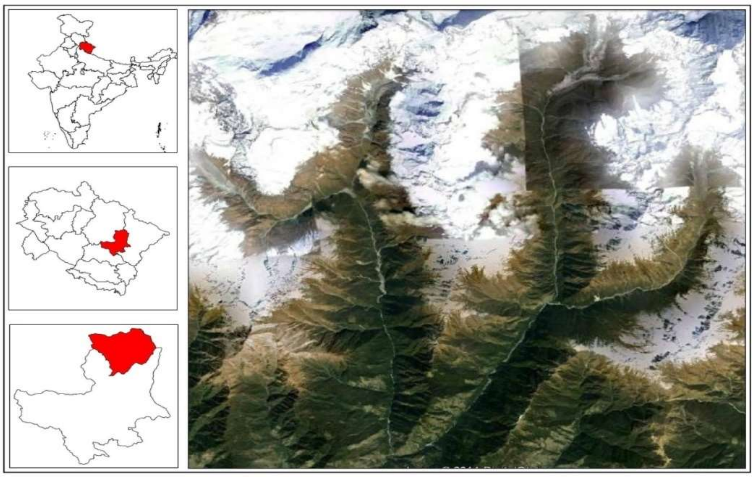

Fig: 1 Study area Map of Pindar Valley

3. Methods and Material

Satellite imagery means that it is a collection of earth images, which are collected by high resolution artificial satellites. These are the satellites which capture very high-resolution images of earth. We can get more detailed information from these pictures. The study area covered Kaphani, Pindari, and Sundardhunga catchment representing an east to west transition from Kaphani to Sundardhunga These catchments were digitized on Google Earth by visual interpretation. High resolution satellite images of natural color of recent time (available from Google Earth) were interpreted visually to map various landuse/landcover features (snow, alpine, forest, scrub, agriculture, rocks, river, cloud). KML files were exported to Arc GIS for further geo-spatial analysis.

4. Results

Landuse/Landcover map of the Pindari catchment using high resolution satellite images. Total area of Pindari Catchment (Sundardhunga, Pindari and Kaphani sub-catchments) is spread in approximately 39735 ha. Vegetation (alpine grasslands, forest, and shrubs) occupies 38.2% of the total area (Table 1) whereas remaining 61.8% area is covered by snow, glacier, rivers, rock, etc.

Study area is largely covered by snow (51.7% of the total; with small portion of clouds) followed by forests (19.7%) and alpine meadows (16.4% Table 1). High altitudes have large areas either under glaciers or denuded slopes of open rocks and soil (3.5% and 3.03%, respectively). High resolution images were used to discriminate patches of shrubs from alpine meadows. The shrubs altogether covered an area of 672.5 ha (1.7% of the total area) 500 ha (approx.) of area lies between the forest or are devoid of tree vegetation, termed as forest blanks, total forest blanks occupy 1.2% of the total area of the Pindari catchment. Lower elevations of catchment are marked by the presence of human settlements on the landscape but confined to only 0.7% of the area. Nearby forests have been utilized by local communities for fulfilling their various needs, resulting in degradation of forest (degraded forest, 0.3% of the total area of catchment). Landuse/Landcover map of the Pindari catchment using high resolution satellite images is presented in Fig. 2.

Table 1. Landuse/Landcover statistics of Pindari Catchment

LULC (Non-Vegetation) class	Area (ha)	**Vegetation Class**	Area (ha)
Snow & Cloud	20,545.1	Alpine	6,537.1
Glacier	1,403.9	Alpine shrubs	672.5
Open rocks & Soil	1,206	Forest	7,828.5
River Bed &Stream	638.2	Forest Blank	499.9
Village	279.5	Degraded Forest	124.2
Total	**24547.1**	**Total**	**15187.8**

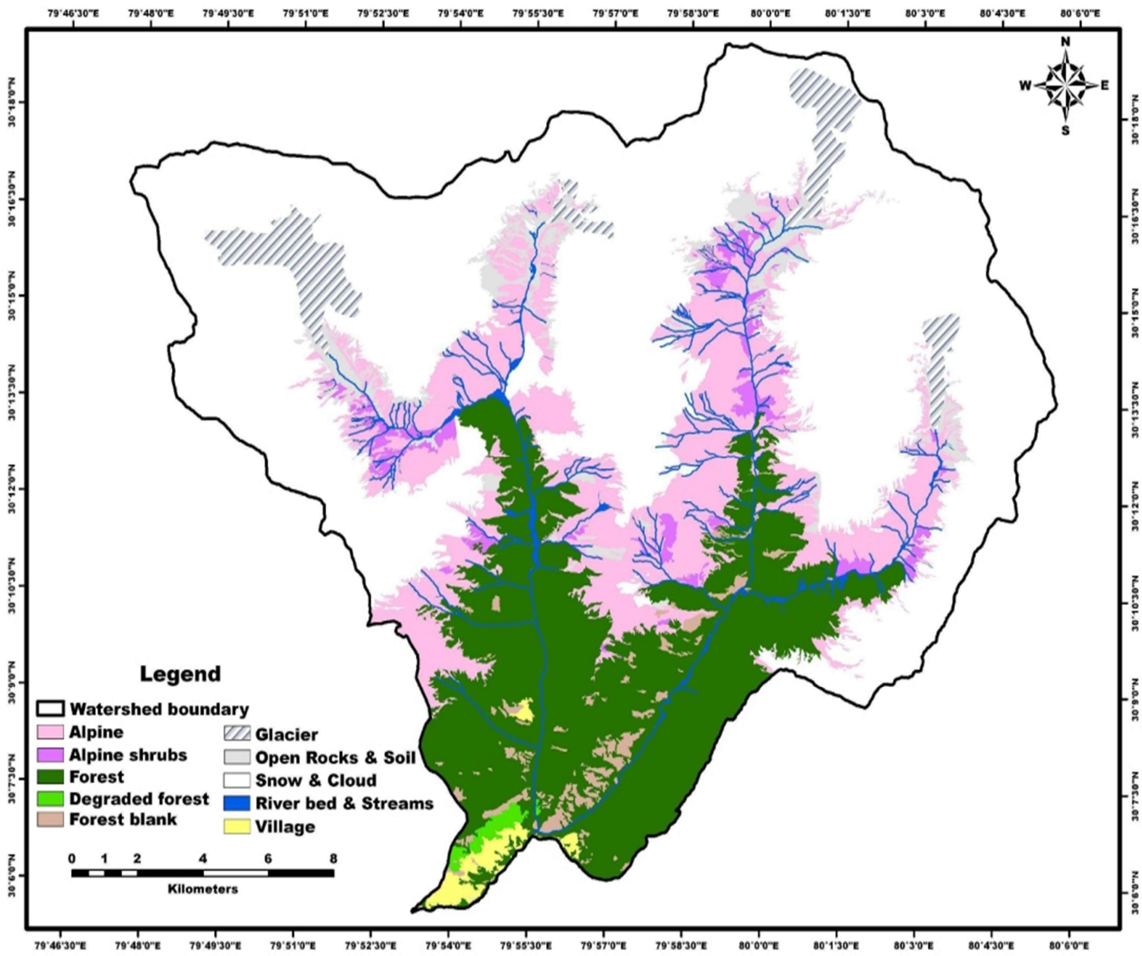

Fig 2: Landuse/Landcover of Pindari Catchment

4.1. Treeline/Forest line and Permanent Snow line in Pindari catchment

Treeline is a dynamic stage of tree vegetation in extremes. In mountains, high elevation restricts further movement of growth and establishment of tree seedlings due to adverse & harsh climate. Elevation in Pindari catchment varies from 2016m amsl (lowest point) to 6829m amsl (highest peak). Pindar and Sundardhunga sub-watersheds have almost similar altitudinal difference (2016-6694m and 2016-6786m, respectively) but Kaphani has a higher lower elevation of 2580m than these two sub-watersheds and highest peak also falls in this area only 6829m.Occurrence of treeline in Pindari catchment varies between 3048m (Kaphni sub-watershed) and

3971m (Pindar sub-watershed), almost an altitudinal variation of about 1 km. This indicates a wide buffer to absorb impacts of climate change in this region. However, a difference of nearly 1000m occurs in the tree line of entire Pindari catchment, it varies between 570m (Sundardhunga sub-watershed) and 700m (Pindar sub-watershed) in different sub-watersheds. Permanent snow starts from 3580m amsl to 4923m amsl at different places of Pindari catchment, thus provide a wide area as home of alpine vegetation in between treeline and permanent snow line.

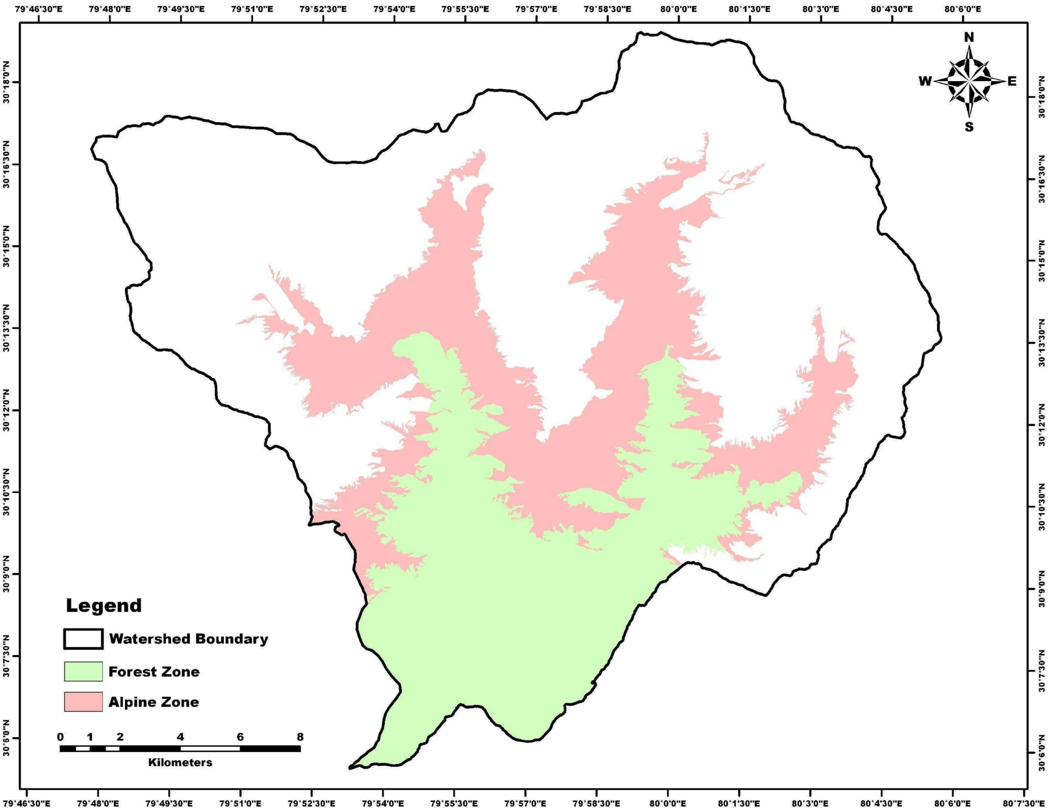

Fig 3: Zones of Forest line, Alpine Line and Snow line vegetation in the Pindari Catchment

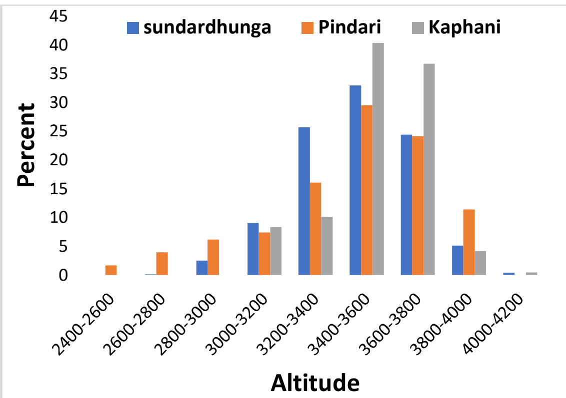

Fig 4: Distribution of Forest line in different altitudinal zone

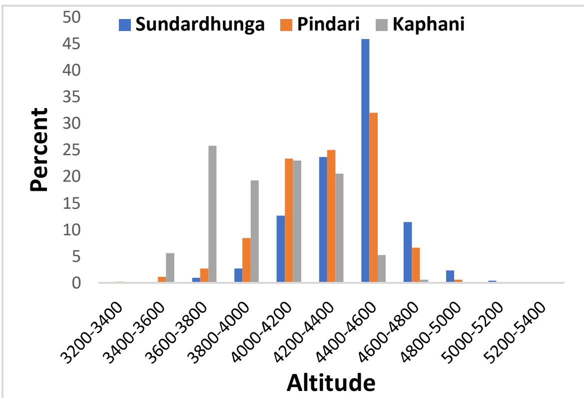

Fig 5: Distribution of Snow line in different altitudinal zone

Distribution of forest line and snow line in different sub-watershed of Pindari valley in fig 5 and fig 6. The occurrence of forest line in all watershed found between altitudinal zone of 3200m and 3800m. Depending upon the topography limitation within a watershed variation in occurrence of forest line may range widely between 2400m and 4200m. The maximum forest line occurrence in an altitudinal zone of 3400m – 3600m altitudes.

Distribution of snow line in different watershed of the Pindari valley (Fig 6). Peak occurrence of snow line in majority of watershed lies between altitudinal zone of 4400m - 4600m. The maximum snow line occurrence in Sundardhunga watershed lies between altitudinal zone of 4400m – 4600m.

4.2.Alpine Zone of Pindari Catchment

Alpine zone is very vulnerable to climate change and most of the Himalayan alpines have long history serving as pasture lands for local inhabitants as well as nomadic societies. In total 462 patches of alpine meadows were present in the Pindari Catchment but majority of them were less than 1 ha in area (203 in number and 44% of all the alpine meadows), overall occupying total area of 84.3 ha (1.3% area under total area of alpines) in this class. Nearly 38.7% (179 in number) of the total patches of alpine meadows have area between 1-10 ha, covering an area of 574.1 ha (8.8% of the total alpine).

Large size alpine meadows are few in number (80) but occupy nearly 90% of the total area under alpine meadows in the Pindari catchment. Among large size alpine areas more than 100 ha of size contribute to 63.2% of the total alpine meadows (Fig. 6). This shows large continuity on the landscape from lower to higher elevations (Fig. 6). After this size class, alpine meadows between 10 ha and 50 ha are more common than other classes and occupy about 21.5% of the area under entire alpine meadows.

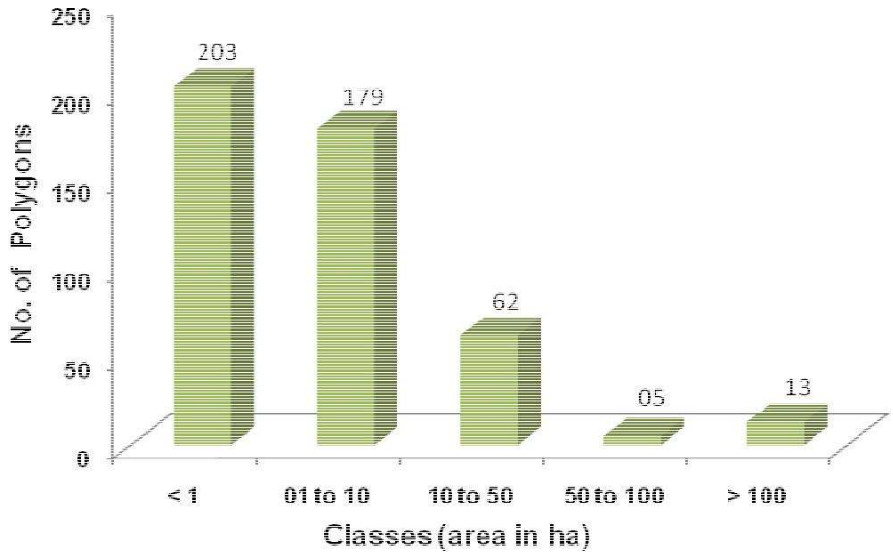

Fig 6: Distribution of Alpine meadows in Pindari catchment in different size classes

5. Conclusion

The highest tree line in different sub-watersheds of Pindari watershed varies considerably with a variation of about 1 km in elevation (3,048m amsl – Kaphni Glacier; 3299m – Sundardhunga Glacier; 3971m – Pindar Glacier), however, it also varies within the sub-watersheds (570m in Sundardhunga sub-watershed to 700m in Pindar sub-watershed. This indicates influence of local topography within valleys, and a wide buffer to absorb impacts of climate change in this region. Mapping is important because it allows us to broaden geographical societal issues maps are useful to understand and identify special links and explain concepts in a visual way that can be easily understood.

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