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### RESEARCH ARTICLE

#### LONG-TERM MODIS BASED NDVI AND LST TRENDS OF NILGIRI BIOSPHERE.

Tabassum Ishrath Fathima<sup>1</sup>, R.K.Somashekar<sup>2</sup> and Mohammed Ahmed. J<sup>3</sup>.

1. Department of Environmental Sciences, Bangalore University, Bangalore.
2. Regional Remote Sensing Centre, ISRO, Bangalore.

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#### Abstract

Land surface temperature is influenced by various factors like precipitation and albedo, which differs from normal atmospheric temperature. At spatial level, land surface temperature plays an important role in depicting the temperature of the area. Although several regional climate models were developed by researchers to overcome uncertainties in understanding the impact of climate change at micro-level changes using satellite data as input, appears to serve as one of the best tools. Keeping this concept in mind, MODIS-LST is used to assess the possible impact of climatic and atmospheric variables on high altitude regions of Nilgiris in the present study. Comparatively, the land surface temperature of Thai shola and Longwood shola was higher than other shola regions. A comparison with night time MODIS land surface temperature with minimum temperature showed that night temperature provides a good estimate over day because of thermal reflectance of NIR band and others like solar radiation and cloud cover. The outcome of the study is likely to assist in drawing plans for biodiversity conservation besides, planning and developing strategies to conserve save shola forest against climate change impact.

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#### Introduction:-

Nilgiris, also called as the blue mountains of Western Ghats, harbors shola forest at above 1800 m. They are situated in undulating terrain and house number of endemic plants and animals, as well are the rich source of water. Various studies have pointed out that shola forests present at higher elevation will be affected by environmental factors, which include climate change (Sukumar et al., 1995; Ravindranath et al., 1998; Suresh et al., 2011 and Robin et al., 2012), even a slight or moderate global warming of 1-2<sup>o</sup>C will impact seriously on forest ecosystem. Many studies also predict the regional shift of species and forests due to change in climate variables. However, tropical forests are more susceptible to climate change, which in turn threaten their structure, function and services (Devi et al., 2018). A slight variation will have effect on the habitat of the region and also shift in forest type from lower to higher altitude and rainfall gradients. (Robin et al., 2012)

The time series data of advanced very high resolution radiometer (AVHRR) and normalized difference vegetation index (NDVI) trends has been used to discern direct impact of local climate change. The LST (Land Surface Temperature), were the earth surface temperature which describes the terrestrial and environmental conditions that is most extensively used climatic variable in global change studies (Rajeshwari et al., 2014 and Yang, et al., 2017). In present study an attempt has been made to estimate the land surface temperature and mapping its spatial distribution

**Corresponding Author:-Tabassum Ishrath Fathima.**

Address:-Department of Environmental Sciences, Bangalore University, Bangalore.

for predicting ecological consequences of climate change on selected forest patches of shola covering both north and south of Nilgiris.

For analysing long term changes statistically both parametric and nonparametric techniques have been used, since long time. In 1945, Mann proposed Mann-kendell test and later it was improved by Kendell in 1975, to test the normality and seasonality using non parametric test. It is an dynamic statistical tool to detect the monotonic test of hydrological paramters (Liu Liu, et al., 2012). This trend test helps in scaling up of data to avoid contradictions in trend analysis studies at local and regional levels.

#### **Study Area:-**

Nilgiris is one of the spectacular hill ranges in South India, located at tri-junction of Tamil Nadu, Kerala and Karnataka states, at 76<sup>o</sup>14' E to 72<sup>o</sup> 2' E covering an area of 2453 sq.km, Elevation range of Nilgiri Biosphere Reserve from 23 m to 2665m. It encompasses substantial intact areas of natural vegetation, contributing to rich biodiversity. The topography of Nilgiri Biosphere Reserve varies from low -lying plains (Nilambur plains) and valleys to mountains (Nilgiri plateau) over more than 2000 m height (Daniels, 1992). At an altitude ranging from low elevation (0-600 m) evergreen forests are found in New Amarambalam and Muthikulam-Palghat hills; Medium elevation evergreen forests are found at an elevation range of 600 to 1400 m in Silent valley, new Amarambalam, Attapadi and Nialmur. Shola forests are present above 1800 m appearing in patches.

#### **Methods And Materials:-**

Eight daily LST MODIS composite products collected between January 2003 to December 2016 were used in the present study. The data products were masked for clouds utilizing the quality flag information in each image, followed by sub setting images for the study area. After cleaning for cloud the sub setting images were analyzed for trend using non parametric trend analysis by adopting Mann-Kendell test. The geospatial analysis was carried out by writing a script in google earth engine which combines a multi-petabyte catalog of satellite imagery. The geospatial datasets with planetary-scale analysis capabilities help to detect changes, map trends of the area, and quantify differences on the Earth's surface. Field visits were carried out to the Shola forest regions of Nilgiri district and GPS points were collected using Garmin GPS. Also, the, basal area and other characteristic of shola species were recorded together with surrounding land use database. These GPS points were overlaid on to the trend maps to know the trends in shola regions.

Further, a comparison was attempted from higher to lower elevation in different landscapes along Pykara, Naduvattum, Doddabetta, Longwood, Avalanche and Thai Sholas. For this purpose, three individual quadrates of 20m x 20m (400<sup>2</sup> m), in each Shola were marked. Primary analysis of the vegetation was carried out for selected species from the three sample plots and density, frequency, abundance, basal area and importance value index (IVI) were estimated using the following formulae.

#### **Frequency:-**

It refers to equal distribution of different species in the ecosystem, usually calculated in terms of percentage.

$$\text{Frequency of species} = \frac{\text{Total Number of quadrates in which species occurred}}{\text{Total number of quadrates studied}} \times 100$$

The species which is well distributed and have a chance of being recorded in any part of the ecosystem will have frequency 100 %. While a species which is restricted to certain areas shows low frequency value

**Abundance:-**Abundance of a species is determined as the number of individuals per quadrate.

$$\text{Abundance} = \frac{\text{Total Number of individuals of species occurring}}{\text{Total number of quadrates in which species occurred}} \times 100$$

**Stand density** was determined for each species using estimated number of trees and basal area of the species per hectare. The estimated number of trees of each species per hectare was obtained by extrapolating the total number of trees enumerated in the respective plots using the formula :

$$N = \frac{h}{a} \times c$$

Where h=one hectare

A = area of the plot in hectare

C = number of trees counted in the plot

N = estimated number of trees per hectare.

**Relative density (RD):-**

Is the numerical strength of a species in relation to total number of all species

$$\text{Relative density} = \frac{\text{Density of species}}{\text{Sum of density of all the species}} \times 100$$

**Relative Frequency:-**

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequency of all the species}} \times 100$$

**Relative dominance**

$$\text{Relative dominance} = \frac{\text{Total stand basal cover of the species}}{\text{Total stand basal cover of all the species}} = 100$$

**Importance Value Index (IVI):-**

Importance Value Index emphasizes an overall importance of a species in a community. It is the sum of Relative Density, Relative Basal area and Relative Frequency for each species and is assessed as

$$\text{Importance Value Index} = \text{Relative density} + \text{Relative frequency} + \text{Relative dominance}$$

With the help of IVI a clear ecological status of the species with respect to community structure was obtained by synthesizing the percentage values of relative frequency, relative density and relative basal area or relative dominance.

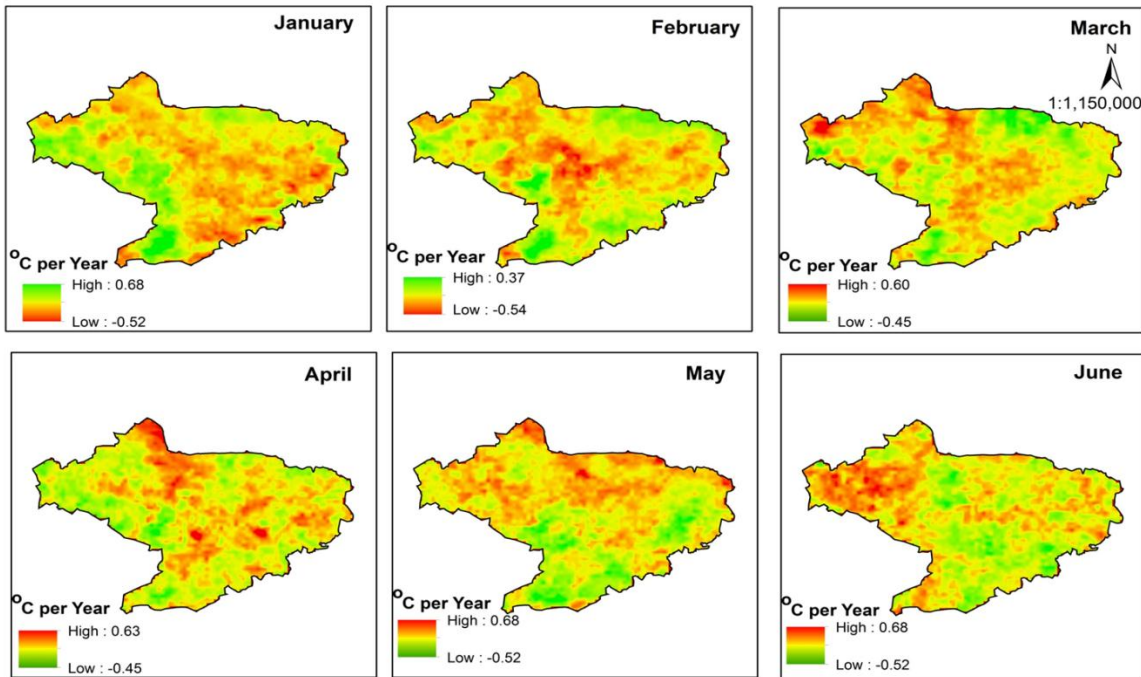
Land surface temperature for all the sampled plots and overall changes in temperature, both night and day were compared with other lower altitude regions and overall trend was assessed using Mankindal test.

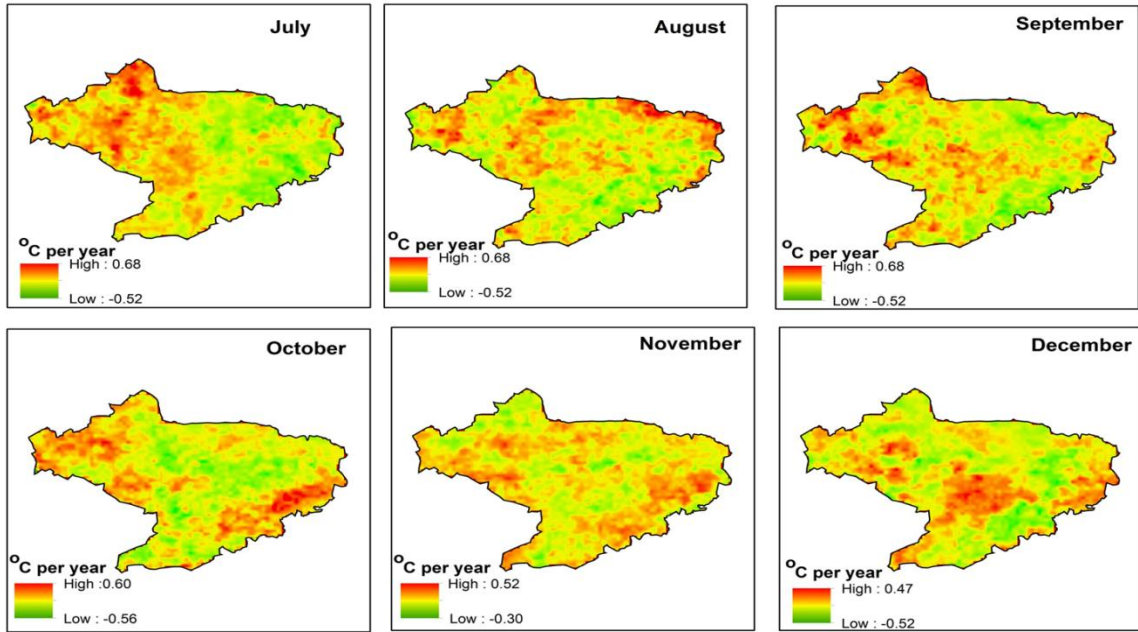
**Results And Discussion:-**

Nilgiri biosphere reserve comprises of moist deciduous forest and evergreen forest towards South-West and scrub forest towards North-East (Singh et al., 2011). Overall, observation is that the land surface temperature increased during night over the past 15 years (Maps 1 & 2), from elevation >2000m msl; <1800-2000 msl; <1500-1000 msl and <1000 msl. Mann-Kindell test analysis and comparison with different landscapes of the region again indicated overall temperature increase in the Nilgiris. The South-West regions of the moist deciduous and evergreen forests are concentrated along with coffee and tea plantation. At this point also temperature is increasing. Surrounding Gudalur dry-deciduous forest comprise of *Tectona grandis*, *Grewia tilifolia*, *Lagerstroemia microcarpa*, *Dillenia pentagyna*, *Dalbergia latifolia*, *Terminalia crenulata*, *Terminalia paniculata*, *Boswellia serrate*, *Anogeissus latifolia* and *Lansea coromandelica* etc., (Singh et al., 2011). At this place the elevation is >900 to 1000m night time temperature is increasing by 0.49°C. At altitude above 1800m MSL and other elevations, with evergreen forest as well as exotic plantations of Acacia, Pinus, Casuarina, Araucaria and Tectona the temperature increased by 0.44°C, as February approaches. The area includes Thaishola, Pykara, Naduvattum, Doddabetta, Avalanche and longwood sholas. From March to June, till the arrival of South East monsoon all the higher altitude regions are experiencing an increase in night temperature by 0.48°C and in June the overall increase is 0.70°C. After the onset of monsoon

during July, a maximum increase of 1<sup>0</sup>C is evident and it gradually comes down to 0.67<sup>0</sup>C during August, as seen at higher altitude region covering part of Thai shola, Avalanche, Longwood, Naduvatum, Pykara and Doddabetta. After the monsoon from August, through September and October all the above Shola regions continue to experience increase in night temperature. During onset of winter overall increase is 0.76<sup>0</sup>C. One possible reason could be possibly because of spread of exotic plantations and various anthropogenic pressures including monoculture agricultural practices.

**Land surface temperature of Nilgiris on day:-**





Land Surface Temperature at Night time:-

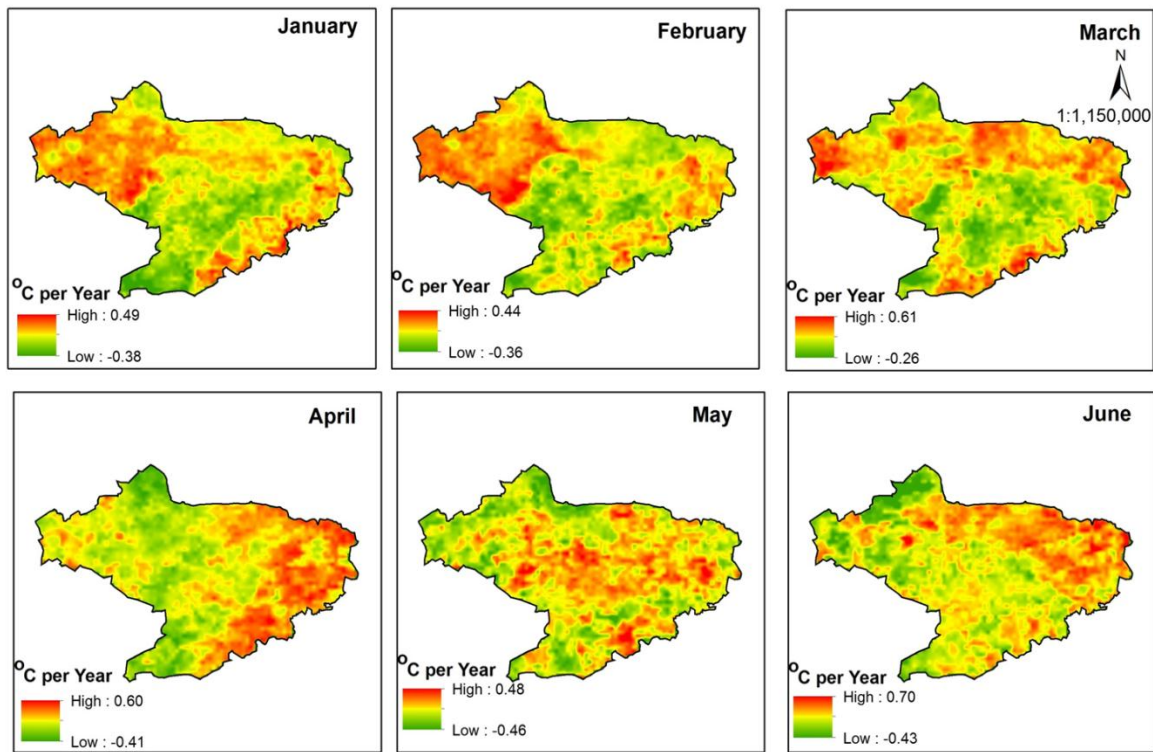


Figure3(a)

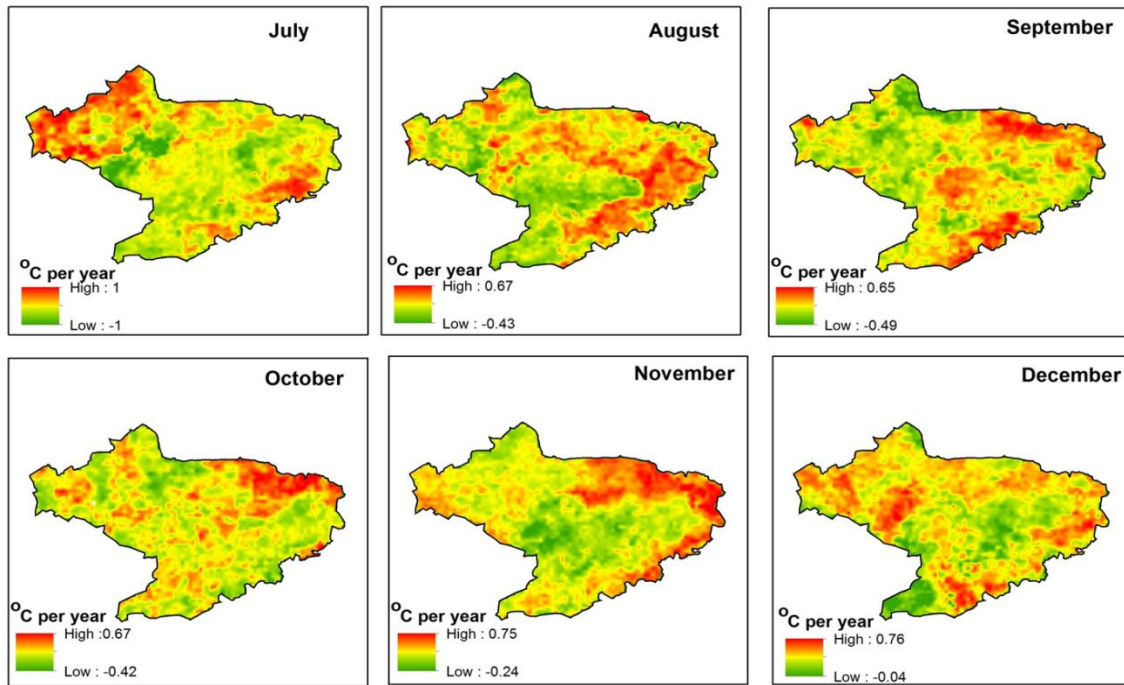
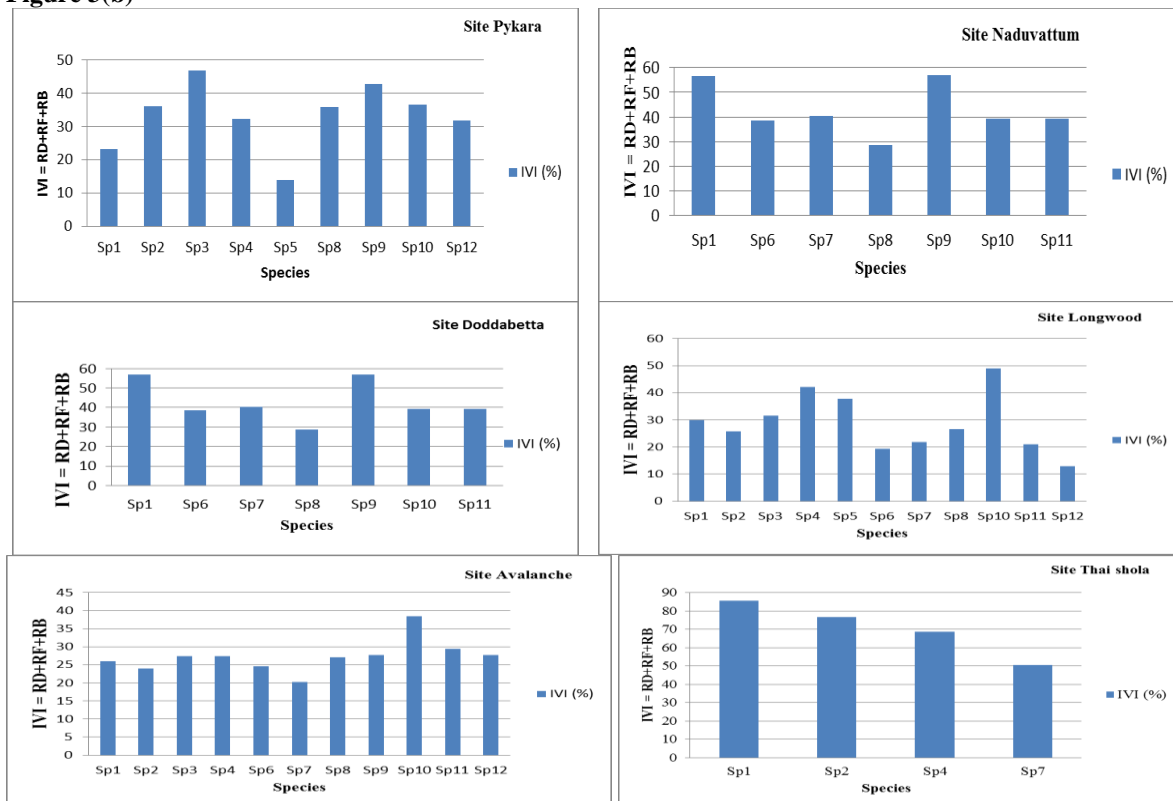


Figure 3(b)



**Chart 1:-**Important Value Index (IVI) of 12 selected species in each plot of the site pykara shola, naduvattum shola, doddabetta shola, long wood shola, Avalanche shola and Thai Shola.

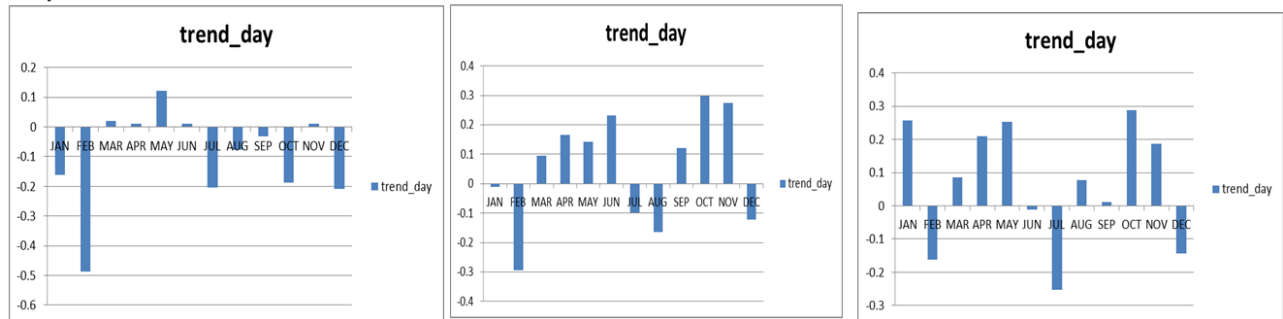
Sp1= *Cinnamomum wightii*; Sp2= *Elaeocarpus recurvatus*; Sp3= *Elaeocarpus munronii*; Sp4= *Elaeocarpus variabilis*; Sp5= *Euonymus crenulatus*; Sp6= *Glochidion ellipticum*; Sp7= *Ilex denticulata*; Sp8= *Magnolia nilagirica*; Sp9= *Mahonia leschenaultii*; Sp10= *Rhododendron arboreum ssp. nilagiricum*; Sp11= *Vaccinium leschenaultii*; Sp12= *Vaccinium neilgherrense*

**Land surface temperature at high altitude Pykara Shola and grassland region:-**

At Pykara, three plots of 20 x 20 m were marked (1) Longitude:76.53059006 and Latitude:11.39101849 (2) Longitude:76.57728195 and Latitude:11.44957389 and (3) Longitude: 76.54792786 and Latitude:11.40582674.

Land surface temperature for both day and night time was screened for 15 year time period and the trend for both day and night was analyzed using Mann-Kindell test. The results showed that in plot two and three during March, April and May there is increasing trend ranging from 0.86<sup>0</sup>C to 0.253<sup>0</sup>C. Whereas in plot three, during January increase in temperature is by 0.257<sup>0</sup>C. In plot one and two, there is decrease in trend in temperature from -0.01<sup>0</sup>C to -0.162<sup>0</sup>C. In plots two and three during winter months in October and November there is an increase ranged from 0.187<sup>0</sup>C to 0.275<sup>0</sup>C during day, probably because of their location adjacent to Acacia, wattle and tea plantations and besides several monoculture agricultural practices. Plot one is located inside, a bit away from Acacia, wattle and tea plantations and the temperature comparatively less. During summer months from March to May, the range of increase between 0.011<sup>0</sup>C and 0.295<sup>0</sup>C. By the end of May following June and July being the monsoon month, night time trend in temperature is increasing ranging from 0.429<sup>0</sup>C to 0.516<sup>0</sup>C, in all the three plots of Pykara region.

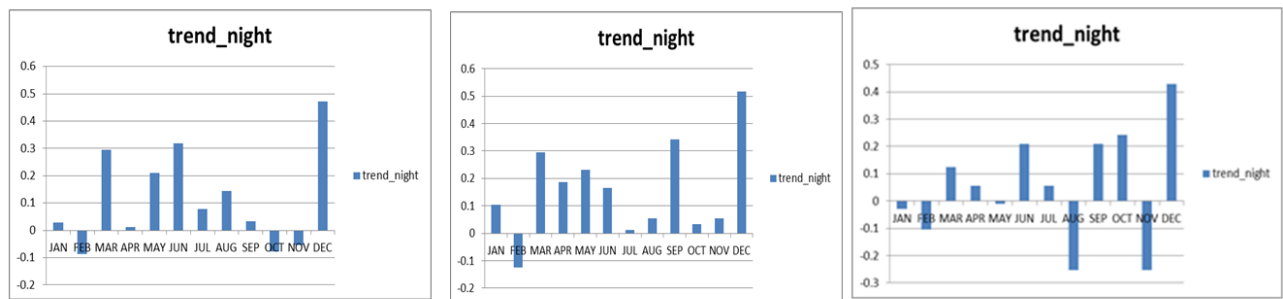
**Pykara**



**a: Trend day - plot 1**

**b: Trend day - plot 2**

**c: Trend day - plot 3**



**d: Trend Night- plot 1**

**e: Trend Night- plot 2**

**f: Trend Night- plot 3**

**Chart 2:-**a,b,c, showing day trend for plot 1,2,3 and d, e, f, showing night trend for plots 1,2,3 for Pykara region

**Vegetation analysis:-**

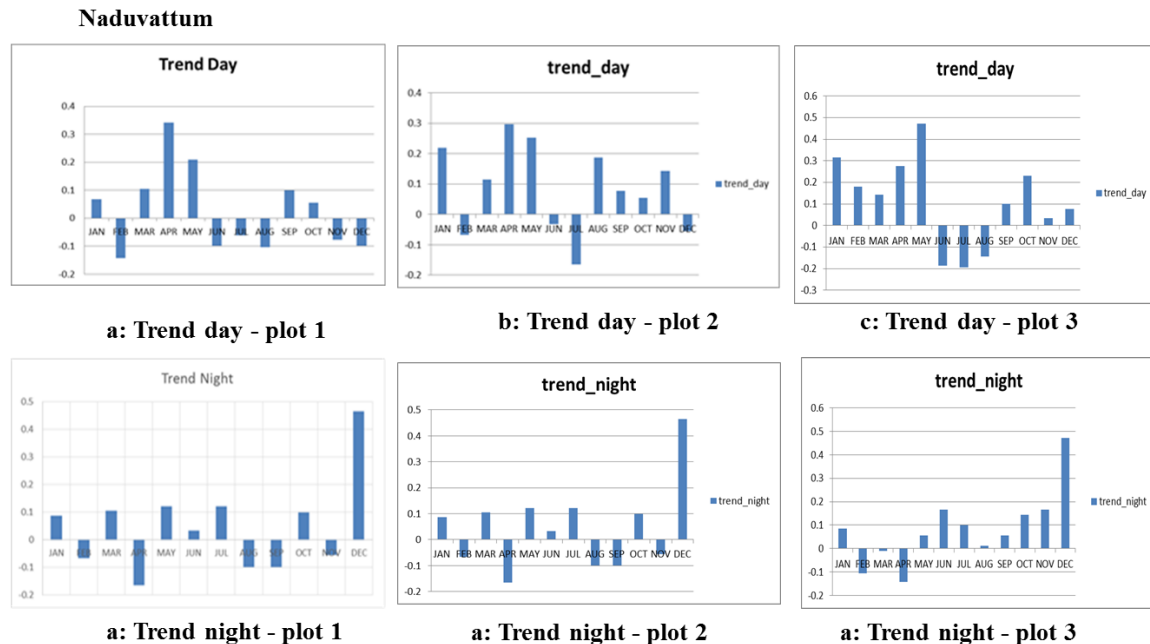
All the species selected for the study are not uniquely distributed in all the selected Shola plots. However, species selected for the study are endemic and confined to high altitude regions of Nilgiris.

### Vegetation analysis of selected woody species of Pykara shola:-

The mean abundance value was 10.18 for the 12 species prioritized for the study. *Elaeocarpus munronii* contributed highest density being 127.78, while *Mahonia leschenaultii* (108.34), *Rhododendron arboreum* ssp. *nilagiricum* and *Magnolia nilagirica* (88.89). The IVI indices are, *Elaeocarpus munronii* (46.95%), *Mahonia leschenaultii* (42.9%), *Rhododendron arboreum* ssp. *nilagiricum* (36.60%), *Elaeocarpus recurvatus* (36.23), *Magnolia nilagirica* (36.01%), *Elaeocarpus variabilis* (32.24%), *Vaccinium neilgherrense* (31.92%), *Cinnamomum wightii* (23.23%), *Euonymus crenulatus* (13.91%) (Chart 1).

### Land surface temperature at high altitude Naduvattum Shola and grassland region:-

At Naduvattum Shola three 20 x 20 m quadrat plots were marked, (1) Longitude:76.53059006 and Latitude:11.39101849 (2) Longitude:76.57728195 and Latitude:11.44957389 and (3) Longitude:76.54792786 and Latitude:11.40582674. Day time temperature showed an increasing trend for all the three plots. Through January till May, range varied from 0.067<sup>0</sup>C to 0.473<sup>0</sup>C. The trend in night time temperature was from 0.086 to 0.1659S. During June and July, there occurred a decrease in day temperature ranging from -0.033<sup>0</sup>C to -0.121<sup>0</sup>C. During peak winter range was -0.55 to -0.099<sup>0</sup>C. The range in night temperature during winter increased from 0.464<sup>0</sup>C to 0.473<sup>0</sup>C.



**Chart 3:-**a,b,c, showing day trend for plot 1,2,3 and d, e, f, showing night trend for plots 1,2,3 for Naduvattum region

### Vegetation analysis of selected woody species of Naduvattum shola:-

Out of 12 species prioritized for the study, 8 species were present at Naduvattum site. Their mean abundance value was 11.88. *Magnolia nilagirica* contributed to higher density of 138.89, along with *Rhododendron arboreum* ssp. *nilagiricum* (136.12), *Euonymus crenulatus* (119.45), *Mahonia leschenaultii* (108.34), *Elaeocarpus recurvatus* (97.23), *Elaeocarpus variabilis* (75), *Vaccinium neilgherrense* (66.67) and *Cinnamomum wightii* (33.34). The IVI indices was highest for *Rhododendron arboreum* ssp. *nilagiricum* (55.16%), *Magnolia nilagirica* (52.14%), *Elaeocarpus recurvatus* (44.90%), *Euonymus crenulatus* (42.85%) and *Elaeocarpus variabilis* (38.14%).

### Land surface temperature at high altitude region of Doddabetta Shola and grassland region:-

At Doddabetta one point was chosen at Longitude:76.73297882 and Latitude: 11.40713084. Here, the day time trend shows increase in temperature upto 0.319<sup>0</sup>C and decrease in the temperature upto -0.341<sup>0</sup>C to -0.143<sup>0</sup>C at nights in October month. Even though Doddabetta represents highest peak of 2100 msl, the night time temperature increased in the range of 0.253<sup>0</sup>C and 0.209<sup>0</sup>C (Chart 3). Doddabetta is present in the middle of the plateau, dividing into two



High altitude region of Avalanche:-

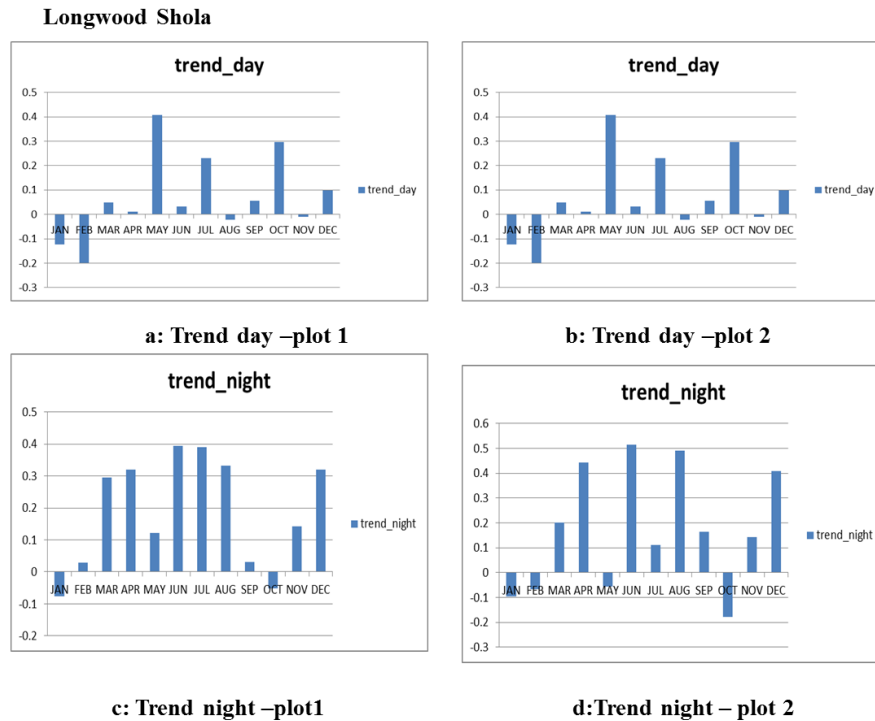


Chart 4: a & b showing day trend t 1 and c & d showing night time trend for 1 & 2 plot

The three plots of Avalanche located are (1) Longitude: 76.60388947 and Latitude:11.29592443 (2)Longitude:76.57899857 and Latitude: 11.29592443 (3) Longitude:76.60886765 and Latitude: 11.30400444. The trend for day as well as night temperature for 15 years showed an overall increase in temperature during February, March, April and May ranging from 20.637<sup>0</sup>C to 25.29<sup>0</sup>C. Comparatively, the increase is more here because of its location adjacent to hydroelectric power station site and monoculture cultivation of cabbage, carrot, potato, beetroot, bean, tea plantations as well as pine plantation. During summer from February to May trend is May (0.253<sup>0</sup>C), June (0.055<sup>0</sup>C), July (0.055<sup>0</sup>C), August (0.055<sup>0</sup>C), September (0.209<sup>0</sup>C) and November (0.231<sup>0</sup>C). During conventional rains in April there is slight decrease in temperature during day (-0.077<sup>0</sup>C) followed by July and October (-0.077<sup>0</sup>C). Thereafter there is increase is an increasing trend in November (0.231<sup>0</sup>C) followed by decrease in December (-0.143<sup>0</sup>C). The night time trend during summer is again on higher side, ranging from (0.143<sup>0</sup>C to 0.181<sup>0</sup>C).

## Avalanche

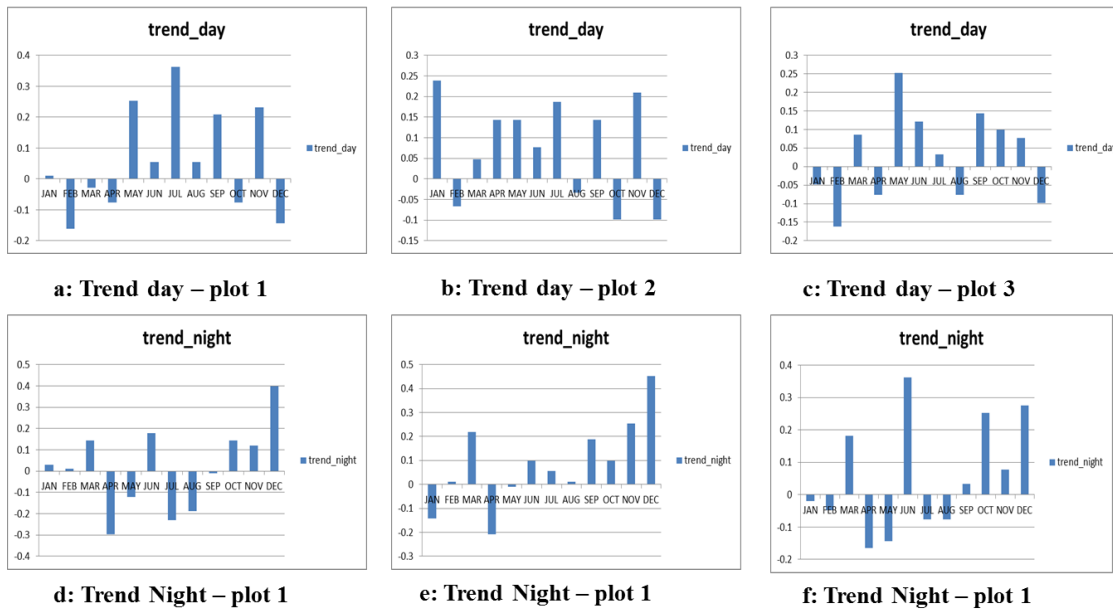


Chart 5: a, b, c, showing day trend for plot 1,2,3 and d, e, f, showing night trend for plots 1,2,3 for Avalanche

## Vegetation analysis of selected woody species of Avalanche:-

All the selected species at Avalanche have a mean abundance value of 37.54. *Rhododendron arboreum* ssp. *nilagiricum* contributed to higher density of 411.12, followed by *Mahonia leschenaultii* (400), *Vaccinium neilgherrense* (372.23), *Vaccinium leschenaultii* (341.67), *Glochidion ellipticum* (297.23), *Elaeocarpus recurvatus* and *Elaeocarpus variabilis* (288.89), *Cinnamomum wightii* (275), *Elaeocarpus munronii* (258.34) and *Ilex denticulate* (227.78). The species maximum IVI indices was 38.48% for *Rhododendron arboreum* ssp. *nilagiricum* followed by 29.37% for *Vaccinium leschenaultii*, *Mahonia leschenaultii* (27.65%), *Vaccinium neilgherrense* (27.64%), *Elaeocarpus munronii* (27.4%), *Elaeocarpus variabilis* (27.32%), *Magnolia nilagirica* (27.13%), *Cinnamomum wightii* (26.05%) and *Elaeocarpus recurvatus* (24.03%).

## High altitude Thai shola region:-

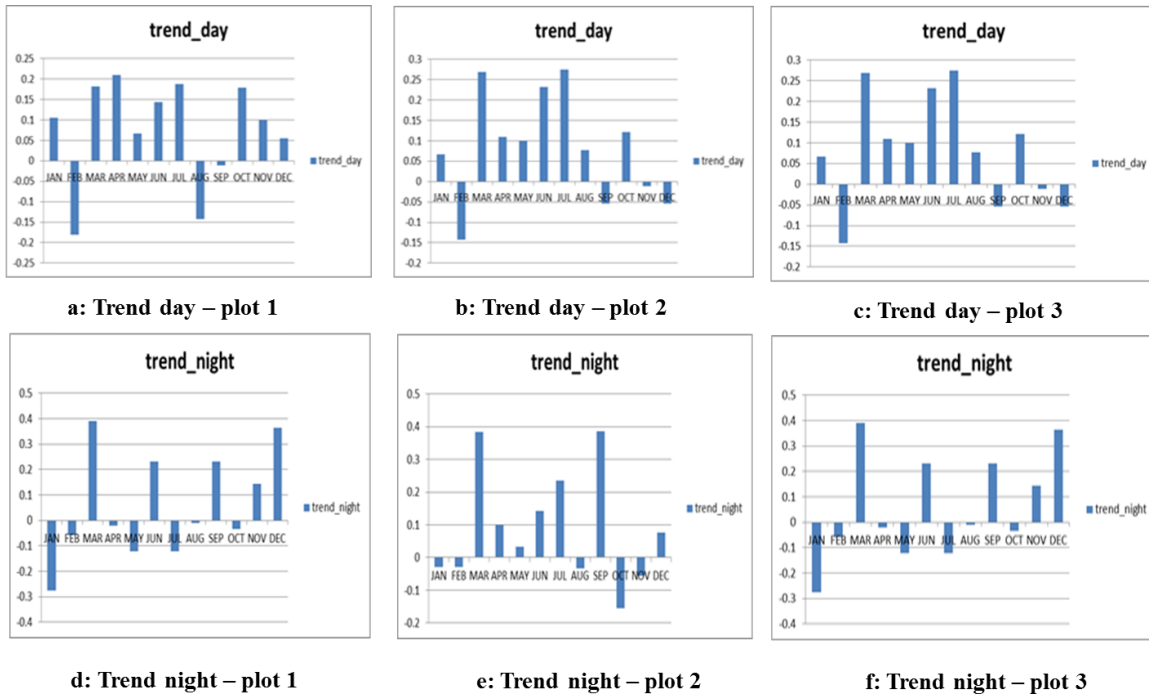
The three plots in Thai shola are located at (1) Longitude: 76.60440445; Latitude:11.21241762 (2) Longitude:76.62912369; Latitude:11.22016322 (3) Longitude: 76.60852432; Latitude: 11.21174408.

Thai is the Tamil name, which means “mother”, it is a mother of all the shola, one of the biggest shola patch in Nilgiris. At thai shola increase in temperature was observed in all the plots, day temperature in these plots ranging from 0.275<sup>0</sup>C to 0.231<sup>0</sup>C. Summer months like March to May the temperature range from 0.11<sup>0</sup>C to 0.209<sup>0</sup>C, during onset of monsoon till June and July, increase in day temperature ranging from 0.143<sup>0</sup>C to 0.275<sup>0</sup>C, whereas during onset of winter in October there is increase in temperature ranging from 0.121<sup>0</sup>C to 0.179<sup>0</sup>C whereas plot two, in November and December months also there is an increase in temperature by 0.099<sup>0</sup>C and 0.055<sup>0</sup>C whereas plot one and plot three, there is decrease -0.011<sup>0</sup>C to -0.055<sup>0</sup>C compared with night time temperature trend, it shows that, during summer months like March temperature is increasing ranging from 0.383<sup>0</sup>C to 0.39<sup>0</sup>C. In plot two, April, May during summer and during winter months June and July, night time temperature is increasing for all the months ranging from 0.099<sup>0</sup>C to 0.236<sup>0</sup>C, September month also shows increase in night time temperature ranging from 0.232<sup>0</sup>C to 0.385<sup>0</sup>C, November and December being the peak of winter, night time temperature is increasing ranging from 0.077<sup>0</sup>C to 0.363<sup>0</sup>C, whereas only in plot two, November month decrease in temperature was observed about -0.055<sup>0</sup>C.

The variation of temperature is entirely dependent on environmental conditions of the region. Thai shola is covered by blue gum, wattle and Thai shola tea estate as well as Carrington tea estate present just beside Thai shola and these tea estate extend upto Korakunda range, during field survey it was observed that landslide has occurred two years

back. It is also observed that in Thai shola is having dry deciduous forest, temperature is increasing in the area, reduction in the rainfall when compared to other shola forest, invasive species like lantana trives very well in hot regions. 50% of the Thai shola is mixed with semi evergreen and evergreen element like Notopogenia heliana, Garcinia cambogia, Santalum album, having symbiotic association with Lantana camera. All the evergreen element regeneration has been observed.

**Thai shola**

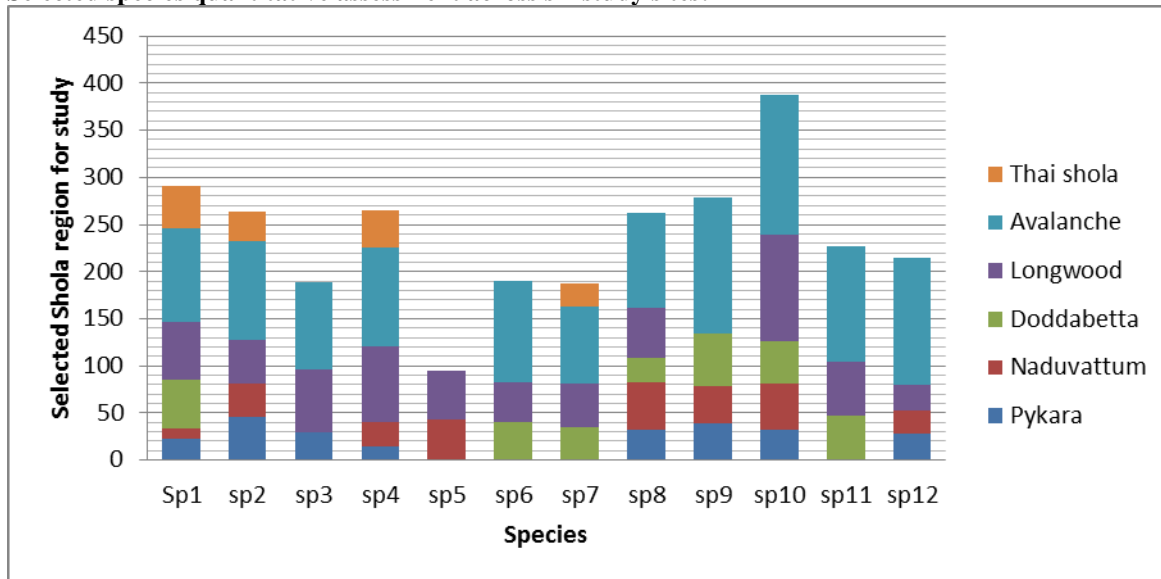


**Chart 6: a, b, c, showing day trend for plot 1,2,3 and d, e, f, showing night trend for plots 1,2,3 for Thai shola**

**Vegetation analysis of selected woody species of Thai shola:-**

All the species exhibited a mean abundance value of 12.75. *Cinnamomum wightii* contributed to higher density with 125; *Elaeocarpus variabilis*, 111.12; *Elaeocarpus recurvatus*, 88.9 and *Ilex denticulate*, 66.67. The IVI indices was highest for *Cinnamomum wightii* (85.5%), *Elaeocarpus recurvatus* (76.7%), followed by *Elaeocarpus variabilis* (68.6%) and *Ilex denticulate* (50.57%)

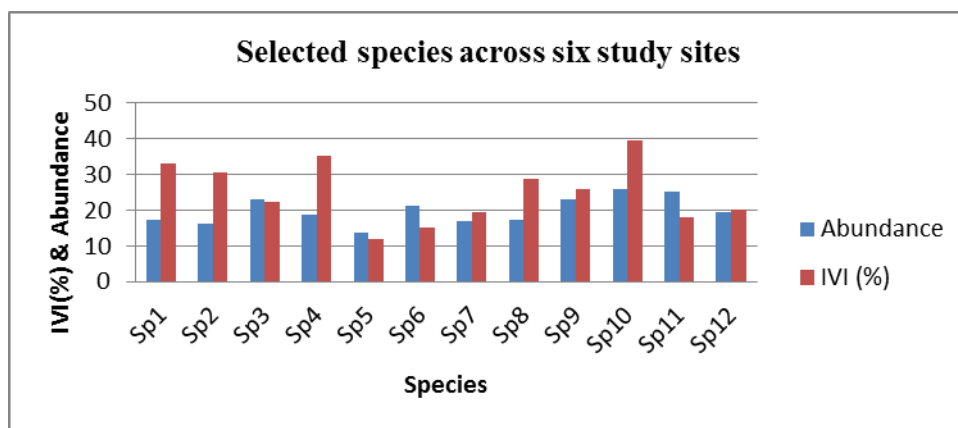
**Selected species quantitative assessment across six study sites:-**



**Chart 7:-**Selected species presence across six study sites, Pykara Shola, Naduvattum shola, Doddabetta shola, Longwood Shola, Avalanche shola and Thai shola in the Nilgiri region, Western Ghats of South India

Sp1= *Cinnamomum wightii*; Sp2= *Elaeocarpus recurvatus*; Sp3= *Elaeocarpus munronii*; Sp4= *Elaeocarpus variabilis*; Sp5= *Euonymus crenulatus*; Sp6= *Glochidion ellipticum*; Sp7= *Ilex denticulata*; Sp8= *Magnolia nilagirica*; Sp9= *Mahonia leschenaultii*; Sp10= *Rhododendron arboreum* ssp. *nilagiricum* ; Sp11= *Vaccinium leschenaultii*; Sp12= *Vaccinium neilgherrense*

A general look across the shola indicate that Sp1(*Cinnamomum wightii*) is present across all the sholas, whereas Sp2 (*Elaeocarpus recurvatus*), Sp4 (*Elaeocarpus variabilis*), Sp8 (*Magnolia nilagirica*) and Sp10 (*Rhododendron arboreum* ssp. *nilagiricum*) are present in five different sites; Sp7, Sp9 and Sp12 are in four study sites; Sp3 (*Elaeocarpus munronii*), Sp6 (*Glochidion ellipticum*) and Sp11(*Vaccinium leschenaultia*) are present in 3 sites whereas Sp5 (*Euonymus crenulatus*) is present in two sites of shola.



**Chart 8:-**Across all the six study shola site

The highest IVI value was found to be 39.49% for Sp10, followed by 35.14% for Sp4 (*Elaeocarpus variabilis*) and Sp1 (*Cinnamomum wightii*) 30.49% for Sp2 (*Elaeocarpus recurvatus*) respectively. Highest abundance value was about 25.23 for species Sp11(*Vaccinium leschenaultia*) followed by 23.17 for Sp9 (*Mahonia leschenaultia*) and 22.9 for Sp3 (*Elaeocarpus munronii*) respectively.

### Conclusion:-

All the species selected for the study are endemic shola species confined to high altitude region. From the MODIS-LST used to assess the possible important of climate and atmospheric variables on high altitude regions of Nilgiris in the present research it shows an increase in temperature at all the shola sites selected for the study. Shola species take quite a long time to regenerate. Being climate complex (Sukumar et al., 1995 and Robin et al., 2012) with the increase in temperature, other lower altitude evergreen species are getting adapted to high altitude region which was observed in Thai shola. Invasive species like *Cestrum* is found to be well adapted to selected study sites and, in Thai shola, *Lantana* species is rampant, an indication of increase in temperature (Thomas and Palmer 2007), where shola species that require immediate attention, those species need to be identified and develop conservation action to be implemented at the sites itself.

Mohandas, et al., (2016) opined that increase in temperature could also impact a shift in the phenology, which would disturb the pollinators affecting the reproduction, growth of shola species, with dominating climate of the region. Therefore, the study on land surface temperature is the best spectral indicators for identifying climate change impact on regional scale and, it helps in developing long term conservation plan for RET species on long term basis.

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