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Full Length Research Paper

Role of sacred groves in ameliorating microclimate: A case study of Nagdev temple forest of Pauri Garhwal, Uttarakhand Himalaya, India

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To show the role of sacred grove in rejuvenating the microclimate, a study was conducted at the temple forest of Nagdev area (Latitude 30° 8' 30" N and Longitude 78° 46' 25" East) of Pauri Garhwal in Uttarakhand Himalaya, India. Nagdev temple forest area was compared with a nearby (control) site, having relatively more biotic disturbances. Weather parameters viz. temperatures- maximum and minimum, wind velocity, rainfall, sunshine hours, etc. have been collected from both study sites, compiled for monthly and annual values and compared. Daily climatic variables showed significant differences in some of the parameters. There are marked variations in the range of daily observations of all the microclimatic parameters of both sites. Relative humidity values both at morning and evening hours have clear differences, similarly, maximum and minimum temperatures have also shown remarkable differences, particularly lower range of minimum temperature at control site was -7.1°C, whereas it was -2.8°C in the temple forest. There were more days (12 days) with minus temperatures at control site as compared to temple forest (4 days). Snowfall was also high in the control site as compared to temple forest; bright sun shine hours and wind speed values are more at control site than temple forest site. Vegetation of both sites was studied following standard nested quadrat method for trees, shrubs and herbs. Phytosociological parameters of the study sites reveal that tree, shrub and herb species were more in number at temple forest site than the control site. All phytosociological parameters of tree, shrub and herb species common at both sites also showed differences in these parameters at both sites. Surface soil of both sites were also analysed for physicochemical attributes of their replicate samples and compared. Average values of soil samples for their different attributes have also shown clear variations in their ranges at both sites.

Key words: Nagdev temple forest, Pauri Garhwal Himalaya, Uttarakhand, vegetation, soil, microclimatic data.

INTRODUCTION

Sacred groves are important reservoirs of biodiversity, preserving indigenous plant species, particularly medicinal, aromatic and other ecologically and economically important plants. Joshi and Gadgil (1991) reported that sacred grove might serve important refugia for threatened and rare species. Besides, they preserve genetic diversity of even the common trees (Nair et al., 1997).

These groves have traditionally been conserved in the

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past, however, in the recent times, the scenario has changed due to decline in traditional value systems. Some authors have reported the depleting values of these groves, which is making them to perish (Chandran and Gadgil, 1993; Chandran, 1997; Singh et al., 1998). With improved accessibility and urbanization, sacred areas have turned into tourist places to serve economic interest (Saxena et al., 1998).

Sacred grove in hills of Garhwal and Kumaon (Uttarakhand) are mentioned in old Hindu scriptures like the *Puranas*. Believing trees to be abode of gods and ancestral spirits, patches of forests near villages are established, where deity/deities are worshipped. The trees/vegetation growing in these groves are not cut, as it is believed to belong to the deity. Only the dead/dried parts are sometimes used as has also been mentioned by Negi (2012). Even sometimes, sudden dying of trees of these forests are said to be indication of misha-ppenings/misfortune for the nearby villages. This type of restriction in these forests has helped conservation of native/indigenous species in these groves.

There are several studies on sacred groves in India, but only a few studies are from Uttarakhand. There are some well known sacred groves which truly represent the wealth of a religion based conservation traditions as reported by Bisht et al*. (*2007), Adhikari and Adhikari (2007), Angihotri et al*.* (2010 and 2012), Anthwal et al. (2010), Negi (2010), Gokhale et al. (2011), Pala et al. (2012) and Singh et al. (2010, 2011, 2012, 2013). Even though the biological diversity of Himalaya is very rich, there is little information available on the sacred groves and the conservation of biodiversity in Garhwal Himalaya (Sinha and Maikhuri, 1998).

It is very difficult to report the exact number of sacred groves in Uttarakhand, however, efforts made by some authors like 32 sacred groves by Sinha and Maikhuri (1998), Bisht et al. (2007) and 128 sacred groves by Negi (2010) are appreciable.

The present study was conducted at Nagdev temple forest in Nagdev Forest Range of Pauri Garhwal Forest Division of Uttarakhand Himalaya, India. The study reveals the status of plant diversity (in compartment 4 and 5), soil and meteorological variations inside the temple forest (a reserved forest) and nearby non-reserved forest area, which has comparatively more biotic interference Photos 1 and 2.

Study site

Nagdev Forest Range comes under Pauri Garhwal Forest Division of Uttarakhand Forest Department (Map 1). The altitudinal range is from 1805 to 2500 m msl and lies at Latitude 30° 8’ 30” N and Longitude 78° 46’ 25” East. The total forest area under Nagdev range is 6641.3 ha of which area of 336.7 ha comes under Nagdev Block.

The experimental area of present study lies under Nagdev Block and covers Compartment No. 4 covering an area of 11.5 ha and Compartment No. 5 with an area of 31.4 ha. Thus, the total area covered under Nagdev temple forest site is 42.9 ha. The nearby area is considered as control site covering an area of about 30 ha. Plants present in this area are being exploited by the nearby villagers to meet their requirement of fuelwood and fodder, thus biotic disturbance is high.

Map 1 shows location of Pauri Garhwal (Garhwal) in Uttarakhand. Map 2 shows Pauri Garhwal Forest Division and location of Nagdev Forest Range in Pauri Garhwal Forest Division. Map 3 shows location of compartments 4 and 5 in Nagdev Forest Range, which represents site II, alongwith nearby relatively disturbed area as control site or site I of the present study.

MATERIALS AND METHODS

Microclimatic studies

To study the microclimatic status of both sites, weather stations were installed inside Nagdev Temple Forest area (site II) and nearby control area (site I). Thermometers for maximum tempe-rature, minimum temperature, wet bulb and dry bulb temperatures were installed inside Stevenson’s double screen for daily recording of maximum and minimum temperatures, wet bulb and dry bulb temperatures for calculation of relative humidity as per conversion tables of India Meteorological Department (IMD), Pune. Other instruments used were rainguage for daily rainfall recording, 3-cup Anemometer for recording of wind speed per hour and per 24 hours and sun shine recorder for recording sunshine hours (per 24 hour) from both sites.

Statistical analyses of these parameters were done by using GenStat Discovery Edition 3 by using general ANOVA.

Vegetational attributes

Tree, shrub and herb species were studied for their structural analysis by laying out nested quadrats as per Mishra (1968). The structural analysis, that is, frequency, density and abundance was studied as per Curtis and McIntosh (1950). The relative frequency, relative density and relative dominance and importance value index (IVI) were determined following Phillips (1959).

Soil samples were collected from 0-30, 30-60 and 60-90 cm depths. Mechanical and chemical analysis was done in the laboratory by following standard methods like pH by Richard's method (1954), organic carbon by Maynard (1991), nitrogen by ‘Macro Kjeldahl’ method (Loomis and Shull, 1937), phosphorus (P), potassium (K) and calcium (Ca) by Vogel's method (1961) and magnesium (Mg) by Young and Gill (1951) method.

RESULTS

Microclimatic studies

Daily data of wind speed (km hr^{-1}), maximum, minimum temperatures (°C), rainfall (mm), sun shine hours were collected from weather stations installed at both study sites (site I = control site, site II = Nagdev Temple Forest site). The daily data of 2008 and 2009 were compared at both sites.

Photo 1. Nagdev temple, Pauri, Garhwal Himalaya, India.

Photo 2. *Cedrus deodara* and C*upressus torulosa* trees at Nagdev temple forest area.

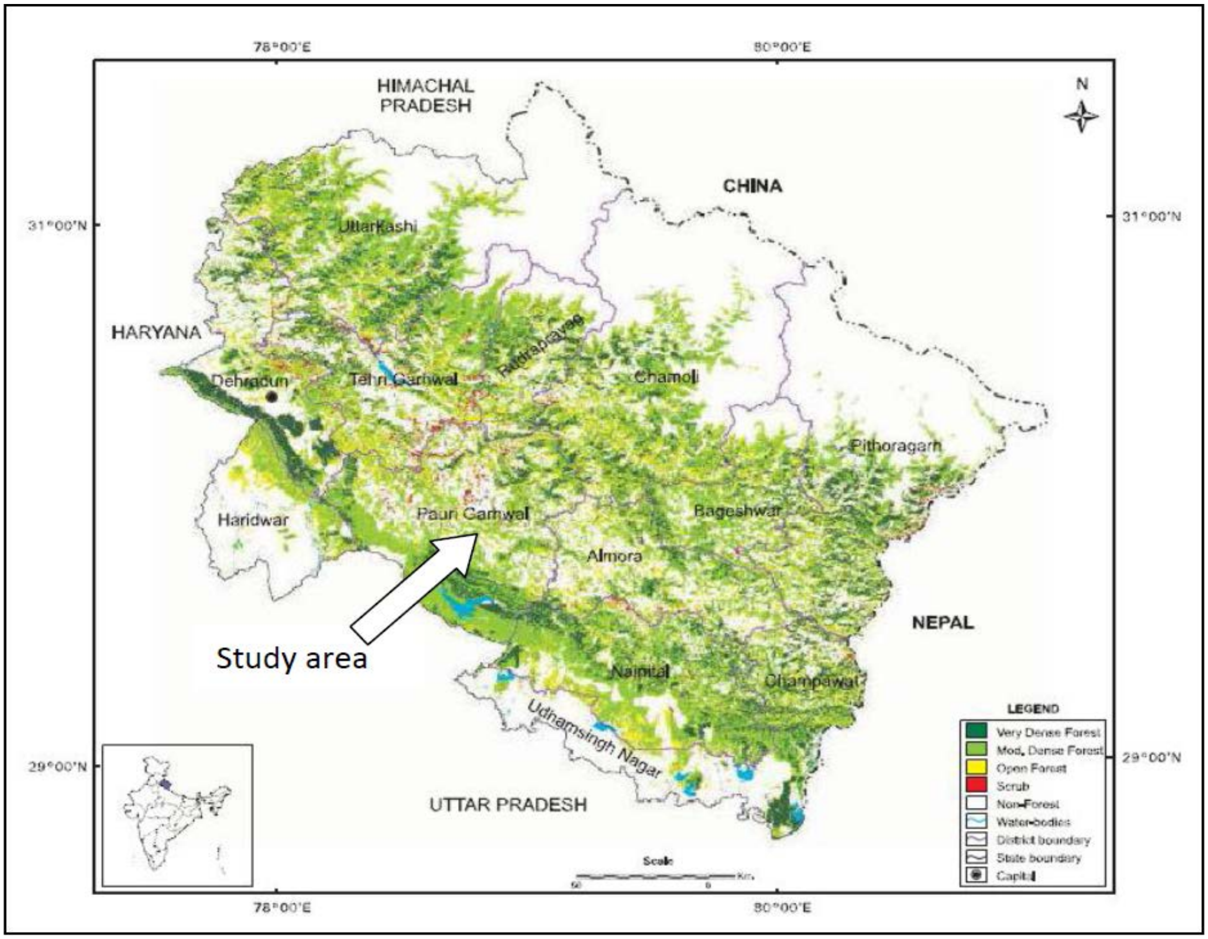
Average monthly and yearly values of both tsites were calculated from the daily data of all parameters. Average wind speed during 2009 was 1.4 km hr^{-1} more at site I as compared to site II, values of 2008 did not show much difference. Minimum temperature was higher during both years (2008 and 2009) at site II, maximum temperature was high (23.51°C) in temple forest than control site (21.66°C) during 2009, but during 2008 there was no much difference in maximum temperature.

Total rainfall was quite high at site II during 2008 (1158.9 mm), whereas at site I, it was 812.5 mm. Contrary to the total rainfall of 2008, the values of rainfall during 2009 were almost equal (577.2 and 577.7 mm, respectively) at site II and site I, as can be in Figure 1. It is noted that the difference in rainfall during the month of July of both years is higher at site II. It seems that the difference in April and July rainfall of 2008 has contributed to the difference of total rainfall (1158.9-812.5 = 346.4 mm) of this year.

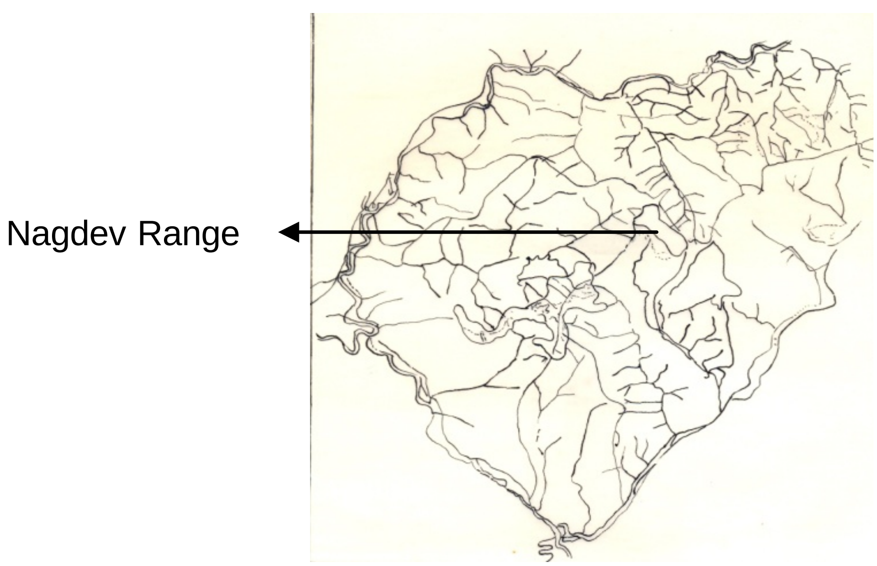
Average sunshine hours have shown difference of 1 h at control site as compared to temple forest (5.7 and 6.7, 6.2 and 7.3) during 2008 and 2009, respectively. Statistical analysis of these parameters using Microsoft Excel GenStat Discovery Edition 3 by using general ANOVA is depicted in Table 1. ANOVA among the months of two sites during 2008 and 2009 were analysed, which showed significant variation in the wind speed between the sites, as can be seen clearly in Table 2. Wind speed was higher at site I, that is, control site (3.32 Km hr^{-1}) than Temple forest area (2.33 Km hr^{-1}). The variation is significant at 5% level as revealed from the table (LSD, 0.44).

Variation in rainfall among months between the two sites is not significant (Table 2), although the total annual rainfall was quite comparable between the sites during 2008. This may be because of natural variability in rainfall during both study years, as is evidenced from the table also, which shows average rainfall of 58 and 72 mm at sites I and site II, respectively.

Variation in minimum temperature among months is not significant between the two sites as is clear from the table, but the annual average minimum temperature values are quite comparable as can be seen in the table. The minimum temperature at the control site was lower (9.68 and 9.06 during 2008 and 2009, respectively) than at the temple forest area site (11.21 and 11.01, during 2008 and 2009, respectively). Variation in maximum



Map 1. Location of Pauri Garhwal (Garhwal) in Uttarakhand, India.



Map not to scale

Map 2. Pauri Garhwal Forest Division.

Map 3. Location of study sites in Nagdev Range (Compartment 4 and 5). Map not to scale.

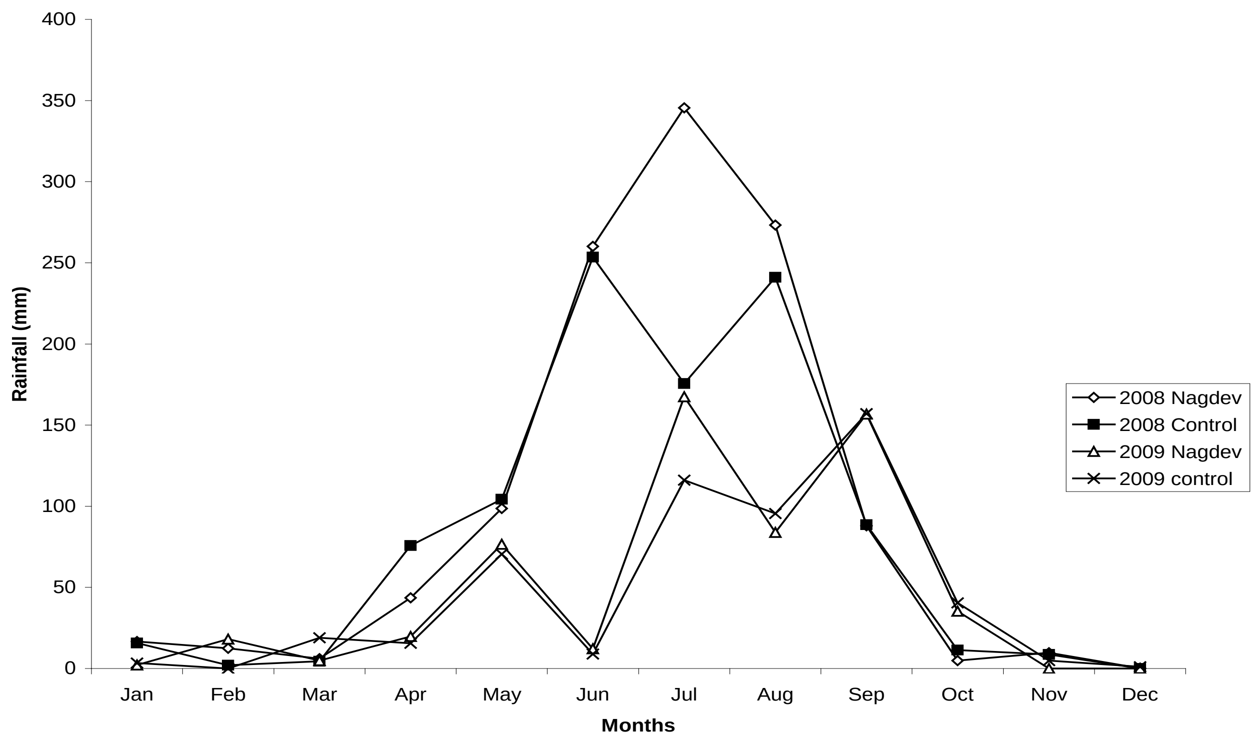


Figure 1. Monthly rainfall (mm) at Nagdev temple forest and the control site.

temperature among months is not significant between the two sites as is clear from Table 2. The maximum temperature at control site is 21.6°C, whereas it is 23.51°C in temple forest during 2009.

For sunshine hours, ANOVA among the months of two sites and between two years were analysed, which showed significant variation between the sites, as can be seen clearly from the Table 2. Sunshine hours are higher at site I (7.04) than Temple forest area (5.98). The variation is significant at 5% level as is revealed from the table (LSD, 1.015). Variability in meteorological data between two years is natural, as is clear from data of 2008 and 2009 at both study sites.

Phytosociological or vegetational studies

Seven tree species were recorded from control site,

Table 1. Statistical variation in different climatic parameters.

Parameter	Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Wind speed (km hr^{-1})	Site	1	11.7019	11.7019	20.05	<.001
	Residual	46	26.8433	0.5836		
	Total	47	38.5452			
Rainfall (mm)	Site	1	2493	2493	0.33	0.568NS
	Residual	46	347190	7548		
	Total	47	349683			
Minimum Temperature (°C)	Site	1	36.21	36.21	1.70	0.198NS
	Residual	46	976.94	21.24		
	Total	47	1013.15			
Maximum temperature (°C)	Site	1	12.0	12.0	0.73	0.398NS
	Residual	46	759.16	16.5		
	Total	47	771.16			
Sun shine hrs	Site	1	13.504	13.504	4.43	0.041
	Residual	46	140.249	3.049		
	Total	47	153.754			

Table 2. Variation in different climatic parameters at both sites.

Site	Wind speed (Km hr^{-1})	Rainfall (mm)	Minimum temperature (°C)	Maximum temperature (°C)	Sun shine hours
I	3.32	58	9.37	21.63	7.04
II	2.33	72	11.11	22.63	5.98
Mean	2.83	65	10.24	22.13	6.51
LSD	0.44	NS	NS	NS	1.015

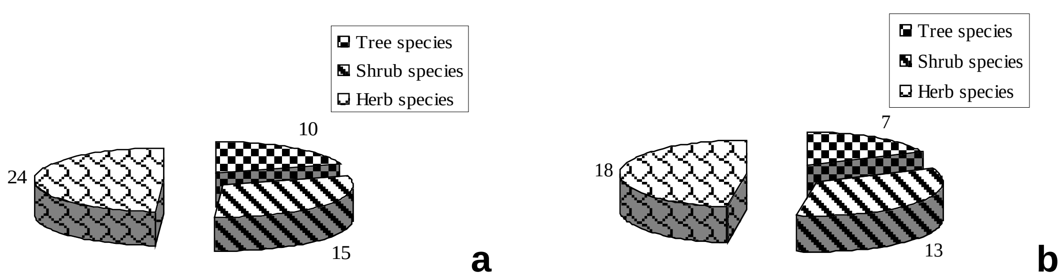


Figure 2. a and b shows number of tree, shrub and herb species at sites I and II.

whereas 10 were recorded from temple forest site (Figure 2a and b), out of which 6 tree species were common at both sites, these were *Cupressus torulosa* Don., *Myrica esculenta* Buch.-Ham. ex D. Don, *Cedrus deodara* Loud., *Quercus leucotrichophora* A. Camus ex Bahadur, *Rhododendron arboreum* Sm., *Pinus wallichiana* AB Jackson. Control site has *Pinus roxburghii*
Sarg. trees in addition to these, which is indicator of disturbances at the site.

Shrub species recorded were more (15) at temple forest site than at the control site (13). Likewise herb species were more (24) at temple forest site as compared to control site (18). Some of shrub species are *Ilex dipyrena* Wall., *Rosa macrophylla* Lindl., *Strobilanthus wallichii* Nees., *Daphne papyracea* Wall., *Berberis aristata* DC., *Rubus ellipticus* Sm., *Lespedeza gerardiana* Grah., *Smilax parvifolia* Wall. etc. and herb species are *Achyranthes aspera* Linn., *Berberis aristata* DC., *Delphinium denudatum* Wall., *Oplismenus compositus* (Linn.) P. Beauv., *Oplismenus burmannii* (Retz.) Beauv., *Fragaria indica* Andrews, *Centella asiatica* (L.) Urb., *Ocimum basilicum* Linn., *Adiantum lunulatum* Burm.,

Table 3. Variations in the daily climatic data, soil and vegetational attributes at temple forest and control sites.

Parameters studied	Study site	
	Temple forest (Site II)	Control (Site I)
Microclimatic attributes		
Relative Humidity (%)		
Morning	61 to 100	28 to 100
Evening	50 to 100	5 to 99
Temperatures (°C)		
Maximum	7.7 to 31.5	5.7 to 29.1
Minimum	-2.8 to 15.0	-7.1 to 11.5
Bright Sun shine Hours	1 to 9.5	1 to 10.8
Wind speed (km hr^{-1})	0 to 4.69	0 to 14.28
Vegetational attributes*		
No. of tree species	10	7
No. of Shrub species	15	13
No. of herb species	24	18
Soil		
Texture	sandy- to loam	sandy- to sandy loam
Moisture	26.46%	10-35%
N	0.17-0.31	0.08-0.18
P	0.01-0.06	0.01-0.03
Ca	0.52-0.69	0.21-0.41
Mg	0.08-0.14	0.03-0.09
C	0.12-1.49	0.08-0.17

*Basal area, IVI, cd and species evenness values of 6 common tree species were more at temple forest site than control site.

Cyperus kyllinga Endi., *Clematis gouriana* Roxb. ex DC., *Rubus ellipticus* Sm., *Olea glandulifera* Wall., *Oxalis latifolia* Kunth, *Neyraudia arundinacea* Munro., *Ajuga parviflora* Benth., *Flueggea microcarpa* Bl. etc.

While calculating similarity index of herb species, dissimilarity index was more (0.6) at temple forest site as compared to the control site. This clearly indicates the role of temple forest in conservation of microclimate, which in turn has great influence on growth of herb species in any area.

While comparing basal area, IVI, diversity index, concentration of dominance (cd) and species evenness values of 6 common tree species at both sites, it was noted that basal area and species diversity index of *C. deodara, Q. leucotrichophora* and *R. arboreum* are more at temple site; IVI and cd of *Q. leucotrichophora* and *R. arboreum* are more at temple site; species richness of all 6 tree species is higher at temple forest site as compared to the control site.

Soil

Surface soil (0-30, 30-60 and 60-90 cm) were taken from both study sites and analysed for their attributes like texture, moisture, nutrients namely nitrogen, phosphorus (P), calcium (Ca), magnesium (Mg) and carbon (C). Both sites have shown remarkable differences in all these parameters. The range of all these parameters is given in Table 3, which clearly shows the ranges of nutrients alongwith moisture higher (26-46%) at temple forest site site II than site I (10-35%). The texture varied from sandy to loam at site II, where as it ranged from sandy to sandy loam at site I. N varied from 0.17 to 0.31%, P from 0.01 to 0.06%, Ca from 0.52 to 0.69%, Mg from 0.08 to 0.14% and C from 0.12 to 1.49% at site II. At site I N varied from 0.08 to 0.18%, P from 0.01 to 0.03%, Ca from 0.21 to 0.41%, Mg from 0.03 to 0.09% and C from 0.08 to 0.17, which are quite high at temple forest site i.e. site II.

DISCUSSION

Daily meteorological data have more importance than average values of months or years, as extreme climatic variables have great impact on local weather. Hence, it is worthwhile to compare daily data of both sites along with average values. Average monthly and yearly values of both the sites have been given in Table 3 for the year 2008 and 2009. There are marked variations in the range of daily observations of all the microclimatic parameters of both sites. Relative humidity values at both morning hours and evening hours have clear differences, similarly maximum and minimum temperatures have also shown remarkable differences, particularly lower range of minimum temperature at control site is -7.1°C, where as it is -2.8°C in the temple forest. There were more days (12 days) with minus temperatures at control site as compared to temple forest (4 days). Snowfall was also high in the control site (there was snowfall of 16.1 mm on 11th and 29.3 mm on 12th February 2009) as compared to temple forest; Bright sun shine hours and wind speed values are more at control site than temple forest. Average values of soil attributes have also shown clear variations in the range.

Blanketing effect of temple forest is clearly depicted by the data of minimum temperature, as it is higher in temple forest (11.11°C) as compared to control site (9.37°C). Similarly, more wind speed and sunshine hours at the control site shows more openness and more desscation at control site, resulting to more evaporation and less soil moisture, which are very important microclimatic effects of this temple forest or sacred grove.

Conclusion

Although, there are many reports on general aspects of the sacred groves (Gadgil and Vartak, 1976; Boojh and Ramakrishnan, 1983; Khiewtan and Ramakrishnan, 1989; Ramakrishnan, 1996; Sinha and Maiklhuri, 1998; Basu, 2000, Murugan et al., 2008; Bhakat et al., 2003; Negi, 2010; Agnihotri et al., 2010; Gokhale, 2011), data based research results on different ecological/-microclimatic aspects of sacred groves are lacking. Hence, the data based research results of the present study can be of great importance for conserving the microclimate/modifying the microclimate of such sacred groves/temple forests or reserved forest areas.

There is an urgent need for recognizing these traditionally valued natural systems at various levels and planning for their better management, ultimately aiming to conserve biodiversity and microclimate. In this context, traditional values that help in conservation should be properly recognized and acknowledged.

Considering the present conditions of the groves, they can be used as repositories of endemic plants, soil seed bank, connective corridor for birds and animals in human dominated landscapes. Therefore, it requires combined and holistic approach to conserve the grove tradition in nearby villages.

Finally, the need of the hour is to make people aware of the importance of such sacred areas, involve people in their conservation and management, and explore their potential in improvement of livelihood of the nearby local inhabitants.

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