Current World Environment Vol. **12**(1), 97-106 (2017)

Impact of Micro-climatic variations on Forest Ecosystem in Mid Hills of Himachal Pradesh

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http://dx.doi.org/10.12944/CWE.12.1.12

(Received: December 06, 2016; Accepted: March 09, 2017)

ABSTRACT

A study was carried out on “Impact of micro-climatic variations on forest ecosystem in mid hills of Himachal Pradesh” during winter and summer seasons of 2015-16. Comparisons of below forest canopy and open sites were carried out for abiotic and biotic factors under five forest ecosystems (chir pine forest, mixed forest, ban oak forest, agriculture field and bare area) and analysed the forest influence on local winter and summer climate according to forest type, soil type, slope orientation, tree height and diameter at breast height by using RBD design. Seasonal and diurnal variations in microclimatic variables viz., air temperature, soil temperature, relative humidity, wind speed and wind direction were measured with Portable weather station (Delta T) at afternoon 2:00-4:00 PM fortnightly in each forest ecosystem and bare area during winter and summer season. Solar radiation and albedo were measured with Pyranometer (Kipp and Zonen) at 1.35 m height. A significant decrease was attained in below forest canopy and bare area data for ambient temperature (2.5-5.0 ^{o}C), soil temperature (1.5-3.6 ^{o}C) solar radiation (13.2-47.4 Wm^{-2}), albedo (0.15-0.21) and increased relative humidity (7-18%), soil moisture (8.0-15.2%). Among different forest ecosystem, the diurnal trends in microclimatic parameters showed large variations. The ambient air temperature ranged from 02.2-16.3 ^{o}C and 14.2- 30.7 ^{o}C where as soil temperature ranged from 07.4- 16.5 ^{o}C and 15.4-32.7 ^{o}C, however relative humidity ranged from 37- 88 per cent and 14-60 per cent among different forest ecosystem during winter and summer seasons, respectively. Mico-climatic variables under Ban-Oak forest revealed significant lowest air temperature, highest relative humidity and less wind speed.

Keywords: Microclimatic variations, Forest ecosystem, Solar Radiation and Albedo.

INTRODUCTION

Forest cover act as buffer and creates a specific understory microclimate that differs from the surrounding local climate[1]. Monitoring the microclimatic data in various micro-habitats of different ecosystems would provide unique data on the long-term impact of global change on microclimate changes[2]. As microclimatic variations effects are usually stronger during summer and the middle of the day in different types of forests[3-4]. Microclimatic variations under overstory canopies of different types of forests are critically important in understanding overall ecosystem structure and function. As it directly influences the ecological and physiological processes e.g. germination, abundance and distribution of understory vegetation and decomposition. Soil temperature and moisture are known to influence biotic and abiotic process rates such as nutrient availability[5], soil carbon sequestration/emission[6] and microbial activity[7].

Microclimatic variation within forest ecosystem are an important consideration in management because various microclimatic variables between adjacent forest types impact the plant and animal community composition[8]. Microclimate variables, particularly solar radiation, air temperature and soil temperature at the ground surface, are highly sensitive to changes in the over-story canopy and exhibit relatively high spatial and temporal variability within a forest[9] . Microclimatic variability within the oldgrowth forests exists because forest canopies are vertically complex and horizontally heterogeneous[10].

Forests are well known for their moderating effect on below canopy local climate, generally allowing lower maximum temperature and wind speed as well as higher minimum temperature and humidity[11-12]. The impact of the canopy on solar radiation and as a result on temperature is the main driver of the forest climatic interactions[13-14]. Knowledge of the impact of different forest types on below canopy climate will enable the bettter forecasting of future below-canopy climate, which in turn will enable the better modelling of ecosystem changes in forests. Naturally regenerated or planted, tree seedlings and sapling are most sensitive to the local microclimatic conditions. Forest environment creates climatic conditions that differs from the conditions of open area. Defining the stimulating effect of thermal and humidity conditions in forests is part of the evaluation of forest bioclimatic and microclimatic potential. The research hypothesis states that compared to open area, forest environment also changes its bioclimate by modifying climatic conditions[15].

The presence of vegetation cover in general and forest cover in particular modifies the climatic parameters and creates a microclimate whose characterstics depends on the general climate itself and the physical characterstics defining the nature and the structure of the cover[16]. Knowledge of microclimatic conditions is of great importance in the study of site conditions, bio-ecological characteristics of tree species and natural ecosystems[2]. Microclimate are key attributes for understanding the distribution of plants and wildlife in forests, as well as for understanding forest ecosystem processes like photosynthesis and nutrient cycling[17].

The importance of microclimate in influencing ecological processes such as plant regeneration and growth, soil respiration and nutrient cycling has became an essential component of ecological research. Microclimate plays an important role to improve models, optimize forest management and

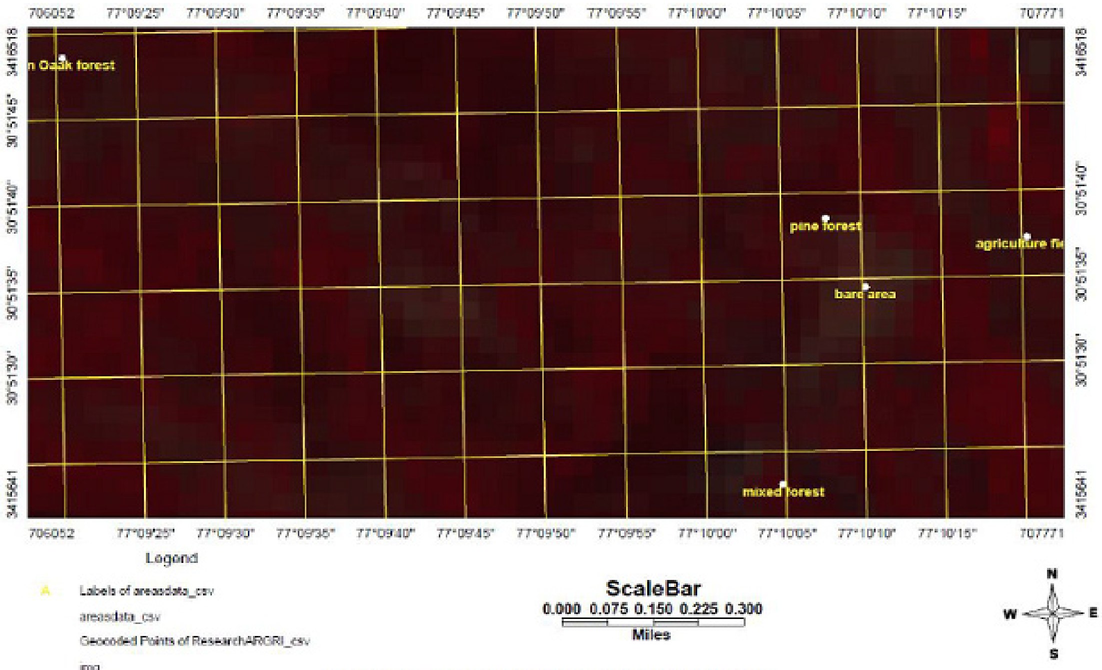

Plate 1: Location map of different Ecosystems

Fig. 1

ultimately, secure future economical and ecological functioning of forest ecosystem[18]. Microclimatic information is, therefore, vital for empirical field studies, theoretical modeling exercises and decision-making. Micorclimatic studies have traditionally focused on statistical summaries of daily, monthly and annual variability[19].

METHODOLOGY

The study was conducted in different forest ecosystems at University campus of Nauni, Solan, Himachal Pradesh. The investigation was carried out in Dr Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Solan (HP) during winter and summer season of 2015-16. The area is situated between 30.52 ° N and 77.10 ° E with elevation ranges from 1232 to 1264m. The research area was divided into five different sites as Chir Pine forest (F_1), Mixed forest (F_2), Ban Oak forest (F_3), Agricutural field (F_4) and Bare area (F_5). The research area was located in stands of trees predominantly dominated by overstorey of *Pinus roxburghii, Quercus leucotricophora, Celtis australis, Grewia optiva, Bauhinia vaerigata, Populus spp, Salix spp*, and under story of *Bidens pilosa, Rubus elipticus, Woodfordia floribunda, Urtica dioca* etc.

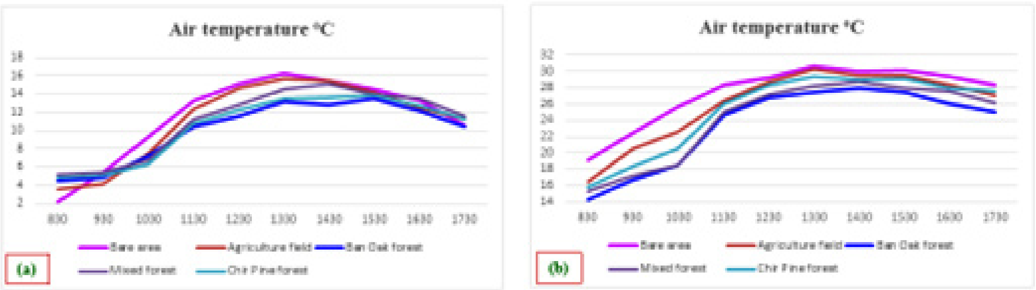

Fig.1 Diurnal pattern of ambient air temperature during winter (a) and summer (b) season in different forest ecosystem in mid hills of Himachal Pradesh

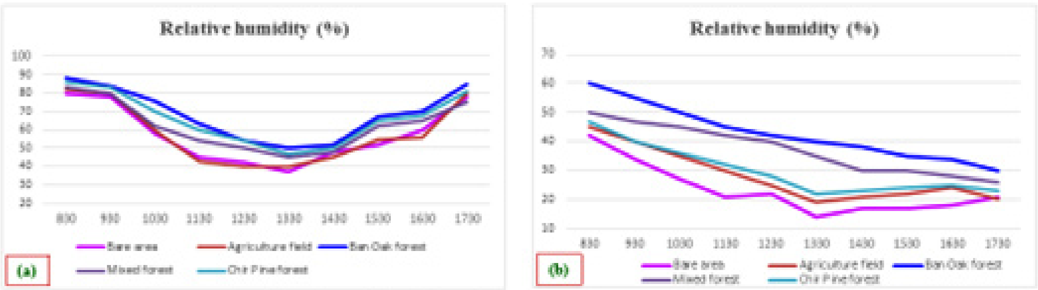

Fig. 2 Diurnal pattern of relative humidity during winter (a) and summer (b) season in different forest ecosystem in mid hills of Himachal Pradesh

Table 1: Site Characteristics

Forest Site	Ecosystem	Slope (% & o)	Aspect (Orientation)	Latitude (N)	Longitude (E)	Altitude (m)
Site I	Chir Pine forest (F1)	50% (26.6 o)	NE	30.52o	77.10o	1245
Site II	Mixed Forest(F2)	45% (24.2 o)	NE	30.51 o	77.10o	1249
Site III	Ban Oak forest(F3)	75% (36.9 o)	NE	30.52 o	77.09o	1264
Site IV	Agriculture Field(F4)	-	-	30.52o	77.09o	1222
Site V	Bare Area(F5)	-	-	30.52o	77.09o	1232

A stratified random sampling technique was used to carry out survey in the study area. The area is divided into three plots randomly in all five forest ecosystem. The data was recorded in forest ecosystem on four microclimatic variables, air temperature, relative humidity, solar radiation and albedo fortnightly during 2:00-4:00PM (peak hours) in two seasons i.e., winter and summer season of 2015-16. Data was recorded in three randomly stratified plots in each ecosystem by using Portable weather station (Delta T) as specified by IMD Pune, India. The Air Temperature, Relative Humidity, Solar Radiation and Albedo data were recorded at height of 1.35 m above ground level and Wind Speed and

Table 2: Seasonal Variation in Ambient Temperature and Relative Humidity under different Forest Ecosystem in Mid Hills of Himachal Pradesh

Forest ecosystem	Air Temperature (˚C)			Relative Humidity (%)		
	Winter	Summer	Mean	Winter	Summer	Mean
Chir pine forest (F1)	18.52	27.28	22.90	50.38	37.18	43.78
Mixed forest (F2)	19.21	26.73	22.97	47.66	41.47	44.56
Ban Oak forest (F3)	15.81	25.14	20.48	64.24	46.14	55.19
Agriculture field (F4)	20.38	28.10	24.24	44.67	35.38	40.02
Bare area (F5)	20.67	30.17	25.42	40.29	32.99	36.64
Mean	18.92	27.48		49.45	38.63	
CD0.05						
Forest ecosystem (F)	: 0.24					
Seasons (S)	: 0.15					
Forest x Season (Fx S)	: 0.34					
Forest ecosystem (F)	: 1.20					
Seasons (S)	: 0.76					
Forest x Season (Fx S)	: 1.69					

Table 3: Seasonal variation in Instantaneous Solar Radiation and Albedo under different forest ecosystem in Mid Hills of Himachal Pradesh

Forest ecosystem	Instantaneous Solar (Wm-2) Radiation			Albedo (unit less)		
	Winter	Summer	Mean	Winter	Summer	Mean
Chir pine forest (F1)	3.15	21.44	12.30	0.18	0.12	0.15
Mixed forest (F2)	33.76	42.18	37.97	0.21	0.14	0.18
Ban Oak forest (F3)	0.92	6.69	3.80	0.13	0.11	0.12
Agriculture field (F4)	43.41	52.54	47.97	0.24	0.29	0.26
Bare area (F5)	43.94	58.41	51.17	0.35	0.31	0.33
Mean	25.04	36.25		0.22	0.19	
CD0.05						
Forest ecosystem (F)	: 3.75					
Seasons (S)	: 2.37					
Forest x Season (Fx S)	: 5.31					
Forest ecosystem (F)	: 0.02					
Seasons (S)	: 0.01					
Forest x Season (Fx S)	: 0.02					

Wind Direction data were recorded at height of 2 m above ground level. Solar radiation and Albedo were recorded using Kipp and Zonen Pyranometer. Differences in mean value of the studied parameters along different sites were determined by analysis of variance (ANOVA) using SYSTAT statistical programme.

RESULTS AND DISCUSSIONS

Air Temperature and Relative Humidity

Table II depicts seasonal variations in air temperature and relative humidity under different forest ecosystem in mid hills of Himachal Pradesh. Significant differences in average air temperature and relative humidity recorded among different forest ecosystem during the year 2015-16. Air temperature of 25.42ÚC was found maximum in bare area (F_5) and minimum of 20.48ÚC in ban oak forest (F_3). However, relative humidity of 55.19 per cent was found maximum in ban oak forest (F_3) and minimum (RH=36.64 %) in bare area (F_5). The results were due to the fact that forest cover acts as screen and prevents sun rays from heating the air inside the forest as compared to bare area. The results are in conformity with the findings of several researchers[20, 2, 18, 21 and 22].

Highly significant differences were found in average air temperature and relative humidity during winter and summer seasons of 2015-16. During summer season the air temperature (27.48ÚC) was significantly higher than winter season (18.92 ÚC). Whereas, significantly high relative humidity of 49.45 per cent was found during winter season as compared to 38.63 per cent in summer season.

The interaction among forest ecosystem (F) X seasons (S) revealed highly significant microclimatic interactions for air temperature and relative humidity recorded fortnightly at 2:00-4:00 PM at a height of 1.35 m during both the seasons of winter and summer in the year 2015-16. Air temperature of 30.17 ÚC was found to be higher in bare area (F_5) during summer season of 2016 whereas, it was found to be lower (T_a=15.81ÚC) in ban oak forest (F_3) in winter season of 2015-16. The relative humidity of 64.24 per cent was found to be higher in ban oak forest (F_3) during winter season of 2015-16 and lower (RH= 32.99 %) in bare area (F_5) during summer season of 2016. This may be due to high cooling effect within the forest canopy which resulted in less latent and sensible fluxes as compared with open bare area. The results are in line with the findings of many research scholars[3, 15, 23, 24, 25, 26, 27, 28 and 29].

Solar Radiation and Albedo

Prusal of Table III depicts seasonal variations in instantaneous solar radiation and albedo under different forest ecosystem in mid hills of Himachal Pradesh. Significant differences were found in average solar radiation and albedo among different forest ecosystem during the year 2015-16. The instantaneous Solar radiation was found maximum (51.17 Wm^{-2}) in bare area (F_5) which was statistically at par with agricultural field (F_4) (47.97 Wm^{-2}) and lowest of 3.80 Wm^{-2} was found minimum in ban oak forest (F_3). However, albedo of 0.33 was found to be maximum in bare area (F_5) and minimum of 0.12 was found in ban oak forest (F_3) which is probably due to architecture and geometry of the tree canopy which controls the amount of penetration,

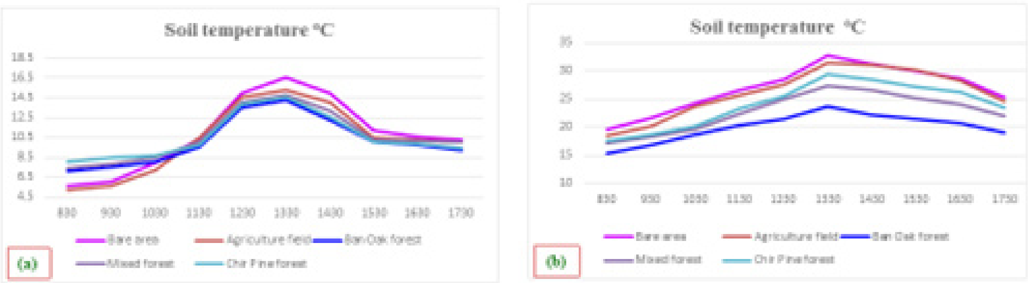

Fig. 3 Diurnal pattern of soil temperature during winter (a) and summer (b) season in different forest ecosystem in mid hills of Himachal Pradesh

Fig. 3

radiation trapping and mutual shading within it. The present trends are in agreement with the findings of [2, 17, 25, 30 and 31].

Highly significant differences were found in average instantaneous solar radiation and albedo during winter and summer seasons of 2015-16. During summer season the instantaneous solar radiation of (36.25 Wm^{-2}) was significantly higher than winter season (25.04 Wm^{-2}). Whereas, significantly high albedo of 0.22 was found during winter season as compared to summer season (0.19).

The interactions among forest ecosystem (F) X seasons (S) analysed highly significant microclimatic interactions for solar radiation and albedo recorded fortnightly at 2:00-4:00 PM at a height of 1.35 m during both the seasons of winter and summer in the year 2015-16. Maximum instantaneous solar radiation of 58.41 Wm^{-2} was found in bare area (F_5) during summer season while minimum 0.92 Wm^{-2} was found in ban oak forest (F_3) during winter season which was statistically at par with chir pine forest (F_1) (3.15 Wm^{-2}) in winter season. albedo was found to be maximum in bare area (F_5) of 0.35 during winter season and minimum in ban oak forest (F_3) 0.11 during summer season which was statistically at par with ban oak forest (F_3) of 0.13 in winter season and chir pine forest (F_1) of 0.12 in summer season due to the integrated effect of changes in forest phenology, angle of incidence of solar beam and weather conditions affecting atmospheric transparency therefore seasonal variation was observed in the radiations received by the forest. The results are in the consonance with the findings of [21, 32, 33 and 34].

Wind Speed and wind Direction

Table IV represents the seasonal variations of wind speed under different forest ecosystem in mid hill Zone of Himachal Pradesh. Significant differences were found in average wind speed recorded among different forest ecosystem during the year 2015-16. Wind speed of 4.29 kmph was found to be maximum in bare area (F_5) and minimum (WS=1.39 kmph) was found in ban oak forest (F_3). It was noticed that wind reduces its speed under the trees when compared to the bare area because of the blockage effect by trees and wind speed was also influenced by both trees height and density. The results are in tune with [35].

Highly significant differences were found in average wind speed during winter and summer seasons of 2015-16. During winter season the wind speed of 2.91 kmph was significantly higher (WS = 2.41 kmph) than summer season because wind

Table 5: Seasonal variation in Wind Speed and Wind Direction under different forest ecosystem in mid hills of Himachal Pradesh

Forest ecosystem	Wind Speed (kmph)			Wind Direction (deg°)		
	Winter	Summer	Mean	Winter	Summer	Mean
Chir pine forest (F1)	1.61	1.56	1.59	218.57	157.39	187.98
Mixed forest (F2)	2.59	1.39	1.99	216.74	155.40	186.07
Ban Oak forest (F3)	1.52	1.26	1.39	213.57	154.10	183.84
Agriculture field (F4)	4.27	3.84	4.06	220.02	159.31	189.66
Bare area (F5)	4.57	4.00	4.29	221.30	159.65	190.47
Mean	2.91	2.41		218.04		
(ssw)	157.17					
(SE)						
CD0.05						
Forest ecosystem (F)	: 0.08					
Seasons (S)	: 0.05					
Forest x Season (Fx S)	: 0.11					
Forest ecosystem (F)	: NS					
Seasons (S)	: 7.75					
Forest x Season (Fx S)	: NS					

speed below the canopy was strongly affected by the presence of leaves and was proportionally lower in summer than winter season.

The interaction among forest ecosystem (F) X seasons (S) analysed highly significant microclimatic interactions for wind speed recorded fortnightly at 2:00-4:00 PM at a height of 2 m during both the seasons of winter and summer in the year 2015-16. Maximum wind speed of 4.57 kmph was recorded in bare area (F_5) during the winter season of 2015-16 and minimum wind speed of 1.26 kmph was recorded in ban oak forest (F_3) during summer season of 2016. The present trend could be explained due to the presence of forest canopy which influences and reduces wind speed in relation to the size and spatial distribution of biomass. The results are in tune with the findings of [27, 31 and 36].

Diurnal Observation

Diurnal observations were recorded on clear days from 08:30 AM to 5:30 PM with one hour interval in the selected forest ecosystem at all the locations on December 16, 2015 and April 15, 2016 to explore the hourly trends of different microclimatic parameters in different forest ecosystem. The point wise results obtained are presented as under:

Air Temperature

Winter Season

The diurnal variation in air temperature was recorded on December 16, 2015 at the understory forest canopy in selected Forest communities (Fig1a). The air temperature ranged from 2.2-16.3 °C in bare area (F_5) followed 3.6-15.7 ° C in agriculture field (F_4) whereas, it was observed to be 4.5-13.5 ° C in ban oak forest (F_3). However the trends of diurnal temperature in mixed forest (F_2) ranged from 4.5 -15.1 °C in followed by chir pine forest (F_1) which experienced highest temperature of 13.8 °C in the afternoon hrs (3:30PM) and lowest in the morning hour. This may be probably due to the reason that forest canopy moderates the microclimatic conditions depending on the their canopy architecture, tree density and type of leaves and colour. The results are in the tone of[37] who studied the response of different forest ecosystem in terms of microclimate variability in tropical moist deciduous forests of North India. Several other researchers have also given their findings in agreement with the results of [15, 38 and 39].

Summer Season

The diurnal trend of air temperature (T_a) during summer season was recorded on April 15, 2016 at a height of 1.35 m above ground in different forest ecosystem (Fig 1b). The hourly trends of ambient temperature in bare area (F_5) was (F_5) was 19.1-30.7 °C followed by agriculture field (F_4) which experienced temperature of 16.4-30.2°C. The highest fluctuations in air temperature were recorded in chir pine forest (F_1) ranged from (T_a: 15.8 -29.3 °C) and followed by (T_a: 15.3-28.7 °C) in mixed forest (F_2) and (T_a: 14.2-27.9 °C) in ban oak forest (F_3). The selected forest communities showed high ambient temperature at 2-4 pm .The lowest air temperature was observed during 08:30 to 10:30 AM in all the communities. Thus the trends confirmed that as during the night cold air sinks downwards so the understory remains cold. The results of present study are in line with the findings of several studies conducted world wide[18, 22, 27,37, 40 and 41].

Relative Humidity

Winter Season

The hourly trends in RH (Fig 2a) were observed among different forest communities on December 16, 2015 during the winter season (Fig 2a). The highest relative humidity (88 %) was recorded in ban oak forest (F_3) at 08:30 AM and followed 86 % in chir pine forest (F_1). However, the relative humidity of 83 per cent was recorded in mixed forest (F_2).The diurnal trend of relative humidity attained its lowest value of 45 per cent at 01:30 PM in mixed forest (F_2) and followed by chir pine forest (F_1) of 47 per cent whereas, it ranged from 37-80 percent and 40-82 per cent in bare area (F_5) and agriculture field (F_4), respectively.

Summer Season

The hourly trends were recorded on April 16, 2016 for relative humidity in different forest communities during summer season (Fig 2b). The highest relative humidity (60 %) was recorded in ban oak forest (F_3) at 08:30 AM and followed by mixed forest (F_2) (50 %). However, the relative humidity of 47 per cent was recorded in chir pine forest (F_1).The diurnal trend of relative humidity attained its lowest value of 22 per cent at 01:30 PM in chir pine forest (F_1). Whereas, it ranged from 14-42 per cent and 20-45 per cent in bare area (F_5) and agriculture field (F_4), respectively.

The results were probably due to accumulation of water vapour at the forest understory layer due to continuous process of evapo-transpiration and photosynthesis in winter days. As the ambient temperature increased during summer season and reached its maximum limit at afternoon hours which leads to closure of stomata and and leaves remained physiologically inactive resulted in less water vapours at the understory layer. The results are in agreement with the studies conducted worldwide by many researchers[15, 18, 37, 40 and 41].

Soil Temperature

Winter season

The hourly trends in soil temperature among different forest communities were recorded on December 16, 2015 during winter season (Fig 3a). The highest soil temperature ranged diurnally from 5.6- 16.5 °C in bare area (F_5) followed by agriculture field (F_4) which was found to be ranged from 5.2 -15.3 °C. Whereas, the soil temperature attained in ban oak forest (F_3) was found to be ranged from 7.1-14.2°C. However the diurnal temperature ranged from 7.4-14.8 °C in mixed forest (F_2) followed by chir pine forest (F_1) which experienced high temperature of 14.6 °C in the afternoon hrs (1330 hr) and lowest at morning hour.

Summer season

The diurnal trend of soil temperature during summer season was recorded on April 16, 2016 at a depth of 5 cm in different forest ecosystem is shown in Fig 3b. The diurnal soil temperature in bare area (F_5) ranged from 19.5-32.7 °C followed by agriculture field (F_4) which experienced temperature of (18.5-31.4 °C). The highest fluctuations in soil temperature were recorded in chir pine forest (F_1) ranged from 17.5-29.4 °C and followed by (17.1-27.4 °C) in mixed forest (F_2) and (15.4-23.7 °C) in ban oak forest (F_3). All the selected forests experienced high temperature at 2-4pm.The lowest soil temperature was observed during 08:30-10:30 AM in all the communities during the summer season.

Soil temperature showed similar behaviour like ambient temperature during summer and winter seasons in all the selected forests.The highest soil temperature was observed during 12:00-01:00 PM due to increase in solar radiation. The surface temperature was lowest during early morning due to dissipation of heat and energy in the form of long wave radiations on clear nights. Which is exactly opposite to day time increase in temperature due to insolation of heat at the surface of earth. The results are in consonance with the findings of[22, 27, 37, 39 and 41].

CONCLUSIONS

Investigation revealed that ban oak forest had greater moderating effects over solar radiations, ambient temperature, relative humidity and wind speed. This impact resulted from biogeographic stand characteristics, forest type, dominant tree species, topography, slope orientation, soil type and soil health which directly influenced the soil physico-chemical properties, nutrient cycling, microbial biomass and therefore affects the natural regeneration process of native species. Thus, there is ample scope for growth of mixed type forest community for protection and management of forests from forest fire threats. It will also help in maintaining the crop weather soil balance. The study opens the scope for further investigations in the same field to determine the weather indicators which are crucial determinants of ecological patterns and drivers of growth and mortality of forest community.

AKNOWLEDGEMENTS

The assistance provided by Dr S K Bhardwaj Prof.& Head, Department of Environmental Science, and Dr. R.K.Gupta, Professor (Statistics),Department of Basic Sciences, Dr Y S Parmar University of Horticulture and Forestry, Nauni, HP-India in the present study is highly acknowledged.

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