Chapter 13
Assessment of Particulate Pollutants (PM_{10} and $PM_{2.5}$), Its Relation with Vegetation Cover and Its Impacts on Apple Orchards in Kullu Valley, Himachal Pradesh, India

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Abstract Present study is an attempt to estimate the effects of roadside dust pollution on apple trees of Mohal (1146 m), Raison (1359 m) and one control site, Beasar (2181 m), Kullu Valley, Himachal Pradesh. In both Mohal and Raison sites, PM_{10} and $PM_{2.5}$ are showing the increasing trend which is affecting the apple farming and production in the area. When the dust particles settle down on the stigma of flower it stops an anther to contact with stigma, which affects the pollination. Thus, the dust particle affects the flower of plant during the time of pollination. Particulate pollutants PM10 (<10 μm) and $PM_{2.5}$ (<2.5 μm) have been monitored in and around of apple orchards. Average PM_{10} concentration has found low (20.9 ± 1.7 μg m^{-3}) at control site Beasar, whereas it shows high value (88.1 ± 2.0 μg m^{-3}) at Raison. Mohal has relatively higher PM_{10} concentration with a mean value of 104.2 ± 1.1 μg m^{-3}. In Mohal and Raison sites, the particulate pollutants have μcrossed the permissible limit (100 μg m^{-3}) as prescribed by National Ambient Air Quality Standards (NAAQS). There is negative correlation with NDVI values and pollutants concentration. It is also made clear from HYSPLIT model and CALIPSO analysis that the sources of pollutants are mainly local in nature. The Air Quality Index (AQI) study reveals that air quality of Mohal falls under good condition. But during spring season, the pollutants cross the permissible limit which affects the pollination process of apple trees.

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13.1 Introduction

Apple farming and its production is directly related to climatic condition of a particular region. At present, the traditional apple farming is under stress due to changes in climate (Basannagari and Kala 2013). Presence of particulate pollutants even in a small quantity can affect the environment by influencing the thermal properties of the environment. Radiative effect is shown by these gases by which they absorb the long wave radiation and reduce the outgoing at the top of atmosphere and this leads to increase in temperature (Wang et al. 1976). Atmospheric pollutants are released into the environment by natural and anthropogenic sources like agricultural, industrial, transportation, residential and natural sources (Bernard et al. 2001; Ramanathan and Feng 2009). Air pollution not only affects the air quality but also its acute and chronic effect can create various health problems in human being (Oberdörster et al. 2004). Especially, particulate matter ($PM_{2.5}$) plays foremost role in creating depression, anxiety and many other neurological problems in human being (Calderón-Garcidueñas et al. 2002; Oberdörster et al. 2004). These particulate matters also affect atmospheric process like reduce visibility, effect precipitation pattern and cloud formation and also play an important role in making rain, clouds and fog acidic in nature (Celis et al. 2004; Khoder 2002). According to Gajananda et al. (2005), the level of air pollution is increasing over the sensitive areas of northwestern part of the Himalayas due to high anthropogenic activities as they monitored the Total Suspended Particulate (TSP), size-separated atmospheric aerosols and Aitken Nuclei (AN) at Mohal (Kullu) and Manali tourist complex since 1996.

The mountain environment is one of the most weak biological systems to the environmental change as are the mountain networks, particularly those essentially rely upon animal husbandry, marginal agriculture and agriculture items. Currently, the Himalayan mountain environment is confronting the difficulties made because of expanding aridity, hotter winter season, inconstancy in precipitation and unexpected frosts and storms (Renton 2009; Dash and Hunt 2007) which generally influence the whole scope of biodiversity, including farming and cultivation crops (Renton 2009; Kala 2013). However, the Himalaya harbors rich biodiversity and is one of the weakest mountain biological systems to environmental change (Xu et al. 2009; Bawa et al. 2010), there is scarcity of orderly examination of environmental change and its effects on the Himalayan biological systems, biodiversity and neighborhood individuals' occupations (Shrestha et al. 2012). Farmers of Indian Himalayan Region (IHR) develop many natural product crops, including pomes (apple and pear) and stone natural products (peach, plum, apricot and cherry) in significant amount, (Ghosh et al. 1999) yet apple has the preference over all other agricultural crops (Kala 2007). The main aim of this study is to know the status and source of particulate pollutants and their effects on apple plantations.

13.2 Study Area

The present study deals with ambient air quality status in and around the apple orchards area in Kullu valley. Kullu is a broad open valley formed by the Beas River situated between Manali and Larji. Kullu valley is famous for its temples, beauty and its majestic hills covered with pine and deodar forest and sprawling apple orchards. Ambient air quality was monitored at Mohal Latitude—31° 54´ 54.15″ N and Longitude—77° 07´ 25.42″ E at the Altitude of 1146 m, Beasar (control site) Latitude—32°01´41.34″ N Longitude—77°05´34.73″ E at the Altitude of 2181 m third site Raison: Latitude—32°03´25.14″ N Longitude—77°08´06.91″ E at the Altitude of 1359 m (Fig. 13.1).

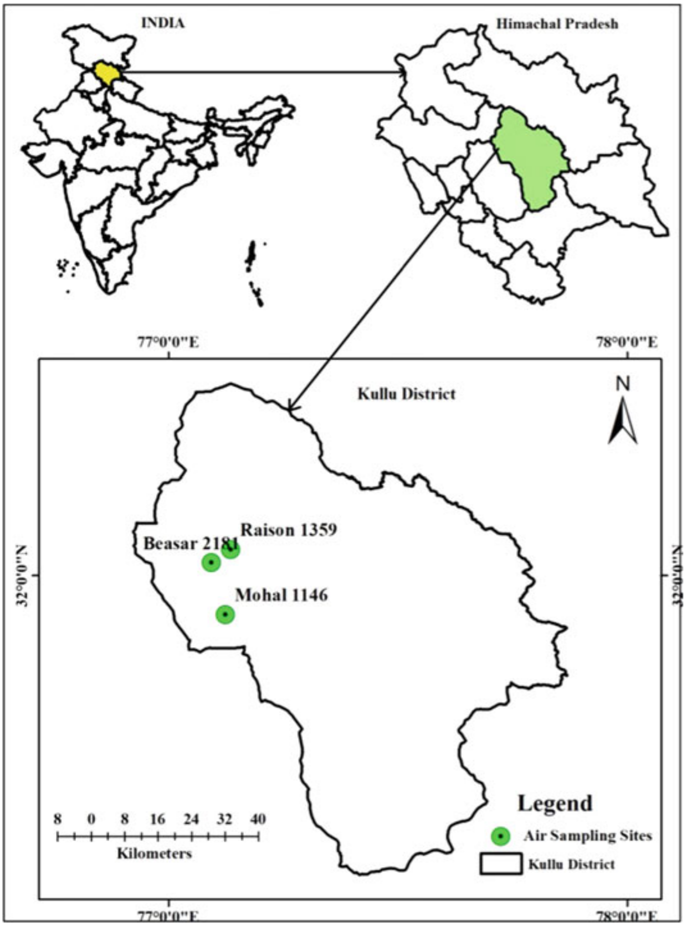

Fig. 13.1 Location of the study area in the Kullu valley, Himachal Pradesh

13.3 Methodology

Current study has been carried out during the winter, spring and summer seasons in 2019 (January to June 2019). The air quality status of Beasar and Raison sites was monitored only in summer season. Respirable Dust Sampler (RDS; Envirotech NL-460) was used to observe PM_{10} under ambient air quality monitoring based on filtration-gravimetric method with Whatman filter paper (20.3 × 25.4 cm). Fine Particulate Sampler (APM-550 make Envirotech) was used for $PM_{2.5}$. The Whatman Glass Micro Fibre Filter paper (GF/A (47 mm) was used to expose $PM_{2.5}$. Samples were exposed on 24 hourly bases during winter season (January to March 2019), spring season (April 2019) and summer season (May to June 2019).

13.3.1 Air Quality Index (AQI)

Air Quality Index (AQI) was computed to know the overall pollution status. The AQI was calculated from the method used by Bhaskar and Mehta (2010) as follows:

$$AQI = \left(\frac{M_{ob}}{M_{st}}\right) \times 100$$

where, M_{ob} = observed value of air pollutants, M_{st} = standard value of acceptable limit of NAAQS.

13.3.2 Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) was calculated in the two selected sites with the help of Remote Sensing (RS) and Geographic Information System (GIS). Cloud Free Landsat-7 and Landsat-8 satellite data of October 2003 and October 2019 had been downloaded from the United States Geological Survey (USGS) Earth Explorer website. All the data were pre-processed and projected to the Universal Transverse Mercator (UTM) projected system. The details of the satellite data collected are shown in Table 13.1. Landsat-7 and Landsat-8 are the satellites of the Landsat series launched by NASA. In this study, bands 2–7 and 2–5 of Landsat-8 and Landsat-7 were, respectively, used to calculate different indices.

Table 13.1 General Information of Landsat-7 (ETM+) and Landsat-8 (OLI) datasets (2003–2019)

Sensor/Satellite	No. of bands	Resolution (m)	Path/Row and reference system	Date of acquisition
ETM +	7	30	WRS-II/146/40	10-05-2003
TIR	2	30	WRS-II/146/40	10-05-2003
OLI	9	30	WRS-II/146/40	28-10-2019
TIR	2	100	WRS-II/146/40	28-10-2019

13.3.3 Derivation of NDVI Image

NDVI images are calculated from NIR and Red bands of the Landsat 8 sensor. Using NDVI maps, we can separate vegetation from the non-vegetation area. The NDVI is related to healthy vegetation because the infrared band is high radiance reflecting and observing as well in the part of the spectrum. Green leaves have a reflectance of 20% or less in the 0.5 to 0.7 range (Green to Red) and about 60% in the 0.7 to 1.3 μm range (near Infrared). The value is then normalized to –1 NDVI + 1 to partially account for differences in illumination and surface slope. The index is defined by Eqs. 13.1 and 13.2. Estimation of NDVI using Landsat-7 and Landsat-8 sensor optical band after layer stacking, mosaicking and subsetting with the help of area of interest (AOI), band 2, 3, 4, 5 and 7 using the algorithm.

$$\text{For Landsat} - 7(\text{ETM+}) \qquad \text{NDVI} = \frac{\text{BAND 4} - \text{BAND 3}}{\text{BAND 4} + \text{BAND 3}} \tag{13.1}$$

$$\text{For Landsat} - 8(\text{OLI}) \qquad \text{NDVI} = \frac{\text{BAND 5} - \text{BAND 4}}{\text{BAND 5} + \text{BAND 4}} \tag{13.2}$$

13.4 Results and Discussion

Is one of the major negative results due to the road construction and other developmental activities particularly during construction stage are one of the major sources of air pollution.

13.4.1 PM_{10} Concentration at Mohal

During winter season, the highest ever concentration of PM_{10} (162.6 μg m^{-3}) was observed on January 16, 2019 (Fig. 13.2). The low concentration of PM_{10} was observed as 25.7 μg m^{-3} on February 25, 2019. Average concentration of PM_{10}

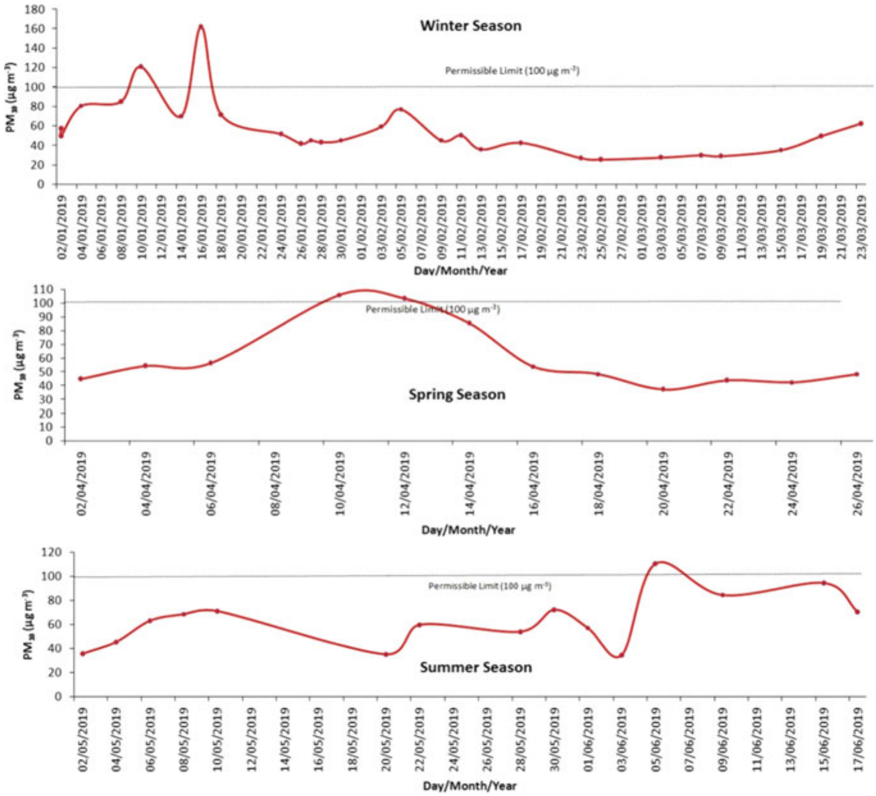

Fig. 13.2 PM_{10} Concentration at Mohal during different season

was observed 56.6 ± 5.8 μg m^{-3}. While the status of PM_{10} during spring season was observed 106.3 μg m^{-3} as maximum on April 10, 2019 and 37.2 μg m^{-3} minimum on April 20, 2019 (see Fig. 13.2). The average concentration of PM_{10} was observed 60.4 ± 6.9 μg m^{-3}. On the other hand, during summer season, the highest ever concentration of PM_{10} (110.6 μg m^{-3}) was observed on June 05, 2019 (see Fig. 13.2). This value of PM_{10} was observed minimum 34.7 μg m^{-3} on June 03, 2019. The average concentration of PM_{10} was observed 63.9 ± 6.9 μg m^{-3}. It is observed that the background values of six samples were beyond the acceptable limit (100 μg m^{-3}) as prescribed by NAAQS, especially in case of the spring season when the flowering on the apple trees was on its peak which affects the pollination.

13.4.2 PM_{10} Concentration at Raison and Beasar

PM_{10} concentration at Raison and Beasar sites were observed only in summer season, ranged between 9.6 $\mu g\ m^{-3}$ and 31.8 $\mu g\ m^{-3}$ with the mean value of 20.9 ± 1.7 $\mu g\ m^{-3}$ at Beasar. Highest ever concentration of PM_{10} (31.8 $\mu g\ m^{-3}$) was observed on June 28, 2019. On the other hand, the Raison site PM_{10} concentration ranged between 34.7 $\mu g\ m^{-3}$ and 112.3 $\mu g\ m^{-3}$ with the mean value of 64.9 ± 6.2 $\mu g\ m^{-3}$ at Raison site (Fig. 13.3).

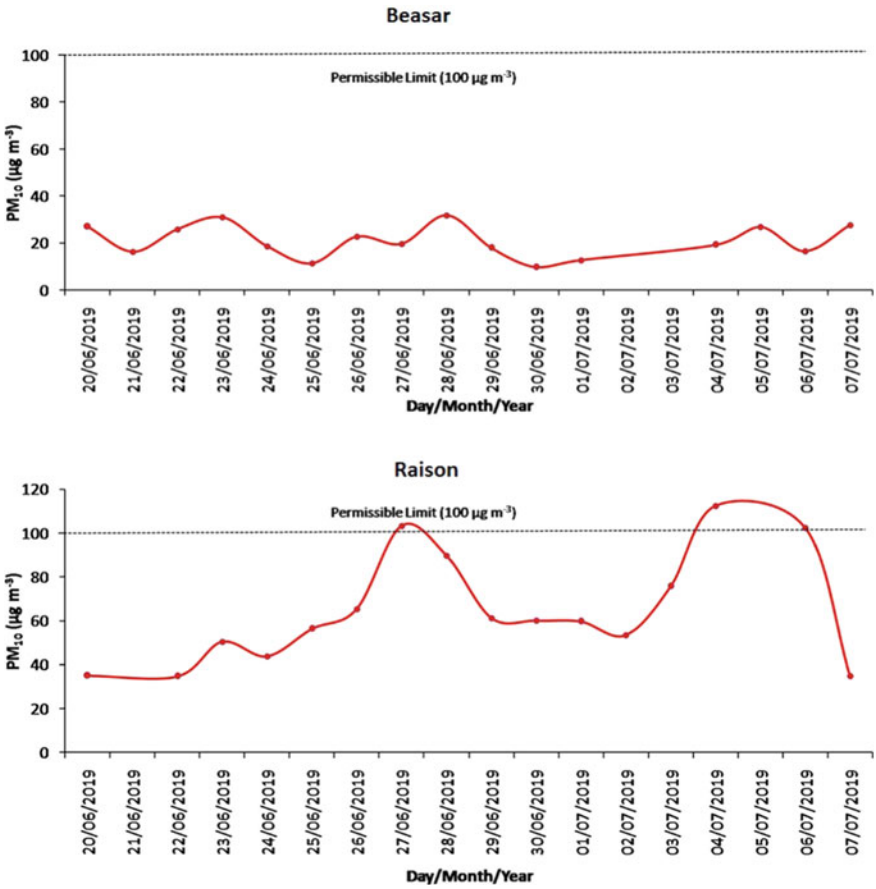

Fig. 13.3 PM_{10} Concentration at Beasar and Raison during summer season

13.4.3 $PM_{2.5}$ Concentration at Mohal

During winter season, the $PM_{2.5}$ concentration ranged between 10.4 $\mu g\ m^{-3}$ and 53.3 $\mu g\ m^{-3}$ with the mean value of 22.7 $\pm$ 1.8 $\mu g\ m^{-3}$. During spring season, the highest ever concentration of $PM_{2.5}$ (51.3 $\mu g\ m^{-3}$) was observed on April 24, 2019 (Fig. 13.4), the low concentration of $PM_{2.5}$ was observed as 5.6 $\mu g\ m^{-3}$ on April 14, 2019. The average concentration of $PM_{2.5}$ was recorded as 23 $\pm$ 3.4 $\mu g\ m^{-3}$. While the status of $PM_{2.5}$ during summer season was observed 42.1 $\mu g\ m^{-3}$ as maximum on May 04, 2019 and 18.4 $\mu g\ m^{-3}$ minimum on June 03, 2019 (see Fig. 13.4). The

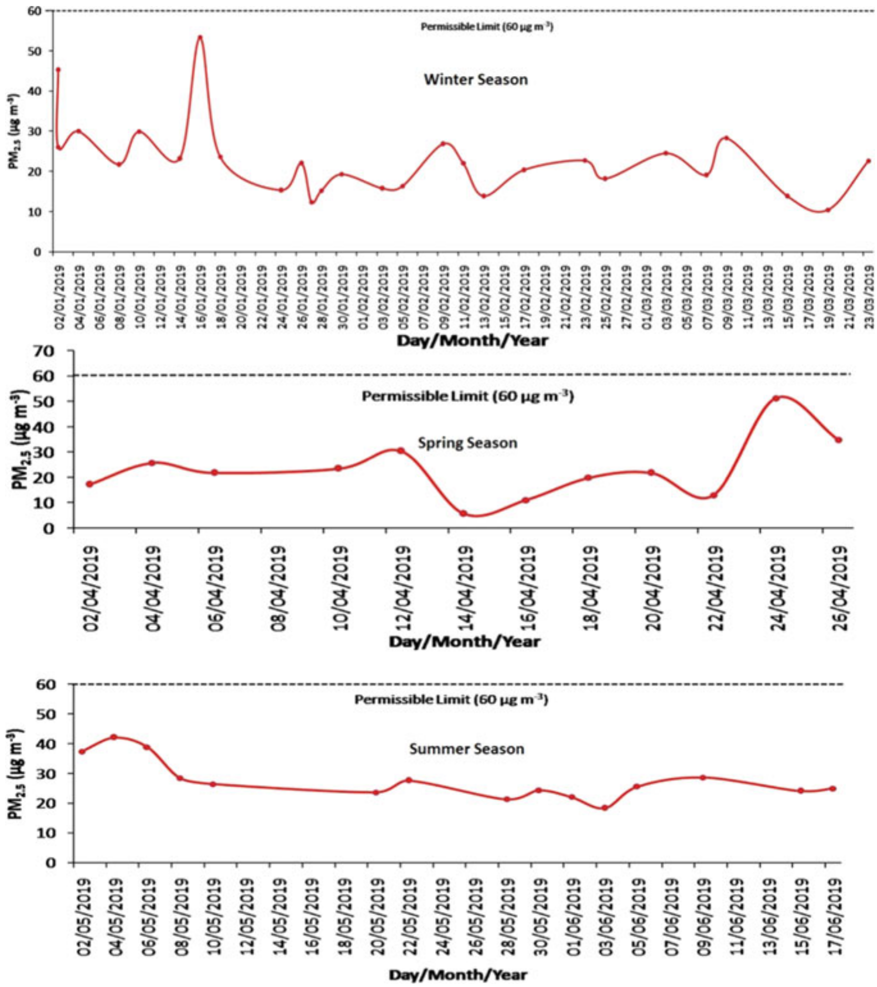

Fig. 13.4 $PM_{2.5}$ Concentration at Mohal during different season

average concentration of $PM_{2.5}$ was observed 27.6 ± 3.1 µg m^{-3}. All these values were within the permissible limit as per NAAQS (see Fig. 13.4).

13.4.4 $PM_{2.5}$ Concentration at Raison and Beasar

The $PM_{2.5}$ concentration ranged between 10.3 µg m^{-3} and 40.6 µg m^{-3} with the mean value of 21.6 ± 1.9 µg m^{-3} at Raison. Highest ever concentration of PM_{25}(40.6 µg m^{-3}) was observed on June 20, 2019. On the other side, the Beasar (Control) site PM_{10} concentration ranged between 3.1 µg m^{-3} and 17.2 µg m^{-3} with the mean value of 10 ± 0.9 µg m^{-3} (Fig. 13.5).

13.4.5 PM_{10} and $PM_{2.5}$ Concentration Compare with Control Sites Beasar

The control site Beasar is an apple orchard sites which undisturbed area by National Highway and other development activities. The PM_{10} concentration of Mohal and Raison was observed to have higher concentration (Mohal 112.2 µg m^{-3}) as

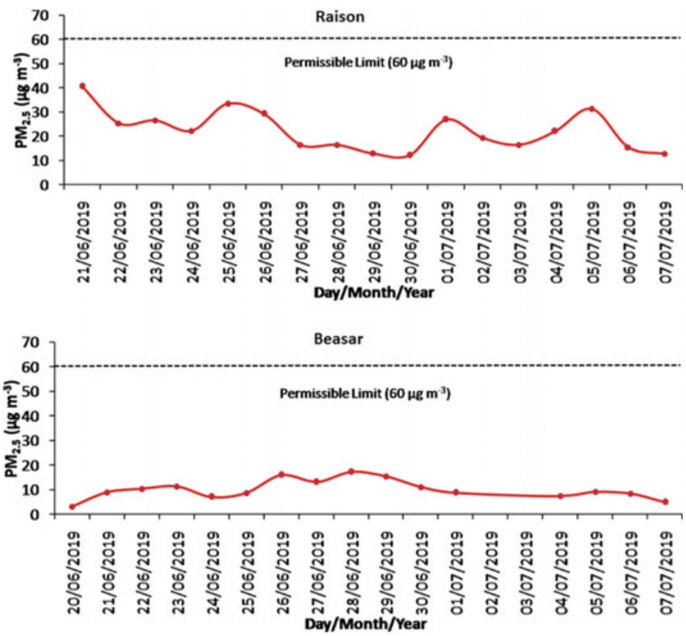

Fig. 13.5 $PM_{2.5}$ Concentration at Raison and Beasar during summer season

compared to control site (31.8 μg m^{-3}). On the other hand, $PM_{2.5}$ concentration was also higher 53.3 μg m^{-3} at Mohal and Raison as compared to Beasar.

13.4.6 Normalized Difference Vegetation Index NDVI and Pollutants

When we compare and evaluate the NDVI values and pollutants concentration in the two selected sites, one of them was Beasar which was control site and second monitoring sites was Mohal. During the study, it was found that the NDVI value was high at Beasar (0.28–0.53), on the other hand in the same site, the particulate pollutants' concentration was low (31.8 μg m^{-3}) as compared to Mohal. The NDVI value was found low (0.11–0.2) at Mohal (Fig. 13.6) while the concentration of pollutants was high (112.2 μg m^{-3}) as compared to Beasar, it means where there is more greenery, there will be less pollutants and where there is less greenery, there will be more pollutants. There is negative correlation between NDVI and pollutants.

13.4.7 Back Trajectories, CALIPSO and Pollution Sources

Using Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model derived by National Oceanographic and Atmospheric Administration (NOAA), the seven days back trajectories were drawn to highlight long-range transport source during pollution episodes. The trajectories were drawn one episode's value during winter season (i.e., January 16, 2019) at Mohal and during spring season episode value on April 10, 2019 at Mohal during the occasion of high pollution days.

In and around Mohal site, the maximum values of particulate pollutants were observed as 162.6 μg m^{-3} on January 16, 2019, where the back trajectory was coming from Morocco, Homoda Desert. The trajectory, thereafter, passed through Algeria, Libya near Sahara Desert, Iraq, Afghanistan, Islamabad (Pakistan), Pathankot (India), Kangra district of Himachal Pradesh (India) and ultimately reached at Mohal (Fig. 13.7a). Meanwhile, observation through CALIPSO indicated that the vertical distribution of dust particles was mainly below 8 km at Tibetan Plateau and Irkustsk (Russia) (Fig. 13.8). Therefore, it is made clear that the entire observations throughout the trajectories have revealed that they did not pass through the Tibetan Plateau and Irkustsk (Russia) region and were not contributing directly to pollution which indicate that these episodes resulted from the local pollutants.

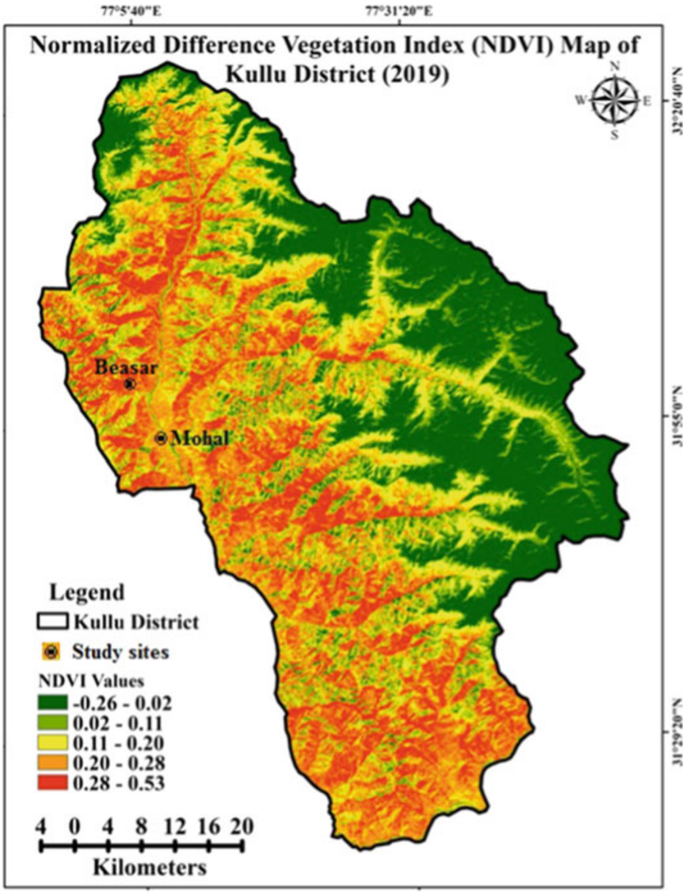

Fig. 13.6 Normalized difference vegetation index of Kullu valley

During the spring period, the CALIPSO image (see Fig. 13.8) indicated that the vertical distribution of dust aerosols at Koppal district of Karnataka (India), the back trajectory shifted from the Western Sahara, Algeria, Libya and passed through Iran, Afghanistan, Pakistan, Kangra (India) and ultimately reached at Mohal (see Fig. 13.7b). However, the trajectories did not cross over the vertical distribution of smoke, aerosols and these observations indicated that there was no other external source contributing to particulate pollution at Mohal.

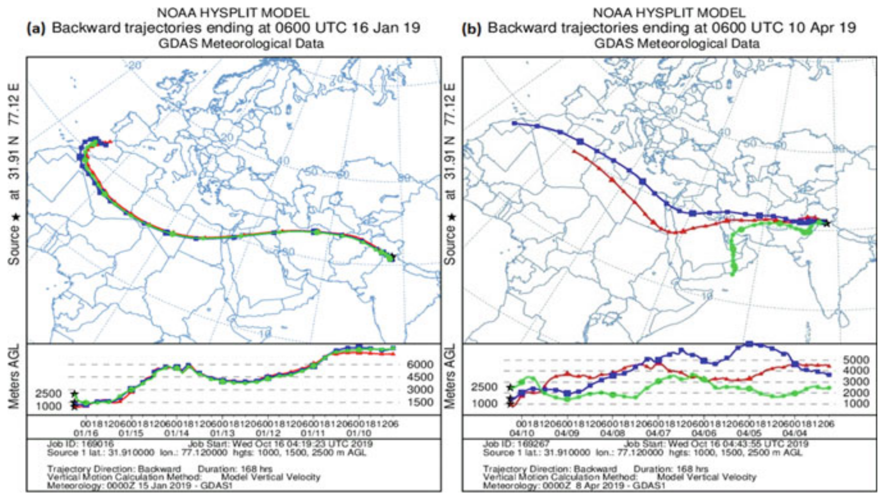

Fig. 13.7 Back trajectories using HYSPLIT Model to relate with highest particulate pollutants for: **a** Winter season **b** Spring season

13.5 Air Quality Index (AQI)

The AQI is one of the major tools which are used to determine the overall air quality status and general trends based on the specific standards. This index indicates the environmental status in the form of air quality and also informs the general public to understand how clear or pollute air they breathe daily. According to Environmental Protection Agency (EPA), it is divided into six different limits (Table 13.2).

It is clear from Fig. 13.9 and Table 13.2 that the values of AQI are in the good range for sampling sites which are under good category.

13.6 Conclusion

The concentration of particulate pollution was observed high at Mohal and Raison as compared to Beasar control site. Because the Mohal and Raison are nearby National Highway (NH3); therefore, the concentration of pollutants was higher as compared to the control site. The concentration of PM_{10}at Mohal and Raison was above the permissible limit (100 $\mu g\ m^{-3}$) prescribed by NAAQS. However, it is noted that concentrations of PM 2.5 at all the sites were well within the permissible limit. The NDVI value was highest at Beasar and lowest at Mohal, whereas the concentration of pollutants was opposite, highest concentration at Mohal and lowest at Beasar. It is also understood from HYSPLIT and CALIPSO analysis that there is local source of pollutants. The AQI study reveals that air quality of Mohal falls under good condition. However, the concentration of the PM10 was above the acceptable limit during spring

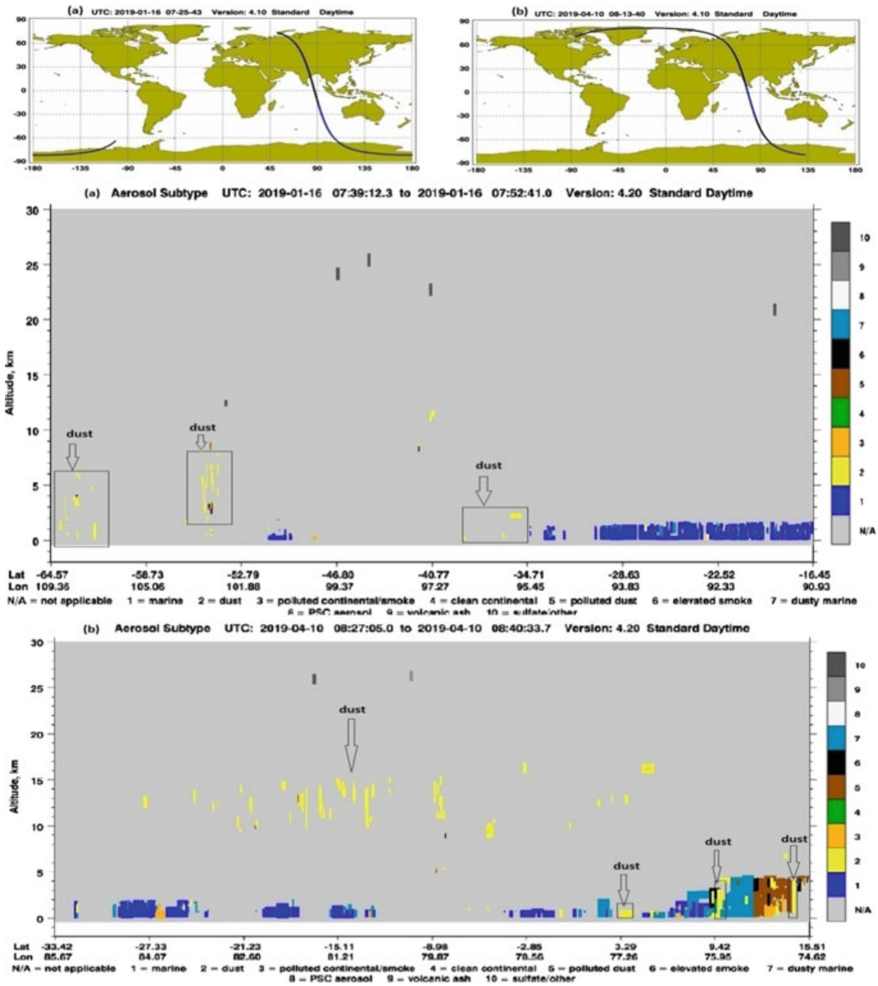

Fig. 13.8 CALIPSO Model to relate with highest particulate pollutants during winter and spring season

Table 13.2 AQI values and level of health concerns

Sr. no	AQI Value	Level of health concern (AQI)
1	0–50	Good
2	50–100	Moderate
3	101–150	Unhealthy for sensitive group
4	151–200	Unhealthy
5	200–300	Very unhealthy
6	301–500	Hazardous

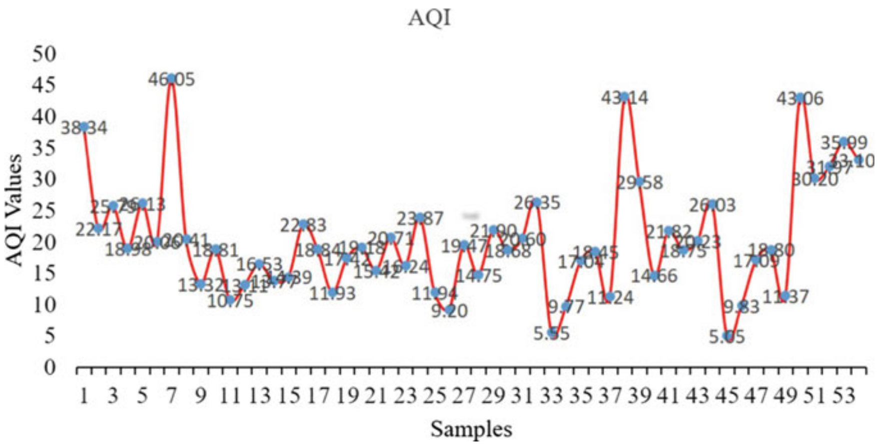

Fig. 13.9 Air quality index (AQI) in selected sites during study period

season when flowering in apple orchard at peak level which might not be so good from viewpoint apple orchards.

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