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Assessment of Air Quality in Dominant Landuses of Low hills in Himachal Pradesh-India

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Abstract: ***The study was carried out to investigate the status of air quality parameters namely Particulate Matter (PM_{10}), Sulphur dioxide (SO_2), Nitrogen-dioxide (NO_2) and VOCs (Volatile Organic Compounds) under four dominant landuses categorised as agriculture, urban, peri-urban and forest at 24 representative locations in low hill region of Himachal Pradesh. The results revealed that the concentration of SO_2, PM_{10} and VOCs found to be maximum in urban site followed by peri-urban and agriculture and minimum at forest landuse except NO_2 which was found maximum at agriculture > urban > peri-urban > forest landuses. Irrespective of seasons, all four pollutants were found maximum during post-monsoon and minimum during pre-monsoon. The air quality index (AQI) of ambient air was found to be good in all the selected landuses and mapped using ERDAS GIS software.***

Keywords: Air quality, dominant landuses, air pollutants, AQI, GIS mapping

1. Introduction

Air pollution has emerged as the most crucial problem globally and a large number of studies in this regard have been undertaken in all over the World (Barman *et al*.2010). In India, there has been a rapid increase in urbanization and industrialization, increase in technological, industrial and agricultural advancement coupled with increase in population growth, have triggered the deterioration of air quality in many cities. Fast growing cities, more traffic on roads, growing energy consumption and waste production and lack of strict implementation of environmental regulation are increasing the emission of pollutants (Agrawal, 2005). Vehicles emit particulate matter, nitric oxide and NO_2, carbon monoxide, organic compounds and lead, account for 60-70% of the pollution in the air in urban environment (Dwivedi *et al*., 2008). Landuse activities affect air quality by emitting manmade and natural pollutants. Developmental activities like industrial expansion, mining exploration, transportation and constructional works etc. cause degradation and drastic changes in every component of environment (Vaidya *et al*., 2018). Naturally, the sources of pollutants are volcanic eruptions, forest fires and dust storms whereas, anthropogenic source of pollutants comes from burning fossil fuels, industrial and vehicular emissions, power plants, mining, drilling and construction of roads (Ghio *et al*., 2012; Supriya *et al*., 2018; Sahil *et al*., 2016). The effect of particulates depends on its shape, size, concentration and time of exposure in relation to its mass and composition (Agrawal and Singh, 2000). Population growth and urbanization have caused immense pressure to convert landuse from natural and agricultural areas into residential and urban uses with significant impacts on ecosystem services. Weng and Yang investigated the relationship of local air pollution patterns to urban land use through Geographic Information System (GIS) and correlation analysis. More recently, Kahyao˘glu-Kora˘cin, *et al*. evaluated a set of alternative future patterns of landuse and found out a Regional Low-Density Future has the greatest impact on air quality. Biogenic VOCs are also important precursors of secondary organic aerosols (SOA) (Henze *et al*., 2008; Liao *et al*., 2007; Racherla and Adams, 2006), which contribute to particulate matter (PM) in air quality. Among air pollutants, particulate matter (PM) is a ubiquitous and it is especially a major problem due to its adverse health effect, visibility reduction and soiling of buildings (Chaurasia *et al*.2013). Compact urban development would likely have both positive and negative effects on air quality. The hilly areas of developing countries are lesser polluted as compared to urban areas. With the economical development and urbanization the air quality of hilly areas needs to be monitored. Therefore a study has been conducted to assess the impact of different landuses on air quality, by focusing on four major pollutants: VOCs, SO_2, NO_2 and PM_{10} in low hills of Himachal Pradesh.

2. Material and Methods

2.1 Study Area

In order to assess the impact of landuses on air quality, the present study has been conducted in some selected regions of Bilaspur, Kangra and Hamirpur districts in lower hill of Himachal Pradesh which is completely mountainous with altitude ranging from 350 to 6975 meter above mean sea level (Figure 1). Bilaspur having an area of 1, 167 km^2 is located at 31.34° N to 76.68° E, lies at the Bandla foot hill near the reservoir of Govind Sagar on the Sutlej River. Kangra district of Himachal Pradesh having an area of 5, 739 km^2 is located at 32.5° N to 77.45° E. Hamirpur district having an area of 1, 118 km sq located between 31.68° N and 76.52°E (Table 1). Two Municipal Committees in each district were selected under four dominant landuses (urban, peri-urban, agriculture and forest) and periodic sampling was done during pre-monsoon and post monsoon seasons. The air quality index (AQI) was calculated from the observed SPM, PM_{10}, NO_2 and SO_2 values using the formula (Rao *et al.*, 2003).

$$AQI = 1/4\times (I_{PM10} / S_{PM10} + I_{SO2}/ S_{SO2} + I_{NO2} / S_{NO2}) \times 100$$

VOCs were not included in the air quality index, as the standard values of VOCs consist of different parameters with different permissible limits not suitable for this formula. The VOCs were calculated by taking average value of two municipal committees for each landuse in low hills of Himachal Pradesh. In geo-spatial mapping of air quality, the blue colour remarks for good ambient air quality, red for moderate and green remarks for unhealthy.

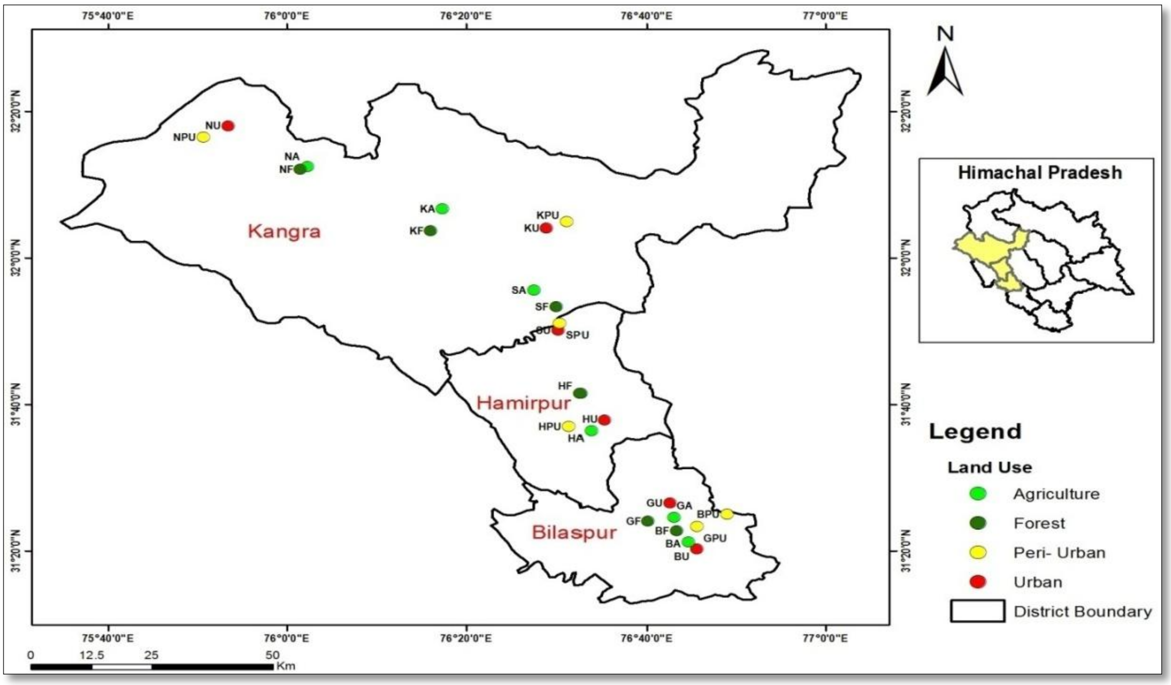

Figure 1: Map of study area

Table 1: Details of selected locations for air sampling in study area

Code	District	Municipal Committee	Location	Latitude	Longitude
BU	Bilaspur	Bilaspur	Bustand	31°20'29"N	76°45'39"E
BPU			Barmana	31°24'43"N	76°49'31"E
BA			Talwar	31°21'11"N	76°44'41"E
BF			Ecopark	31°20'06"N	76°46'16"E
GU		Ghumarwin	Ghumarwin	31°26'23"N	76°42'31"E
GPU			Kandraur	31°23'30"N	76°45"15"E
GA			Berthin	31°25'08"N	76°38'34"E
GF			Sunhani	31°24'25"N	76°40'47"E
HU	Hamirpur	Hamirpur	Bustand	31°41'1"1N	76°31'19"E
HPU			Barsar	31°31'35"N	76°27'45"E
HA			Taal	31°37'48"N	76°35'23"E
HF			Bhated Khas	31°41'31"N	76°32'41"E
SU		Sujanpur	Sujanpur	31°50'4"N	76°30'16"E
SPU			Jawalamukhi, Bustand	31°52'18"N	76°19'17"E
SA			Shiv Mandir, Nadaun	31°48'2"N	76°28'55"E
SF			Choa	31°33'43"N	76°34'01"E
KU	Kanga	Kangra	Bustand	32°06'30"N	76°22'53"E
KPU			Thakurdwara	32°05'02"N	76°30'40"E
KA			Matour	32°08'17"N	76°17'36"E
KF			Paraur	32°04'59"N	76°27"14"E
NU		Nurpur	Bustand	32°18'14"N	75°53"41"E
NPU			Shahpur	32°13'02"N	76°10'29"E
NA			Kulan	32°15'54"N	75°54'14"E
NF			Narial	32°13'20"N	75°57'34"E

(BU= Bilaspur urban, BPU= Bilaspur peri-urban, BA= Bilaspur agriculture, BF= Bilaspur forest, GU= Ghumarwin urban, GPU= Ghumarwin peri-urban, GA= Ghumarwin agriculture, GF= Ghumarwin forest, HU= Hamirpur urban, HPU= Hamirpur peri-urban, HA= Hamirpur agriculture, HF= Hamirpur forest, SU= Sujanpur urban, SPU= Sujanpur peri-urban, SA= Sujanpur agriculture, SF= Sujanpur forest, KU= Kangra urban, KPU= Kangra peri-urban, KA= Kangra agriculture, KF= Kangra forest, NU= Nurpur urban, NPU= Nurpur peri-urban, NA= Nurpur agriculture, NF= Nurpur forest)

2.2 Air sampling

The air quality has been assessed periodically in each season and the data was recorded for eight hours, periodically three times in day time at each location, during pre monsoon and post monsoon months using Respirable Dust Sampler (Cat. No MBLRDS-002) and Environmental Perimeter Air Station (EPAS).

3. Results and Discussions

3.1 Concentration of Respirable suspended particulate matter (PM_{10})

The data presented in Table 2 revealed that under different landuses the concentration of PM_{10} in ambient air ranged from 18.75 to 61.92 µg/m^3, whereas, season wise the concentration of PM_{10} was found to vary from 34.69 to 49.64 µg/m^3, which was within the permissible limits as prescribed by National Ambient Air Quality Standards (NAAQS). The highest PM_{10} level found in urban landuse with respective value of 61.92 µg/m^3, which was significantly at par with peri-urban landuse (60.0 µg/m^3) followed by agriculture landuse (26.95 µg/m^3) and minimum concentration was found at forest landuse with respective value of 18.75 µg/m^3 (Figure 2). The lowest concentration at the forest site attributed to the presence of sufficient vegetation, which helped in removing the particulate matter from the atmosphere.

Table 2: Seasonal variations in PM_{10} concentration (µg/m^3) under different landuses

Landuse / Season	Pre-monsoon	Post-monsoon	Mean
Agriculture	22.67	31.25	26.96
Urban	50.50	73.33	61.92
Peri-urban	52.50	69.50	61.00
Forest	13.08	24.42	18.75
Mean	34.69	49.64	
C. D. $_{(0.05)}$	**Landuse**		3.09
	Season		2.19
	Landuse x Season		4.38

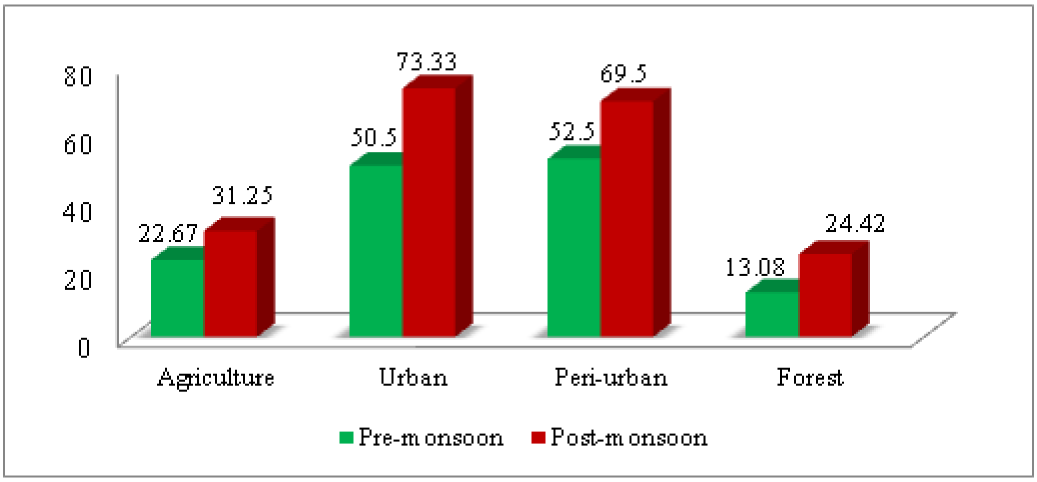

Figure 2: Graphical representation of seasonal variations in PM_{10} concentration under dominant landuses

Irrespective of landuses, the maximum (49.64 µg/m^3) concentration of PM_{10} was found in post-monsoon and minimum (34.69 µg/m^3) in pre-monsoon season. The results are in line with the findings of Lalrinzuali (2018), Sahil *et al.* (2016), Jain and Saxena (2002) who reported that maximum PM_{10} concentration was found in post-monsoon season. The interaction effect of landuse and season was also found to exert significant influence on concentration of PM_{10}. The maximum (73.33 µg/m^3) PM_{10} concentration was observed under urban landuse in post-monsoon season and minimum (13.08 µg/m^3) under forest landuse in pre-monsoon season. The similar findings are in line with Lalrinzuali (2018) who found maximum PM_{10} concentration under urban landuse in post-monsoon season (Table 2).

3.2 Concentration of sulphur-dioxide (SO_2)

The data presented in the Table 3 revealed that under different landuses, the SO_2 ranged from 2.70 to 7.03 µg/m^3, whereas, season wise concentration of SO_2 was found to vary from 4.83 to 5.32 µg/m^3, which was within the permissible limits as prescribed by NAAQS. The graphical representation shown in Figure 3 predicted that the seasons exerted a significant variations with highest (5.31µg/m^3) in post-monsoon and lowest (4.83 µg/m^3) in pre-monsoon season. Irrespective of landuses, the data indicated the trend in SO_2 level as urban > peri-urban > agriculture > forest with respective values of 7.03, 6.32, 4.24 and 2.70 µg/m^3 (Figure 3).

Table 3: Seasonal variations in SO_2 concentration (µg/m^3) under different landuses

Landuse / Season	Pre-monsoon	Post-monsoon	Mean
Agriculture	4.07	4.41	4.24
Urban	6.71	7.36	7.03
Peri-urban	6.07	6.58	6.32
Forest	2.48	2.93	2.70
Mean	4.83	5.32	
C. D. $_{(0.05)}$	**Landuse**		0.29
	Season		0.21
	Landuse x Season		NS

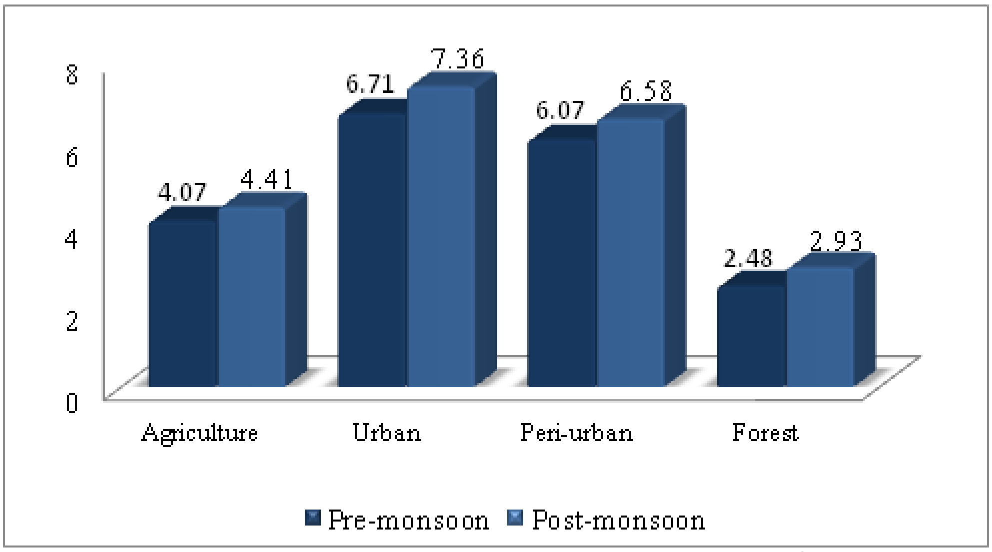

Figure 3: Graphical representation of seasonal variation in SO_2 concentration (µg/m^3) under dominant landuses

The highest SO_2 concentration was found at urban site in post-monsoon it ascribed due to the incomplete combustion of fossil fuels, enhanced vehicular emission and chemical transformation of interacting gases in the dry season where calm meteorological conditions resulting in a stable atmosphere that restricted the dispersion of the pollutant to other areas in comparison to pre-monsoon (Sahil *et al.*2016; Lalrinzuali, 2018; Saini *et al.*2008). The lowest SO_2 concentration at the forest site attributed to less vehicular activities in comparison to selected landuses and presence of trees that absorbed the pollutants, which lead to decrease in the concentration of SO_2. The results are in accordance with the findings of Akabueze *et al.* (2012) and Chao *et al.* (2014).

3.3 Concentration of nitrogen-dioxide (NO_2)

The data presented in the Table 4 revealed that under different landuses, the NO_2 in the ambient air ranged from 29.08 to 34.71 µg/m^3, whereas, season wise, the concentration of NO_2 was found to vary from 31.92 to 33.06 µg/m^3, which was within the permissible limits as prescribed by NAAQS.

Table 4: Seasonal variations in SO_2 concentration (µg/m^3) under different landuses

Landuse / Season	Pre-monsoon	Post-monsoon	Mean
Agriculture	33.33	36.08	34.71
Urban	32.83	33.33	33.08
Peri-urban	32.58	33.58	33.08
Forest	28.92	29.25	29.08
Mean	31.92	33.06	
C. D. $_{(0.05)}$	**Landuse**		0.58
	Season		0.41
	Landuse x Season		0.83

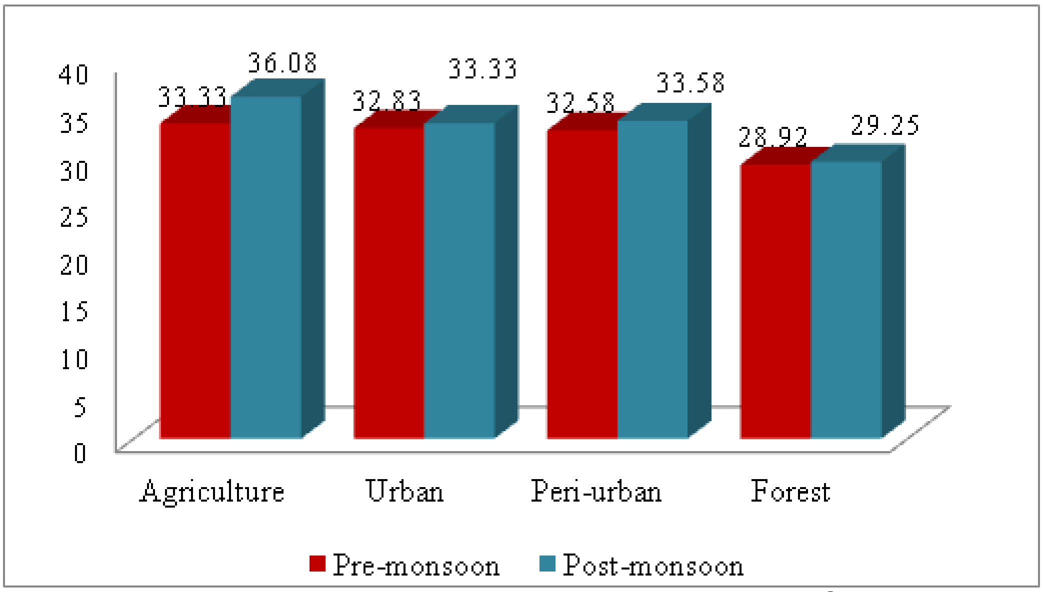

Figure 4: Graphical representation of seasonal variation in NO_2 concentration (µg/m^3) under dominant landuses

The data in Table 4 showed that the seasons exerted significant variations with highest (33.06 µg/m^3) in post-monsoon and lowest (31.92 µg/m^3) in pre-monsoon season. Irrespective of seasons, the data further indicated that maximum (34.71 µg/m^3) concentration of NO_2 was found at agriculture landuse, which was at par with urban and peri-urban landuses (33.08 µg/m^3) and minimum was found at forest landuse with respective value of 29.08 µg/m^3 (Figure 4). The lowest NO_2 concentration at the forest site attributed due to less vehicular activities in comparison to other landuses (urban, peri-urban and agriculture) and presence of trees that absorbed the pollutants, which lead to decrease in the concentration of NO_2 in the ambient air. The results are in line with the findings of Almaraz *et al.* (2018) where they found that the agriculture was a major source of NO_2. The interaction effect of landuse and season was found to exert significant influence on NO_2. The maximum (36.08 µg/m^3) NO_2 concentration was observed under agriculture landuse in post-monsoon season and minimum (28.92 µg/m^3) under forest landuse in pre-monsoon season (Table 4).

3.4 Concentration of volatile organic compounds (VOCs)

The data presented in the Table 5 revealed that under different landuses the VOCs in the ambient air ranged from 2.13 to 5.49 µg/m^3, whereas, season wise, VOCs concentration was found to vary from 3.78 to 4.32 µg/m^3. The VOCs concentration in Table 5 showed that the seasons exerted a significant variations with highest (4.32 µg/m^3) in post-monsoon and lowest (3.78 µg/m^3) in pre-monsoon season. Irrespective of seasons, the data further indicated the trend of VOCs level as urban > peri-urban > agriculture > forest with respective values of 5.49, 5.06, 3.55 and 2.12 µg/m^3 (Figure 5).

Table 5: Seasonal variations in VOCs concentration (µg/m^3) under different landuses

Landuse / Season	Pre-monsoon	Post-monsoon	Mean
Agriculture	3.21	3.86	3.53
Urban	5.43	5.55	5.49
Peri-urban	4.73	5.38	5.06
Forest	1.76	2.48	2.13
Mean	3.78	4.32	
C. D. (0.05)	**Landuse**		0.26
	Season		0.19
	Landuse x Season		NS

The highest VOCs concentration under urban landuse ascribed due to vehicular exhaust as well as the use of chemicals and paints from nearby buildings and farms. The results are in line with the findings of Edwards *et al.* (2006) who concluded that the VOCs were emitted from automobiles and were higher in heavy traffic areas. The lowest VOCs concentration was found at the forest site because the sources of emissions was mainly natural i. e. from the plants, sometimes the combustion of material like wood and coal burning during forest fires, and there was no vehicular activity to add up the emission. The results are also in accordance with the findings of Chao *et al.* (2014) and Lalrinzuali (2018) who observed maximum VOCs concentration under urban landuse in post-monsoon season.

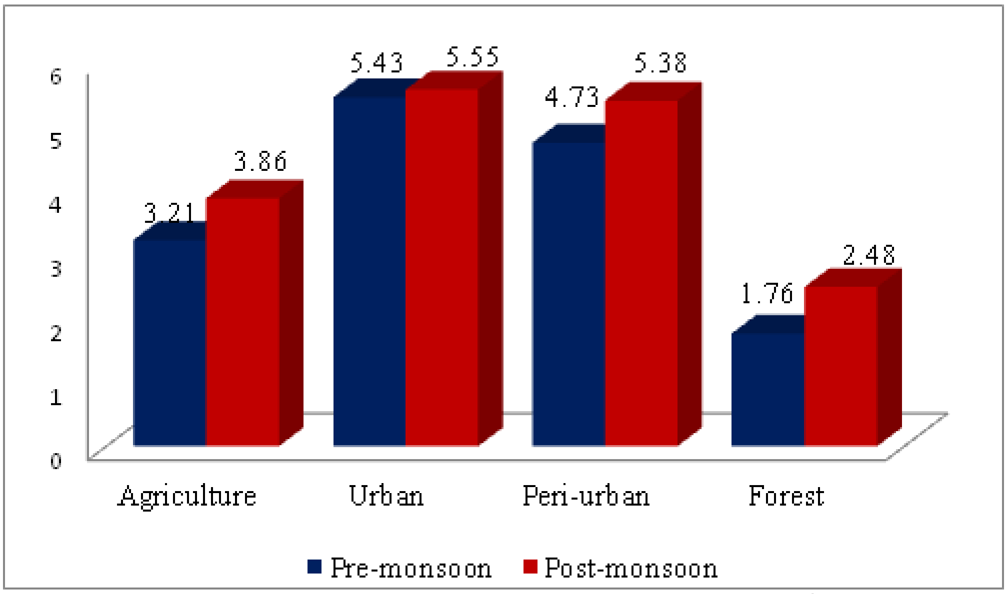

Figure 5: Graphical representation of seasonal variation in NO_2 concentration (µg/m^3) under dominant landuses

3.5 Geo-Spatial Mapping

The GIS maps include information relating to air quality and its distribution over the study area. The geo-spatial mapping was carried out using ERDAS software.

3.5.1 Air Quality Index (AQI)

The selected landuses were found to exert a significant influence on air quality index but within permissible limit. The perusal of the Table 6 showed that under different landuses in the study area, the air quality index (AQI) ranged from 25.76 to 46.57 which was classified as good. The results are in line with Lalrinzuali (2018) who recorded good air quality index under different landuses (urban, agriculture and forest).

In Bilaspur district, highest (33.17) AQI value was observed under urban landuse followed by peri-urban and agriculture landuses (44.77, 33.17) respectively and the lowest (26.29) AQI was noticed under forest landuse. It has been observed that the AQI for different landuses in Bilaspur district remarked as good (Figure 6). In Hamirpur district, the AQI under urban landuse was found to be highest (46.57) followed by peri-urban and agriculture landuses (46.17, 33.38) respectively and the lowest (26.36) AQI was noticed under forest landuse. It has been observed that the AQI for different landuses in Hamirpur remarked as good (Figure 7). In Kangra district, the AQI under urban landuse was found to have highest (45.48) followed by peri-urban and agriculture landuses (44.72, 32.46) respectively and the lowest (25.76) AQI was noticed under forest landuse, the AQI for different landuses in Kangra also remarked as good (Figure 8).

The Table 7 showed the variations in VOCs concentration under different landuses in Bilaspur, Hamirpur and Kangra districts. In Bilaspur district the maximum (5.7 µg/m^3) VOCs concentration on an average was observed under urban landuse followed by peri-urban and agriculture landuses (5.2, 3.8 µg/m^3) respectively and minimum (2.2 µg/m^3) was found under forest landuse. In district Hamirpur on an average the maximum (5.8 µg/m^3) VOCs concentration was observed under urban landuse followed by peri-urban and agriculture landuses (5.1, 3.5 µg/m^3) respectively and minimum (2.0 µg/m^3) was found under forest landuse. In district Kangra, on an average the maximum (4.9 µg/m^3) VOCs concentration was observed under urban and peri-urban landuses followed by agriculture landuse (3.3 µg/m^3) and minimum (2.2 µg/m^3) was found under forest landuse**.** The VOCs variation under different landuses in selected areas has been depicted in map (**Figure 9).**

Table 6: AQI under selected landuses in low hills

Landuses	Districts	AQI
Agriculture	Bilaspur	33.17
Urban		45.32
Peri-urban		44.77
Forest		26.29
Agriculture	Hamirpur	33.38
Urban		46.57
Peri-urban		46.17
Forest		26.36
Agriculture	Kangra	32.46
Urban		45.48
Peri-urban		44.72
Forest		25.76

Table 7: VOCs under selected landuses in low hills

Landuses	Districts	VOCs
Agriculture	Bilaspur	3.8
Urban		5.7
Peri-urban		5.2
Forest		2.2
Agriculture	Hamirpur	3.5
Urban		5.8
Peri-urban		5.1
Forest		2.0
Agriculture	Kangra	3.3
Urban		4.9
Peri-urban		4.9
Forest		3.3

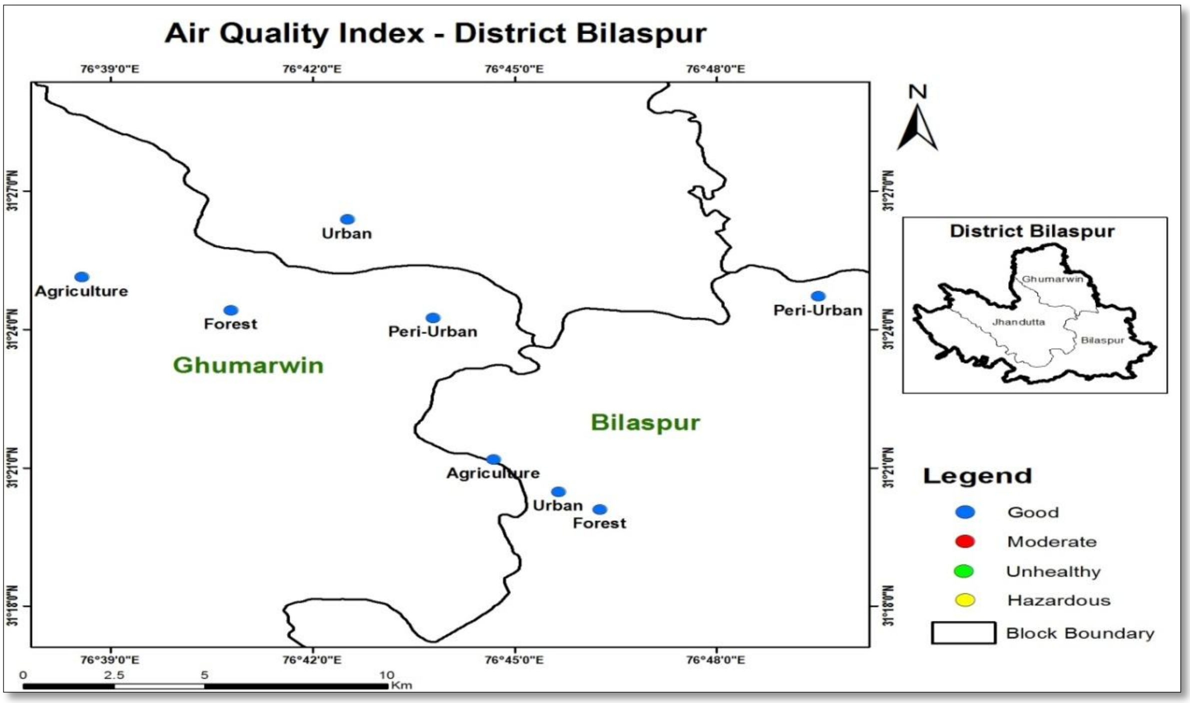

Figure 6: Air Quality Index under different landuses in Bilaspur district

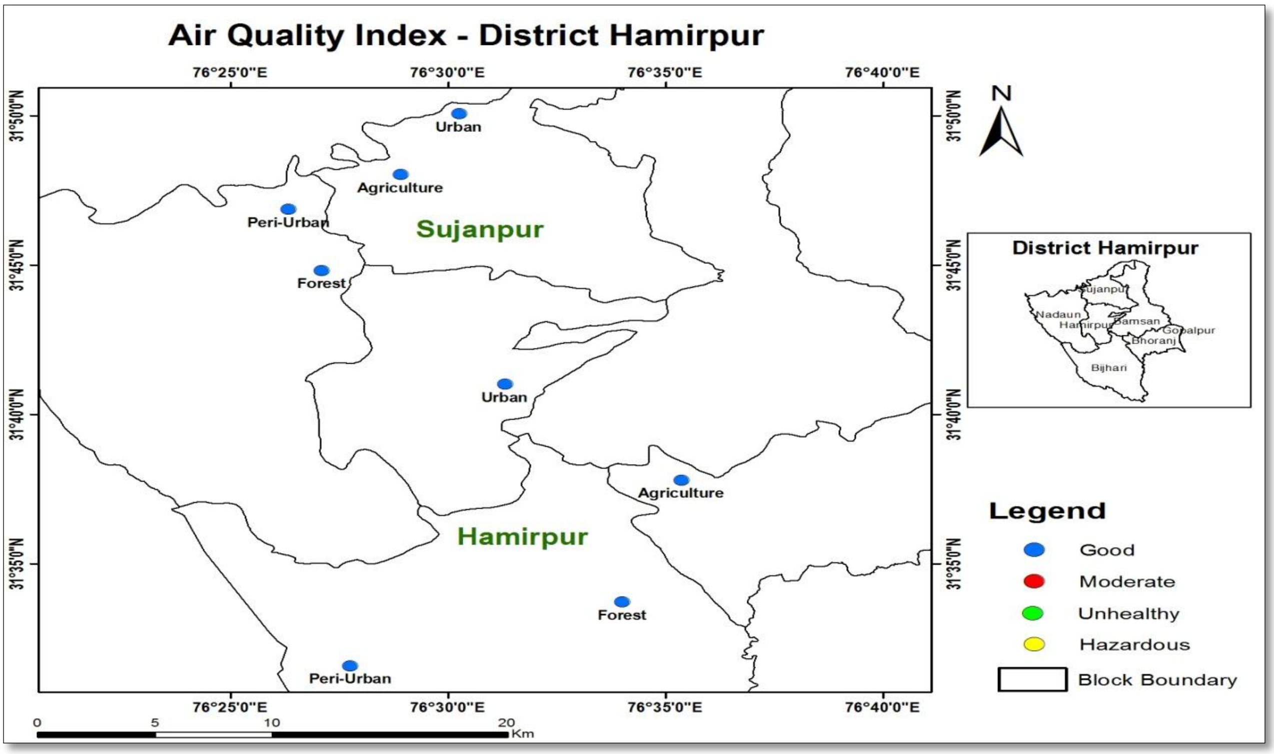

Figure 7: Air Quality Index under different landuses in Hamirpur district

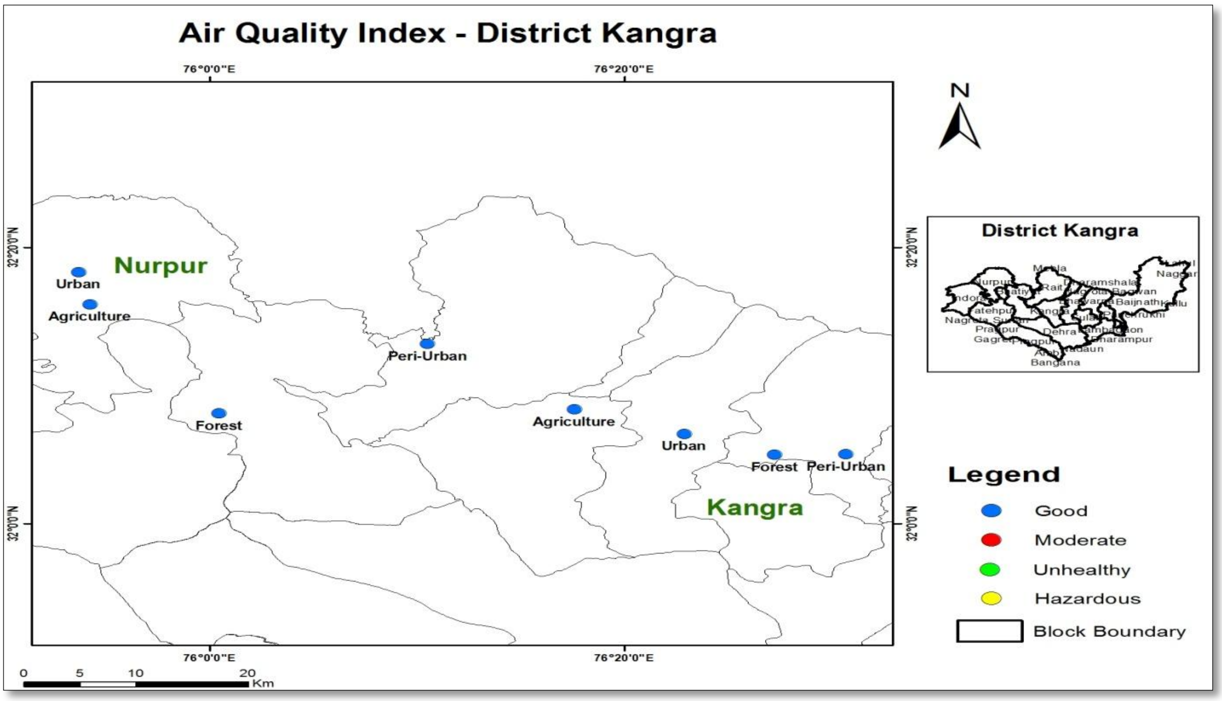

Figure 8: Air Quality Index under different landuses in Kangra district

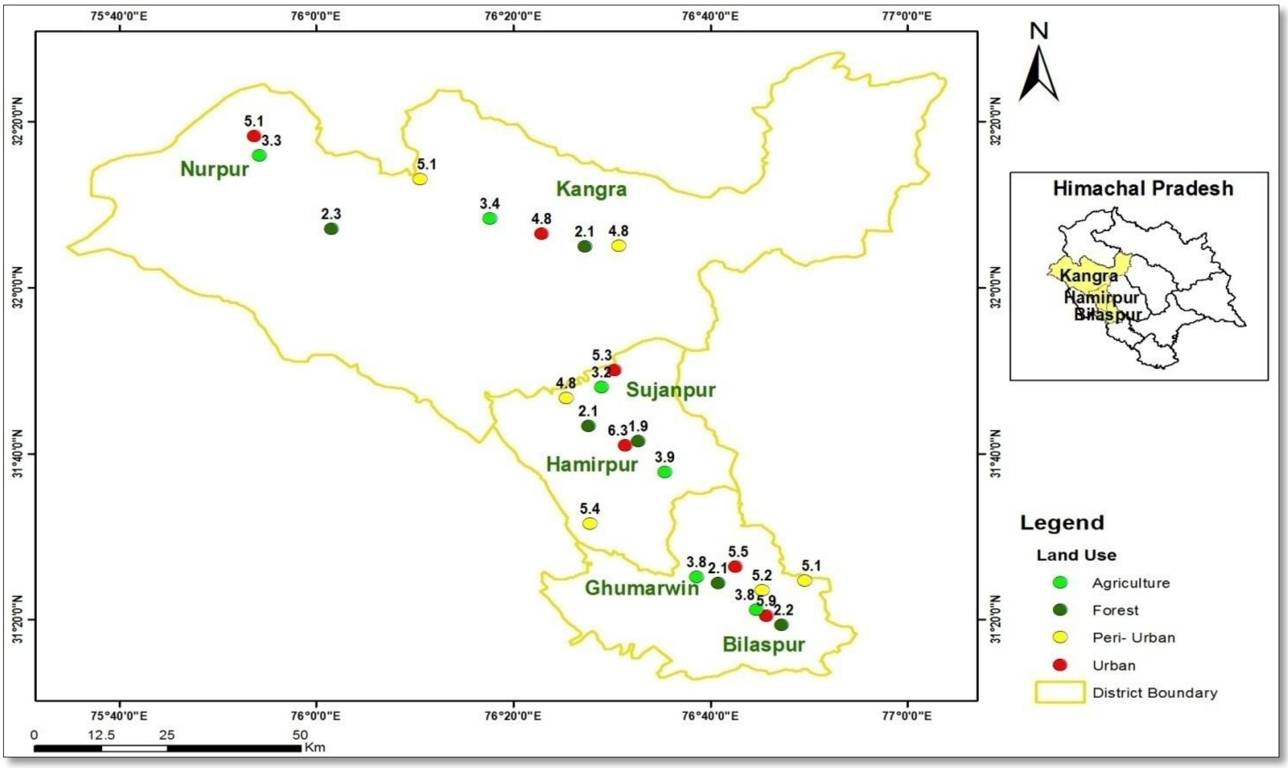

Figure 9: VOCs concentration under different landuses in selected areas of low hills

4. Conclusion

The investigations shown that concentration of air quality parameters were found to be within the permissible limits of NAAQS in the study area. The concentrations of air quality parameters were found to vary significantly during all the seasons and under different landuses. These variations may be linked to the landuse practices. It was found that the urban landues has the highest concentration of the pollutants (PM_{10}, SO_2, VOCs) followed by peri-urban and agriculture and lowest concentration found at forest site except NO_2 which was found maximum under agriculture > urban > peri-urban> forest during post-monsoon and pre-monsoon seasons. The air quality index (AQI) under different landuses was classified as good for Bilaspur, Hamirpur and Kangra districts which was mapped by using ERDAS software. In future, these changes in landuse pattern may result in increase of these variables (SO_2, NO_2, PM_{10} and VOCs) in atmosphere and this could pose risk to aerial as well as terrestrial life. Thus it is essential to monitor the atmospheric air quality on regular basis so that corrective methods could be engaged to prevent harmful effects of these pollutants.

Acknowledgement

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