RESEARCH ARTICLE

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Effects of forest areas on air quality; Aras Basin and its environment

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Abstract

Background: In the study, the Aras Basin and its environment, one of the most important hydrological basins of Turkey, was evaluated. In survey area, to determine the change of air quality, it was benefited from 23,770 pieces of hourly measured SO₂ (Sulfur dioxide) and PM₁₀ (particulate matter) concentration values for the December, January and February of 2009–2010 in which the pollution is at peak, by forming database in geographical information system (GIS), spatial analyze maps were attained. By comparing; maps showing attained numeral air quality and maps showing the spread of forest lands in the region, it was tried to determine the relation and interaction between air quality and forest lands.

Results: The results indicated that the Air Quality Index (AQI) values were the lowest for the forest land in the months which mean that the forest land was the most convenient place for health. The increase the AQI, air pollution also increases. The results indicated that the air quality index changed from 1 to 4 within the region. In the forest areas, the AQI values for the months were the lowest. This indicated that the most suitable places for health are the places with a high forest coverage rates (76,50; 66,46 and 96,78%). There was no forest area within the region where the AQI values were the highest, so the risk was maximum, for the months.

Conclusions: Authorities should create new afforestation areas and rehabilitate degraded forest lands to limit air pollution by increasing the quality of urban life.

Keywords: Air quality, Air control, Forest land, Aras Basin, Planning

Introduction

Forest land is equal to 31% of the territory in the world. More than 1,5 billion people get living from forests. Besides countless benefits, forests have great importance in sustainability of important ecosystem functions as protecting biological variation, protecting earth, water quality and supply, flood control, climate adjustment and recreation [1,2].

Forests are one of the most important ecosystems affecting earth climate. They carry out important functions enhancing air quality. They prevent pollution of the cities by sticking particle and aerosols on leaf surface, absorbing and by slowing down the air movements make them fall into surface. Also, they reduce greenhouse gas effect by avoiding CO₂. In many surveys conducted, it was

shown that a green zone surrounding a city decreases the lead percentage approximately 85% [3].

As a result of developments on urbanization and especially increase in the city populations, air pollution is the leading environmental problem affecting human health and decreasing quality of life in especially cities.

Air pollution can be defined as being pollutants as sulfur dioxide, particulate matter, nitrogen oxide, and ozone in such a level that have negative effects on environment and health [4-9].

Among the main causes of air pollution in our country, industrial facilities, fossil fuels and exhaust gases are the most important. However the main reason triggering these causes, uncontrolled population increase and concordantly, urbanization and destroying or exterminating green spaces can be counted [10,11].

For this reason, it is required to make air quality management plans, have valid and reliable information about existing pollution for a rationale planning. For this purpose, level of pollutant concentration must be measured

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in several time intervals, and it has to be known the reliability of these measurements.

It is very important observing air quality to determine the sources of air pollution and topographical distribution, to develop control strategies, and to control the effectiveness of these basic air pollutants. Possible to be found in urban areas can be counted as carbon monoxide (CO), sulfur dioxide (SO₂), particulate matter (PM), ozone (O₃), nitrogen dioxide (NO₂), and lead (Pb). Negative risks that can be caused by these pollutants are also related to many factors as meteorological and physiographic features as well as uncontrolled industrialization, population growth and transportation [12].

For observation of air pollution data, spatial analyzes and modeling, observation, analyze, modeling and showing on the map functions of the geographical information systems (GIS) can be used [13-17].

In this study, it is aimed to analyze relation and interaction between air quality and forest lands in Aras Basin and its environment. For this purpose, it is benefited from sulfur dioxide (SO₂) and particulate matter (PM₁₀) values while forming Air Quality Index maps in GIS. Air Quality Index maps are evaluated by comparing numerical Forest management maps showing present forest land and its distribution in the region.

Materials and methods

The main material of the research is formed by one of the important hydrological basin Aras Basin (Figure 1), forest management plans showing interior natural forest

existence and Air Quality Index map (AQI) values of inside the basin borders and Erzurum, Erzincan, Ardahan, Iğdır, Kars, Ağrı, Bingöl, Muş, Bayburt, Rize cities in its environment. In Figure 2, the location of the 11 stations of which measurement values used, in Figure 3, the numerical maps showing forest existence in these lands are given. Important rivers of the region are Aras and Kura rivers [18] (EAP 2010). Research area is 54.605 km² and it is between 40°02'0'' and 39°45'0'' north latitudes and 40°30'0'' and 44°15'0'' east longitudes.

In this study, numerical forest management maps showing present forest lands in the survey borders and inside the survey area and its environment, Air Quality Index values of 11 cities of 2009–2010 years December, January and February months were analyzed. In the survey area, changes in air quality because of heating in winter months are seen. The most important cause of the air pollution in the region is fossil fuels used in residence and industrial areas in winter months. As a result, in the study, the AQI of dense heating periods; December, January and February are used.

Air Quality Index (AQI) is an index used for reporting daily the air quality of the environment where we live. It gives information about how clean or polluted the air of the area where we live and what health effects it may cause.

The AQI give information about effects that may appear after a couple of hours or a couple of days after polluted air inhaled. The AQI is a scale formed in the range of 0–500 (Table 1). As The AQI increases, air pollution

Figure 1 Research area "Aras Basin and its environment".

Figure 2 Air quality index measurement station locations.

increases and directly or indirectly some health problems arises [19]. The AQI scale can be examined in 6 categories [20].

The AQI values were calculated separately for every pollutant in the region (ozone, particles, carbon monoxide, sulfur dioxide, and nitrogen dioxide). Maximum calculated the AQI value, forms the the AQI value of the day [12].

In the study, Geographical Information System (GIS) is used as a means. Firstly, for measurement stations, spot

Figure 3 Forest areas of research area.

Table 1 Air quality index scales [20]

AQI scale value	Air Quality Index (AQI)	Health level
1	0-50	Good
2	51-100	Middle
3	101-150	Unhealthy for sensitive groups
4	151-200	Unhealthy
5	201-300	Very unhealthy
6	301-500	Dangerous

database is formed by means of ArcGIS 9.3 software according to national coordinate system (UTM-37 Zone). Forming maps showing the distribution of AQI and pollutant value onto the region best, “Kriking” interpolation in the Spatial analyst extension tab of ArcGIS 9.3 software of ESRI Firms used. Using maps based on this technique, spatial analyzes realized and, distribution of SO₂ and PM₁₀ amounts were determined. By Kriking method, making use of data present in the study field experimental variogram model is formed. By determining the optimal model, areal transformation was carried out. Kriking formula related to the model is given below [21].

$$Z_p = \sum_{i=1}^n W_i Z_i$$

Here; Z_p : expected undulation value of P point.

W_i : weight values corresponding to every Z_i

Z_i : undulation value of used spots

n : number of spots used.

Involve of the areas that has no station values in survey area in to the analyses analyzes, can be possible by transferring spatial AQI values of the stations near environment of the survey area with Kriking interpolation technique into GIS. While creating air quality maps

“Geostatistical Analyst” module was used and different models were evaluated on ArcGIS 9.3 software.

While evaluating models, mean error (ME) must be close to 0 and approximate standardized mean errors’ square root (RMSSE) close to 1 [22]. While implementing the formulas, it is surveyed whether there is anisotropy effect or not. Also to evaluate the AQI values of the areas where there is no station data, the measurement results of neighbor areas; Rize, Artvin, Bayburt, Erzincan, Muş and Bingöl were used (Table 2).

While forming database of the AOI values, in 11 cities 23770 pieces of hourly sulfur dioxide (SO₂) and Particulate Matter (PM) measurement results of ministry of environment and urban planning inside Aras Basin were evaluated (Table 3) [23].

In the study, to determine the effect of forest lands on air quality, AQI maps formed on GIS are compared with numerical forest management maps showing the present forest areas inside the survey area and the distribution, and the interaction and relation between air quality and forest area are tried to be evaluated.

Results

The study area was the Aras Basin which include Erzurum, Ardahan, Iğdır, Kars, and Ağrı cities, and total area is 227.951 km². According to [24] report, when we think of the water shortage the world will go through and the climate change, importance of this survey will be seen better in terms of pointing out basins.

Data attained from the 11 measurement stations, reveal that there are differences in air quality in winter months; in terms of months and distribution of area.

For air quality values in the survey area did not show directional change, therefore isotropic semivariogram model was preferred. Spatial dependency (Nugget/Sill ratio) is about autocorrelation degree of sampling points. If

Table 2 Location and time of observations at air quality measurement stations

No	Air quality measure station	Coordinates (Latitude-Longitude)	Altitude (m)	Observation months (2009–2010)
1	AĞRI	39.722222-43.405000	1632	December-January-February
2	ERZURUM	39.898056-41.272500	1950	December-January-February
3	ARDAHAN	41.110833-42.701111	1810	December-January-February
4	IĞDIR	39.926111-44.053611	865	December-January-February
5	KARS	40.605000-43.104444	1758	December-January-February
6	MUŞ	38.748611-41.509444	1312	December-January-February
7	BİNGÖL	38.883889-40.503611	1140	December-January-February
8	ERZİNCAN	39.743056-39.495000	1193	December-January-February
9	BAYBURT	40.258889-40.224167	1568	December-January-February
10	ARTVİN	41.175278-41.818333	628	December-January-February
11	RİZE	41.021944-40.532500	21	December-January-February

Table 3 (SO₂) and (PM₁₀) measurements attained in survey area

Number no	Date	Station	SO ₂	PM 10	MAX	Max Name
1	12.01.2009 00:00	AGRI	1	2	2	PM 10
2	12.01.2009 01:00	AGRI	1	2	2	PM 10
3	12.01.2009 02:00	AGRI	2	2	2	SO2
4	12.01.2009 03:00	AGRI	1	2	2	PM 10
..						
...						
....						
23767	2/28/2010 9:00:00 PM	RIZE	1	2	2	PM 10
23768	2/28/2010 10:00:00 PM	RIZE	1	2	2	PM 10
23769	2/28/2010 11:00:00 PM	RIZE	1	2	2	PM 10
23770	03.01.2010 00:00	RIZE	1	2	2	PM 10

spatial dependency is high, spatial correlation between sampling points are so high. Spatial dependency (%177 and %153) found as a low between sampling points out of the distributions of meteorological stations are not enough. Effective range where spatial dependency active are 271470 meters (Table 4). Kriking interpolation that is used for converting spot data to areal, "Exponential" model has low failure rate for SO₂. Other hand Gaussian model has more spatial correlation with PM₁₀. Map suitable for this model was formed and areal data was attained from this map.

When the AQI values for Decemcer, January and February of 2009–2010, it would be seen that the AQI scale gets values between 1 and 4. It was determined that Ağrı was the region which is exposed to the dens-est pollution in December (Figure 4). In this region the AQI value changes between 2.0-3.3 range and poses a risk for sensitive groups. However in January, it was determined that the AQI values changes between 2.0-3.9 and risky regions for sensitive groups were Iğdır, Ağrı, Kars, Erzurum and Ardahan (Figure 5). However in February, it gives the results that the AQI values changes between 2.0-3.1 range and this change affect spatially Iğdır and Ağrı cities (Figure 6). When the concentrations of pollutants in December, January and February were analyzed, in December in most of the survey area high concentrated pollutant PM10 is found (Figure 7). In January, high concentrated pollutant PM₁₀ was less than December and (SO₂) concentration intensi-fies to the west of Erzurum (Figure 8). Also in February,

there is a possibility of the population to be exposed to pollution, and the areas where the highest SO2 concentra-tions seen were: Erzurum, Ardahan, and Ağrı city centers (Figure 9).

When we evaluate forest lands according to months and areas depending on the AQI values in survey basin, the areas of which AQI values in December was the lowest and the most appropriate for health, contains % 76,50 forest lands which was the highest ratio of all (Figure 10). In January, in areas where the AQI is the lowest, forest lands have the greatest area of % 66, 46 (Figure 11). In February, it has been understood that in areas where the AQI values were the lowest, forest lands had a great ratio as % 96,78 (Figure 12). It deter-mined that in all of December, January and February months, the AQI values were the highest, in other words there was no forest land in places where the risk was the highest (Table 5).

Discussions

To protect habitats, climatic and natural sources as soil, water and air must be kept out of negative pressures. Despite controlling air pollution levels regularly, negative effects range over limit values. The reason is that the increase especially in industrial facilities, using low quality heating fuels and vehicles exhaust gases. Rapid urbanization which causes all these and decrease of green land which tolerate these causes, show that who important to handle this problem [25-30].

Table 4 Variogram models and model parameters of attained spatial maps regarding air quality

Pollutants type	Model	Nugget	Range	Sill	(Nugget/Sill) %	ME ¹	RMSSE ²
SO ₂	Exponential	0,0479	271470	0,0270	177,41	0,2965	0,8813
PM ₁₀	Gaussian	0,3920	271470	0,2560	153,13	0,8223	0,8577

ME1: standard error of the mean.

RMSSE2: estimated standardized mean of error of mean square root.

When we analyze the information attained from this survey, air quality index gets values between 1 and 4 and it is seen that these values are above WHO values. Iğdır city, which has the highest values that is in the first place unhealthy for sensitive groups, is on the one hand surrounded by Ağrı mountain chain, on the other hand

being a plain which brings a hollow terrain structure, has an area which blocks airflow.

Because of this terrain structure, Iğdır experience serious air pollution problem in winter months. Parallel to survey results, according to Turkish Statistical Institute air pollution values, Iğdır is the city which has the highest

mean particulate matter ratio. Iğdır has the first place according to pollution row [31].

Though natural effects has little effect ration on air pollution, the real effect is human activities. This bad condition in air quality can be explained with solid and liquid fuels which do not meet standards, locally burning materials as

cow dung which billows, air pollution resulting from traffic and inadequate controlling. Not reaching of natural gas attained from Iran to Iğdır and Ağrı, restrains air quality in these cities reach to desired WHO levels. It seems that making the air quality in Iğdır is bound to using natural gas and enhancing controls in the city.

Figure 8 Spatial analyze map of 2009-2010 year January month SO_2 and particulate matter concentrations.

Erzurum, Kars, Ağrı and Ardahan cities, are in a area, with their topographic and geographic structure, which lives through continental climate. In these cities, which have the lowest mean temperature degrees, winters are very harsh and cold. From the results attained, the most

notably one is that in February, Kars has the most particulate matter ratio than Erzurum, Kars and Ardahan despite the fact that they have the same continental climate conditions. It is seen that because of using fossil fuels for heating, also because of socio-economic conditions using

Figure 9 Spatial analyze map of 2009-2010 year February month SO_2 and particulate matter concentrations.

cheap but low calorie and high sulfur ratio coals much, and because of bad meteorological conditions which needs high energy for heating, air pollution come to a position which need to be taken precautions.

As seen from the spatial analyze maps prepared according to geographical information system (GIS) measurement values, parallel to results of many studies proving the relation between air quality and forest lands, forest land affect air quality positively. Regarding survey results attained form comparing spatial distribution of the AQI bound to time with forest land existence in the area, the AQI values is low in areas where forest land density is

Acknowledgment

Authors present their great thanks to Prof. Dr. TASKIN OZTAS (University of Ataturk, Department of Soil Science and Plant Nutrition) for proofreading our study his suggestions and corrections in our study.

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Received: 14 April 2013 Accepted: 26 February 2014

Published: 10 March 2014

References

- Öner N, Ayan S, Sivaciolu A, Mal B: **Environmental impacts of urban forestry and urban forests.** *Kastamonu Univ Faculty For* 2007, **2**:1303–2399.
- Fidan C, Duran C, Kiriş R: **Effect of Plant Formations of Water Resources.** Ankara, Turkey: TMMOB 2 Water Policy Conference: 20–22 March 2008; 2007.
- Keller T: **The Possibilities of Using Plants to Alleviate the Effects of Motorvehicles.** ; 1979.
- Bridgman HA, Davies TD, Jickells T, Hunova J, Tovey K, Bridges K, Surapipith V: **Air pollution in the Krusne Hory region, Czech Republic during the 1990s.** *Atmos Environ* 2002, **36**:3375–3389.
- Afroz R, Hassan MN, Ibrahim NA: **Review of air pollution and health impacts in Malaysia.** *Environ Res* 2003, **92**:71–77.
- Bayram H, Dörtbudak Z, Eyyapan F, Kargin M, Bülbül B: **Human health effects of air pollution in the world, our country and our region, air pollution problem.** *Dicle Med J* 2006, **2**:105–112.
- Anyanwu EC, Kanu I: **The role of urban forest in the protection of human environmental health in geographically-prone unpredictable hostile weather conditions.** *Int J Environ Sci Tech* 2006, **3**:197–201.
- Richards M, Ghanem M, Osmond M, Guo MY, Hassard J: **Grid-based analysis of air pollution data.** *Ecol Model* 2006, **194**:274–286.
- Aydın ME, Durduran SS, Özcan S, Bedük F: **Evaluation changes in air quality using geographic information system (GIS) a in Konya.** 7. İzmir, Turkey: National environmental engineering, environmental technology congress of life; 2007.
- State Planning Organization: **Air Pollution from the Energy Sector.** Ankara: National Environmental Action Plan; 1997.
- Elbir T, Muezzinoglu A, Bayram A: **Evaluation of some air pollution indicators in Turkey.** *Environ Int J* 2000, **26**:5–10.
- Yeşilyurt C, Akçan N: **Criteria for Air pollution monitoring and sampling methodologies.** Republic of Turkey ministry of health. *Refik Saydam Hygiene Center Res Inst Environ Health* 2005.
- Ferreira F, Tente H, Torres P, Cardoso S, Palma-Oliveira JM: **Air quality monitoring and management in Lizbon.** *Environ Monit Assess* 2000, **65**:443–450.
- Tayanç M: **An assessment of spatial and temporal variation of sulfur dioxide levels over İstanbul, Turkey.** *Environ Pollut* 2000, **107**:61–69.
- Nas B, Berktaş A: **Using Geographic Information Systems for Environmental Problem Solving 2.** İstanbul, Turkey: Geographical Information Systems Information Days 2002; 2006.
- Puliafito E, Guevara M, Puliafito C: **Characterization of urban air quality using GIS as a management system.** *Environ Pollut* 2003, **122**:105–117.
- Alesheikh AA, Oskoueï AK, Atabi F, Helali H: **Providing interoperability for air quality in-situ sensors observations using GML technology.** *Int J Environ Sci Tech* 2005, **2**:133–140.
- Eastern Anatolia Project Master Plan: **Eastern Anatolia Project Master Plan, Prime Ministry State Planning Organization.** Volume 11th edition. Ankara: Present Situation and Analysis; 2010.
- Aydinlar B, Güven H, Kirksekiz S: **What is air pollution. What are the methods of measurement and air quality modeling. Air pollution and modelling.** *Sakarya Univ Institute Sci Environ Eng* 2009.
- World health organization. **Air quality guidelines - global update 2005.** http://www.who.int/phe/health_topics/outdoorair/outdoorair_aqg/en/index.html.
- Isaaks EH, Srivastava RM: **An Introduction to Applied Geostatistics.** New York: Oxford University Press; 1989.
- Johnston K, Hoef M, Krivoruchko K, Lucas N: **Using ArcGIS Geostatistical Analyst.** New York: ESRI; 2001.
- National air quality monitoring network. Ministry of Forest and Water Affairs. http://www.havaizleme.gov.tr/Default.htm.
- The Physical Science Basis: **The Scientific Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.** New York, USA: Summary for Policy Makers; 2007.
- World Health Organization: **WHO United Nations Environment Program. Urban Air Pollution in Megacities of the World.** UK: Blackwell; 1992.
- Elbir T, Muezzinoglu A: **Estimation of emission strengths of primary air pollutants in the city of İzmir, Turkey.** *Atmospheric Environ* 2004, **38**:1851–1857.
- Simkhada K, Murthy VK, Khanal SN: **Assessment of ambient air quality in Bishnumati corridor, Kathmandu metropolis.** *Int J Environ Sci Tech* 2005, **2**:217–222.
- Giri D, Murthy VK, Adhikary PR, Khanal SN: **Ambient air quality of Kathmandu valley as reflected by atmospheric particulate matter concentrations (PM10).** *Int J Environ Sci Tech* 2006, **3**:403–410.
- Özer U, Aydın R, Akçay H: **Air pollution profile of Turkey.** *Chem Int* 1997, **19**:190–191.
- Altıkat A, Torun FE, Bayram TT: **Global pollution: an example of air pollution in the world, European Union and Turkey.** *Erciyes Univ J Institute Sci Technol* 2011, **27**:134–149.
- The air quality of the statistical data. Turkey Statistical Institute. www.tuik.gov.tr.
- McPherson EG: **Benefits of urban forest.** *J Soc Municipal Arborists* 2003, **39**:12–23.
- Asan Ü, Destan S, Özkan Y: **Role and Importance of Prevention of Global Warming on Forests. Symposium on Turkish Forestry.** Antalya, Turkey: Immediate Action Required Topics and Legislation Effects on Structure during the Process of International Transformation; 2005.
- Nowak DJ, McPherson EG: **Quantifying the impact of trees.** Unasylva: The Chicago Urban Forest Climate Project; 1993.
- Nowak DJ: **Air pollution removal by Chicago's urban forest.** In *Chicago's Urban forest Ecosystem: Results of the Chicago Urban forest Climate Project.* Edited by McPherson EG, Nowak DJ, Rowntree RA. Radnor, PA: USDA Forest Service, Northeastern Forest Experimental Station; 1994.
- Acar C, Günay K, Acar H: **Urban Ecosystem and its Functions, the Contribution of Urban Forestry, Landscape Ecology in Terms of Evaluation.** Ankara, Turkey: I. Proceedings of the National Urban Forestry Congress; 2004.
- Dirik H, Ata C: **Urban forestry, benefits, planning and technical principles.** *İstanbul Univ J Faculty For* 2005, **55**:1–14.
- Yang J, McRide J, Zhou J, Sun Z: **The urban forest in Beijing and its role in air pollution reduction.** *Urban For Urban Greening* 2005, **3**:65–78.
- Tilki F, Güner S, Tüfekçioğlu A: **Urban forestry and urban forestry practices in artvin province Artvin Çoruh university.** *Faculty Forestry J* 2008, **9**:92–100.
- Saraçoğlu N: **The role of forests in global climate change slowing down.** *Sci Ed Mental Brightness* 2011, **135**:60–71.

doi:10.1186/2052-336X-12-60

Cite this article as: Demir et al.: Effects of forest areas on air quality; Aras Basin and its environment. *Journal of Environmental Health Science & Engineering* 2014 **12**:60.

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