

Analysis of Odor Distribution in Urban Landscape With GIS

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Abstract

A component of urban landscape, smell sources affect the urban atmosphere based on various activities. In this atmosphere, several unpleasant odors and pleasant smells are present and dispersion of these smells vary based on spatial attributes. Thus, in the present study, urban smellscape in Kastamonu province urban center with various smellscape and diverse physical structure were determined with human evaluator and smell measurement device to determine whether urban physical structure and climatic factors were effective on the dispersion modeled with the IDW method in GIS. Since the odor density changes depending on temperature and humidity, the study was carried out in all seasons for 1 year and serial measurements were analyzed for 1 month in August in the most suitable climatic period.

The study findings demonstrated that smell sources and intensity varied based on spatial and climatic properties on a route with different occupancy types; thus, smell did not affect the space at different point but as an area. Therefore, the element of smell should be integrated into planning and design work based on the dispersion property of smell.

1. Introduction

The interest in smellscape increased during the last decade among urbanism scholars with the employment of advanced technologies and various analysis methods. The improvement of multisensory perception in urban space led to the significance of sensory perceptions other than visual. Although the smell is not visible, it is a significant factor in urban spaces since individuals perceive and react to olfactory elements. Urban areas are not perceived only as a built environment but based on the impact of sensory and climatic events on these spaces (Thibaud, 2014). Smellscape were initially defined by Porteus (Porteus, 2016) to emphasize the relationship between the space and memory, and in following years, Drobnick (Drobnick, 2010) discussed smellscape within the concept of place. Smellspace were described as an environment shaped by experience and behavior (Henshaw, 2011; Kabat-Zinn, 2005), as affected by individual's experiences (Xiao J, 2018), as a part of life (McLean, 2019), and as an environment formed by an object-based and temporal perception process (Young, 2020).

Although it is not expressed significantly with this term in urban spaces, smellscape is mentioned in planning and design stages as preferred and non-preferred smells. However, the mentioned smells in these stages are often limited to plant and/or sewage, waste and industrial zone smells. There are various smells induced by diverse activities in urban areas. Urban smells induced by various occupancy types include domestic waste smells in residential areas, sewage smell due to wastewater and solid and liquid waste, emission and waste smells in industrial zones, solid and liquid waste facility smells, smells dispersed by restaurants, ovens, etc., vegetables, fruit and animal smells in commercial zones such as markets. These smell sources are observed in all cities, regions and countries, but smell type could vary based on the source (Muallim Mubina Auwal, 2019). Similarly, the Environmental Protection Agency (EPA) classified the smell sources as industrial sources such as sewage, treatment plant, animal processing plant, slaughterhouse, landfill, and composting facilities, and local smell sources such as store and restaurant smells. It could be observed that various smell sources affect human behavior in urban spaces. In land use analysis, which is a significant component of urban planning, it was demonstrated that smell is a factor in the preference of residential areas based on their relationship with industrial zones (Batalhone, 2002), and the preference of clean and non-noisy routes that are far away from intense traffic and without exhaust emissions by bicycle riders (Gössling et al., 2019; Simpson, 2018). Quercia et al. (2016) emphasized that urban administrators do not consider olfactory opportunities fully and consider smell a negative factor; however, smellscape could be developed by controlling the air flow at transportation stops and pedestrian streets with plant arrangements. Various smell control applications have been developed in urban areas and Henshaw (2011) listed these applications as masking, removal, separation and odorization. In these studies, removal aims to completely remove the smell and is different from the other techniques and generally used to remove exhaust smell and pedestrianization is recommended. Other control studies focused on the promotion of other smell sources that would mask or isolate the undesired smells.

A smell is characterized by factors such as climate conditions, density, duration, volume and volatility, and temperature fluctuations, wind speed, relative humidity and/or atmospheric pressure significantly affect the character and the perception of the smell (Badach et al., 2018). The wind significantly affects the smell cloud dissipated at the smell source (Le et al., 2015). There is an inverse proportion between the wind speed and the size and permanence of the smell cloud. The smell is dispersed to a larger area at high wind speeds, while the intensity of the smell is lower (Ayan Çeven, 2020; Lin et al., 2006; Song & Wu, 2022). The wind transports and disperses the smell based on the wind direction (Conchou et al., 2019). In a smell perception experiment conducted during a walk, it was reported that the wind dispersed the smell and smell was not perceived (Bouchard Natalie, 2013). The temperature affects the dispersion of the smell. Since temperature leads to convection, the smell moves at a higher rate in the air based on the temperature increase. Thus, in warm weather (22.5°C or above), the smell is dispersed at a higher rate. Furthermore, the smell could stay at ground level based on the temperature (Lin et al., 2006). In an indoors cigarette smoke study, the smell intensity increased at 25.5°C (Cain et al., 1983). Cold and freezing temperatures reduce the strength of smells. Snow cover and freezing temperatures reduce smell perception. In a smell emission study conducted with pig manure, it was determined that a reduction in temperature led to a decrease in smell dispersion [15]. Another environmental factor, humidity changes smell intensity. As humidity increases, smell intensity increases (Bottcher, 2001). In other words, humidity emphasizes the presence of smells. For example, the smell of wet soil after the rain blurs the smell of minerals and emphasizes plant smells (Le et al., 2015). Bouchard (Bouchard Natalie, 2013) reported that humidity emphasizes smells and Cain et al. (Cain et al., 1983) stated that 70% humidity increases the intensity of the smell. As the humidity rate increases, the air becomes heavier, increasing the perception of the smell (Bouchard Natalie, 2013). The perception of the smell could be improved with humidification (Pearce, 2006) based on water/temperature/evaporation relationship and formation of humid environments (Bouchard Natalie, 2013).

The main aim of the present study was to determine the integration of the variations in smell sources in urban landscape based on climatic and spatial factors that influence urban experiences and preferences with landscape planning and design processes and the spatial constructs of smell sources that could be emphasized in the whole urban center. These analyses would allow the development of smell maps with human and mechanical smell

measurements and employ these maps in smell dispersion models and land use analysis. Furthermore, it should also be remembered that new touristic routes could be developed based on the smell maps, which in turn could contribute to urban tourism.

Smell Dispersion Modeling

Dispersion models are particularly employed in air studies to mediate certain regulations. In air quality studies, these models interpret short and long-term atmospheric movements to develop future projections. Dispersion models are employed to analyze the correlations between human health and air pollution based on the analysis of PM_{10} and NO_2 that affect air quality based on traffic density (Gulliver & Briggs, 2011). These dispersion models support air quality monitoring networks, allowing the development of temporal and spatial contexts (Munir et al., 2020).

The discomfort due to smell increases due to urban land use and the number of analyses conducted on related regulations has increased in the last decade (Nicell, 2009). Several studies have been conducted on smell measurement and analysis methods and standardization (Wojnarowska et al., 2021). Dispersion models have been developed with various software to determine the environmental effects of undesired smells particularly generated in urban industrial zones and the smell sources measured with various techniques and the distance between smell source and residential areas (Wu et al., 2019). The most common software is the AERMOD, which is employed in air quality models developed by the Environmental Protection Agency. These models are employed to determine national smell effect criteria for smell-based discomfort (Wu et al., 2019). Another software, CALPUFF employs the Gaussian cloud model (Fallah-Shorshani et al., 2017). Both AERMOD and CALPUFF software are complex systems based on topographic and climatic factors and used in the United States and Europe (Daly & Zannetti, 2007). Another computer software, Along with basic data management and mapping tools, ArcGIS includes analytical techniques that have long served as a foundation for GIS. The spatial statistics toolbox includes a set of methods for describing and modeling spatial information. Besides that, they expand to assess spatial pattern, processing, trends, distributions, and relationships. The methodology of the study was applied in three steps; Inverse distance weighted (IDW) geostatistical technical analysis, creation and validation of regression models. IDW Inverse distance weighting (IDW) is the most common operation in GIS. IDW is a special interpolator, so its statistics values are well thought out (Jumaah vd., 2019).

GIS produces smell dispersion maps based on statistical interpolation formulas using smell source measurements obtained with inverse distance weighed (IDW) and Kriging methods (Ramirez & Intarakosit, 2007; Sówka et al., 2017; Wojnarowska et al., 2021). Sówka et al. (2017) reported that a higher number of measurement points would lead to a more accurate interpolation based on the number of points and the area size. GIS provides more data processing options when compared to AERMOD (Maantay et al., 2009). Thus, dispersion was modeled with GIS software that integrates the area bases in the study.

2. Material And Method

The study was conducted at Kastamonu in Turkey, which is located at the intersection of Europe and Asia and has hosted several civilizations and cultures throughout history. Kastamonu urban center dates back to the Roman Empire, where daily practices are still preserved, providing smell sources that reflect traditional regional products; thus, the urban center was determined as the study area. Kastamonu is located in western Black Sea region in Turkey and the surface area of the urban center is 1829 km² (Turgay YILDIZ Planlama & ve Stratejik Araştırmalar Birimi Uzmanı, n.d.). The main urban circulation is along the Karacomak Creek that passes through the urban center. The urban center is located in a valley and the settlements are dispersed on the hills. The study area, in other words, Kastamano archeological site is at the nucleus of the urban center between 41° 23' 47"-41° 21' 42" northern latitudes and 33° 45' 58" – 33° 47' 94" eastern longitudes, and it covers 2,87% of the urban center (126, 8 hectares) (Fig. 1). Karaçomak creek passes thorough the urban center and the initial settlements expanded on eastern and western banks and newer settlements are located in the north and the south. The urban archeological site in the urban center includes commercial and administrative zones. Also, the two most important main squares and tourist destinations are within these limits. Furthermore, there are older settlements, educational institutions and religious buildings within the urban archeological site. Depending on land use, local dining smells and gastronomical specialty garlic and pastrami smells, copper and tin smells due to historical copper production, fabric smell due to the production and sales of the regional woven cloth, natural stone and wood smells due to historical buildings, and plant smells from the parks in urban open green spaces and historic mansion gardens are present in the area.

Evaluation of the smellscape depending on the spatial characteristics in order to reveal the value of different scents in urban areas; The study was conducted by the determination of the smells with a combination of human evaluator and smell measurement instrument. The smell sources were determined with the human evaluation method based on spatial and climatic properties, smell intensity and strength were determined with the odor measurement device based on climatic properties. Geographical information systems (GIS), which are frequently used in analysis and decision-making processes in landscape planning studies, provide convenience to reveal the landscape character. For this reason, in this study, IDW analysis was carried out in Arc GIS version 13.02 in order to determine the odor distributions in the odor landscape. In the priority of the study, the route was determined by using the sensory walking method (Henshaw, 2011; Diaconu, 2011; McLean 2014; Xiao et al., 2018; Xiao, 2020) with observations made at different times in a 1-year period.

Field measurements were conducted with the OMX-ADM model handheld odor meter. The device measures smell strength within the range of 0 and 999 µg/m³ (microgram percentage in 1 cubic meter air), and smell density within the range of 2.5-5.0. The device measurements do not provide the type of smell. The type of smell was determined by the human evaluator. The smell strength and intensity were measured in 3 stages;

- i. **Determination of the hiking route for smell measurements**, In the first stage of smell level detection, the smell route was determined. The route was determined based on smell sources that vary based on various activities conducted in the urban archeological site, occupancy density, and tourist routes (Fig. 1) (Table 1).
- ii. **Determination of smell strength and intensity and climatic data in predetermined points**, During all measurements (2019 November-2020 September), the coordinates of the smell measurement points (Fig. 2), and the daily temperature, humidity and wind speed data obtained from the meteorological station

were recorded in a computer database (Table 3). All smell level measurements were transferred to a computer with Handheld Odor Meter OMX-ADM Data Filing Software.

- iii. **Serial measurements conducted at smell measurement points in adequate climatic conditions**, In second stage measurements, the maximum smell strength was obtained at measurement points and daily mean values were calculated with the 1-month data in the third stage (Table 4) (Appendix A). Performing odor distribution modeling with IDW analysis in ArcGIS program (Fig. 3).

In the first phase of the smell measurements conducted in 3 stages in different seasons (between November and May), in different hours of the day (morning, lunch, evening), the walks were organized in the same tempo. Seasonal smell changes were determined with the measurements conducted on different days (Table 1).

Table 1
Smell measurements

Measurement	Walking date	Walking time	Measurement method	^a Os and ^b Oi	Temperature °C	Humidity %	Wind km/sa
1 stage	6.11.2019	12:30	walking	-	11	63	8
	27.11.2019	17:30			9	73	5
	12.12.2019	12:30			2	91	3
		17:30					
	22.02.2020	12:30			4	78	8
	27.02.2020	12:30			14	42	16
		17:30					
	8.03.2020	12:30			19	43	3
		18:00					
	8.05.2020	12:30		+	11	55	11
2 stage	18.05.2020	12:30	point	+	29	28	16
	6.06.2020	12:30			29	23	6
	20.06.2020	12:30			21	70	13
	18.07.2020	12:30			28	43	8
3 stage	12.08–12.09.20	11:30			29,3*	62,4*	10,5*
^a Os Odor strenght max, ^b Oi Odor intensity,							
*Average climatic values of 1-month continuous measurements in stage 3							

In the first 9 measurements obtained in the walks, no smell strength was determined, smell strength was measured in certain locations during the last march conducted on May 8th, and the coordinates of these locations was determined with GPS. During the measurements, smell strength and density values were determined in three locations (vehicle road, in front of a store) in the commercial zone on the route, and two locations in the residential zone (vehicle road and in front of a café) (Fig. 2).

The measurements were conducted in a stationary position and for 15 minutes in 5 smell sources based on the study findings reported by Eckmann et al. (2018), since the route passed through various occupancy zones and the smells varied due to these zones. Lin et al. (Lin et al., 2006) reported that the best smell intensity could be determined at 22.5°C or over; thus, the second measurements were conducted May and June. In these measurements, climate data were also recorded to investigate the changes in smell levels based on climate conditions. Also, based on the studies by Schanberger et al. (2012), the measurements were conducted at certain hours of the day (9:00 am, 12:30 pm and 6 pm).

The first and second measurements were analyzed, and it was determined that the best measurements were obtained at 25-30°C temperature, 45–65% humidity, and under 6-11km/h wind speed, study area occupancy increased between 11:30 am and 1:30 pm, and smell values increased; accordingly, the third smell level measurements were conducted in a 30-day period (August 12 – September 12) at locations where the smell measurements were previously possible and at best climate conditions. The simple arithmetic means of the data collected in the 30-day period were calculated, and the dispersion model for the mean values was developed with a CBS-based spatial interpolation model, namely the inverse distance weighed (IDW) interpolation method previously employed by Intrakositi and Ramirez (2007), Sowka et al.(2017) Eckmann et al. (2018), Sowka et al. (2020), Wojnarowska et al. 2021) IDW interpolation method is commonly used with various types of data due to simplicity, calculation speed, convenience and reliable results in interpolation surfaces (Xu et al., 2020). The basic assumption in the IDW method is that each sample affects the environment. In the IDW method, the value of the variable at the interpolation point is determined as the weighted average of the surrounding sampling points (Sówka et al., 2017). Thus, smell dispersion maps were developed with the IDW method.

3. Results

To determine the smellscape, smell level measurements were conducted in 3 stages to analyze the volumetric (dispersion) property of the smell based on climatic and spatial properties. In the first stage, the smell levels were measured with the measurement instrument by walking on the route. The climatic and measurement data for this walk are presented in Table 2.

Table 2
Smell level measurements

Yer	6.11.19	27.11.19	12.12.19	22.02.20	27.02.20	8.03.20	8.05.20
	^a O _s max/ ^b O _i	^a O _s max/ ^b O _i	^a O _s max/ ^b O _i	^a O _s max/ ^b O _i	^a O _s max/ ^b O _i	^a O _s max/ ^b O _i	^a O _s max/ ^b O _i
Route	- -	- -	- -	- -	- -	-	+ +
Measurement time	12:30	17:30	12:30 – 17:30	12:30	12:30 – 17:30	12:30 – 18:00	12:30
Tempature °C	11	9	2	4	14	19	11
Humidity %	63	73	91	78	42	43	55
Wind km/sa	8	5	3	8	16	3	11
^a O _s Odor strenght max, ^b O _i Odor intensity							

3.1. Smell measurement analysis

As seen in Table 2, it was not possible to determine smell strength during the walks conducted between November and March in human evaluation and device measurements, smell strength was determined on the final walk conducted on May 8th. In human evaluation, it was determined that the scents were exhaust smell due to the vehicle traffic and drapery and food smells in the commercial zone.

3.2. Smell measurements along the walk route

The second stage device measurements were conducted in a stationary position and for 15 minutes at 5 smell sources determined in the first stage measurements on different days in May, June and July and at different hours. The measurements were conducted in morning, midday and evening hours, and smell levels were identified in midday measurements. On May 8th, under 8km/h wind speed, the smell intensity was identified at 4 locations (vehicle road and sales unit in commercial zone, vehicle road in residential area) and maximum smell intensities were 2.5 OU/m³ at first location, 3.2 OU/m³ at second location, 3.5 OU/m³ at third location, and 2.5 OU/m³ at fourth location. On May 18th, under 16km/h wind speed, the maximum smell intensity was determined at a single location (sales unit in commercial zone) as 4.5 OU/m³ (Table 2). In human evaluator assessments, exhaust smell due to vehicle traffic was perceived at location 1, food smell (coffee) from the sales unit was perceived in location 2, exhaust and metal smell due to the traffic was perceived in location 3, exhaust, wood and stone smells were perceived in location 4, and cigarette smoke and exhaust smells were perceived in location 5. In the measurements conducted in two days in June, the maximum smell intensity was 2.8 OU/m³ at location1, 2.5 OU/m³ at location 2, and on June 20, the maximum smell intensity was 3.5 OU/m³ at location 2, 2.5 OU/m³ at location 3, and 4.0 OU/m³ at location 4. In July measurements, smell intensity was determined at all locations. As seen in Table 2, smell density was identified in location 2 (sales unit in commercial zone) in all measurements in different dates. The third smell measurements were conducted at 5 locations in 30 days (Table 3).

Table 3
1st stage smell measurements

place	1st stage - smell measurements									
	08.05.2020		18.05.2020		6.06.2020		20.06.2020		18.07.2020	
	^a O _s	^b O _i	^a O _s	^b O _i	^a O _s	^b O _i	^a O _s	^b O _i	^a O _s	^b O _i
commercial zone	7	2,5	-	-	4	2,5	-	-	1	2,5
commercial zone	253	3,2	354	4,5	67,7	2,8	248,6	3,5	12	2,5
commercial zone	1	2,5	-	-	-	-	14	2,5	635	4,5
residential area	-	-	-	-	-	-	-	-	3	2,5
residential area	1	2,5	-	-	-	-	5	3	8	2,5
residential area	-	-	-	-	-	-	-	-	28	2,5
Measurement time	12:30		12:30		12:30		12:30		13:30	
Tempature °C	11		29		29		21		28	
Humidity %	55		28		23		70		43	
Wind km/sa	11		16		6		13		8	
^a O _s Odor strenght max, ^b O _i Odor intensity										

3.3. Smell source measurements

In the 3rd measurement conducted with the device, the smell density was 0.4 OU/m³ at the 1st location (vehicle road in commercial zone), OU/m³ at the 2nd location (sales unit in commercial zone), OU/m³ at the 3rd location (vehicle road in commercial zone), and 0.3 OU/m³ at the 4th location (vehicle road in residential area) (Table 4). In human evaluator measurements, it was determined that smell intensity was dependent on vehicle traffic in 1st, 3rd and 4th locations. Among all locations, the maximum smell intensity was determined at 2nd location (sales unit in commercial zone), and was coffee based on the human evaluator, and smell intensity was 1.8 OU/m³ at the 5th location (in front of a café in residential area), and it was mainly cigarette smoke.

In the third stage smell measurements, it was determined that the smell intensity varied at the same temperature in the analysis the effects of climatic factors. In 1st (vehicle road in commercial zone) and 3rd (vehicle road in residential area) locations, the smell intensity variations were based on vehicle traffic. Similarly, in the measurements conducted at 2nd location, smell intensity variations were determined by amount of milled coffee. The analysis of the smell intensity variations based on humidity revealed that under the same temperatures, smell intensity increased with the increase in humidity. However, although the humidity increases with an increase in wind speed, it was determined that smell intensity decreased. In serial measurements, it was determined that smell intensity increased with the increase in smell strength. The lowest smell strength was 0.1, while the smell intensity was 0.1 and the highest smell strength was 283, while the smell intensity was 3.4 (Table 4).

Table 4
The mean third stage smell measurement

12.08–12.09.2020		
	Odor strenght	Odor intensity
1. point	13,0	0,4
2. point	65,1	2,1
3. point	7,6	0,9
4. point	6,6	0,3
5. point	50,6	1,8
Temperature	°C	29,3
Humidity	%	62,4
Winf	km/sa	10,5

The review of all measurements revealed that smell strength and intensity were identifiable during the 10-month period between November and September due to the increase in temperature, and smell intensity increased when the temperature was over 25°C, with an increase in humidity and the wind altered smell strength and intensity by dispersing the smell. Furthermore, it was determined that perception of the smells varied between indoor and outdoor spaces and exhaust smell was perceived more at sloped vehicle roads.

3.4. Spatial smell dispersion model

After the measurements conducted for 30 days, a smell dispersion map was developed with IDW analysis on GIS based on the mean data collected from 5 smell sources (Fig. 3). The analysis of smell dispersion based on smell strength and density revealed that the highest dispersion covered 46.03% of the urban site between 21 and 26 smell strength, and the lowest dispersion covered 0.02% of the urban site between 51–56 and 61–67 smell strength. It was observed that smell strength was 6,64 – 11 in 0.9% of the site, 11–16 in 2.9% of the site, 16–21 in 2.9% of the site, 31–36 in 14.4% of the site. 36–41 in 6.1% of the site, and 41–46 in 2.2% of the site.

It was determined that the smell strength was lower in the 1st, 3rd and 4th locations when compared to 2nd and 5th locations. However, it was observed that although the smell strength was high in location 2, the smell dispersion was low, and although smell strength was low in location 4, smell dispersion was high. Although smell strength was high in 2nd and 5th locations, the smell dispersion in location 5 was higher when compared to location 2. These findings and smell strength dispersion map demonstrated that distance affected smell dispersion. Since the locations 1, 2 and 3 were close, the dispersions were similar despite the smell intensity differences. Although smell strength was low in locations 1, 3, and 4, it was observed that smell dispersion was higher at location 4.

Although vehicle traffic was present in several measurement locations, the exhaust smell was only identified in 1st, 3rd and 4th locations. The analysis of spatial properties of these locations revealed that the vehicle traffics was in narrow streets (5 m) and surrounded by single to 3-floor buildings (Figs. 4 and 5). It was determined that tin smell was identified in location 3 and wood smell was identified in location 4 and the review of the locations revealed that these were historic smells. In the observations conducted during the measurements, it was determined that smell intensity varied based on the presence of more than one vehicle. The smell was intense in locations 1 and 3 when there was a traffic jam, while the smell was intense in location 4 when there was only one vehicle due to the slope.

In the measurements conducted in front of a café in the residential area, exhaust smell was not identified due to the larger vehicle road width (11 m) and the lower height of the buildings in the location. Cigarette smoke intensity was determined due to cigarette smoking in front of the café (Fig. 5).

Based on the measurements, the smell source dispersion and temporal and spatial qualities were significant factors for the development of smellscape. Smell intensity and strength varies based on the physical properties of the space, wind speed, temperature, and humidity. It was observed that smell intensity and

strength increased in closed spaces due to the lack of wind effect even when the temperature and humidity were low, and smell intensity and strength did not increase when the space was open to the wind effects, even when temperature and humidity were high.

4. Discussion

In the present study, where the smell dispersion in smellscape was scrutinized, it was found that smell intensity varied based on spatial qualities. In the measurements, exhaust smell was not identified despite intensive traffic flow in main vehicle road, while smell intensity was high in closed narrow streets with low traffic. Battistimo and Mondino (Battistini & Mondino, 2017) reported that exhaust smell was perceived in narrow streets, a study by Pettarin et al. (Pettarin et al., 2015) demonstrated that smell intensity was higher in narrow streets when compared to wide roads. In terms of topographic properties, it was determined that smell intensity was higher in climbing roads. Based on temporal properties, it was observed that smell intensity increased with an increase in the temperature, and smell intensity was identified on the device in 25°C or higher temperatures. Also smell intensity increased with an increase in humidity and decreased with an increase in wind speed. Similarly, Bottcher (Bottcher, 2001) reported that the increase in humidity elevates smell intensity, Le et al. (Le et al., 2015) stated that wind directs the smell and is effective on the dispersion of the smell cloud, Lin et al. (Lin et al., 2006) concluded that the scent dispersion distance increased with the wind, Bouchard (Bouchard Natalie, 2013) reported that all climate data affect smell perception. The smell dispersion model allowed to determine the employment of the distance to preferred odors. In a field study, Capelli et al. (2013) reported that the implementation of smell dispersion models allowed the determination of the land use distances. Similarly, Wojnarowska et al. (2021) stated that dispersion models based on smell concentrations could be employed in residential zoning plans. Based on the study findings, pedestrian traffic in vehicle traffic zones could be designed. It was determined that smell intensity was moderate in urban site based on the smell dispersion map, and the smells perceived in the locations where smell measurements were conducted were not dispersed through the entire urban site. As the distance between measurement locations decreased, it was observed that smell dispersion was reduced. Based on the proximity of the measurement locations, it was determined that the dispersion was lower than the smell intensity. However, it was observed that smell dispersion increased in the location where smell intensity and the distance between the measurement locations were high (location 5). Sowka et al. (Sówka et al., 2020) determined that dispersion varied based on the distance between the measurement locations.

5. Conclusion

The urban atmosphere that has been changing due to urbanization and smells that are one of the most significant components of this atmosphere has been analyzed with various methods and analyses. It is important to determine the distances to calculate the smell dispersion for fitness analyses for land use and associated smell controls. Also, the openness and closure of the space that affect smell dispersion and the increase in smell intensity due to increases in temperatures and humidity affect several structures including spatial design and urban tourism organization.

In the present study, it was determined that smell intensity increased at 27°C and higher temperatures and 55% humidity. In particular, seasonally, the intensity was not noticeable between November and May period due to cold weather, while it increased between May and September. Furthermore, the perception of smell intensity in narrow streets, spaces surrounded by high walls and tall buildings was higher, while it was lower in spaces with short buildings.

It is observed that smell dispersion increased with the increase in the distance between smell sources. Smell strength was also effective on smell dispersion based on the distance. The distance between smell sources is significant in smell control and zoning. The comparison of human evaluator and measurement instrument data revealed predominant emission (exhaust), food (coffee), and tobacco (cigarette) smells in the urban site smell route. The analysis of these smells based on the quality of urban life and urban identity revealed that odor control was necessary.

Based on the above-mentioned findings, the following were recommended for urban smell control based on smell preferences and the smell dispersion based on climatic and spatial properties:

- The correlations between various land uses could be established by determining the limits of preferred smell sources in spatial and landscape urban design with smell dispersion maps. Thus, the smell relationships could be established between spaces with close relationships.
- Screening and masking facilities should be adopted in landscape designs to control undesirable smells especially in spaces where tobacco smell is identified due to the adverse effects of this smell on public health. In particular, the locations around the cafes should be scrutinized and evergreen coniferous medium-height shrubs with dense branches should be included in landscape designs to provide screening between these spaces and pedestrian areas. Strong smell sources should be included around open seating areas for masking in addition to screening. Depending on the land use objective, strong smell sources that could be perceived and preferred by all age groups (such as citrus and coffee smells) could be utilized for masking around seating areas.
- Spatial closeness rate could be achieved with screening due to high smell perception in spaces with high closeness and low smell perception in spaces with high openness based on the smell perception analyzed with spatial properties and determined by the human evaluator and the smell could be oriented with the wind direction. Thus, smell could be used as a factor of orientation.
- To ensure the dispersion of the coffee smell through the whole urban site, it is necessary to increase the distance between coffee smell sources and other smell sources due to the inviting character of this smell.
- The dispersion of smoke and exhaust smells, which are hazardous for human health and the environment, to a wide area could be prevented by the increase of pleasant smell sources and the distance between these sources in screening, removal and odorization applications. Thus, a smell character suitable for the urban identity and is not prevalent in the whole city could be achieved.

Limitations

When compared to previous studies, the scent measurements were conducted with a handheld device. However, these measurements led to certain limitations. The fact that the device could only determine values for certain smells limited the study. Future multidisciplinary studies could develop devices that could detect all smell sources in urban spaces to identify smell strength and density. Thus, the smell control distances provided for industrial areas could be used to determine other smell distances in urban areas.

Declarations

Ethical Approval

This study was prepared in accordance with the ethical criteria of the journal. The authors assume all responsibility within the framework of ethical rules.

-Consent to Participate

There is no voluntary participant in this study. The data obtained with the people who carried out the study and the odor measurement device were evaluated.

-Consent to Publish

This study was authorized by the authors with approval for publication by the journal.

-Authors Contributions

All authors contributed to the study conception and design. Material preparation, data collection by [Elif Ayan Çeven] and analysis were performed by [Miraç Aydın]. The first draft of the manuscript was written by [Elif Ayan Çeven], [Nur Belkayalı] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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-Competing Interests

The authors have no relevant financial or non-financial interests to disclose

-Availability of data and materials

	1. point		2. point		3. point		4. point		5. point		TEMPERATURE	HUM
	odor strenght	odor intensity	odor strenght	odor intensity	odor strenght	odor intensity	odor strenght	odor intensity	odor strenght	odor intensity	oC	%
12.08.2020	0,1	0,2	2,4	1,1	0,2	0,2	0,7	0,2	5,4	2,4	31	64
13.08.2020	0,3	0,2	50,7	2,4	0,4	0,3	7,7	0,2	1,3	0,7	30	68
14.08.2020	0,1	0,1	13,3	2,1	5,2	1,1	8,7	0,2	5,7	1,5	32	56
15.08.2020	22	0,1	88,5	2	0,8	1,2	0,2	0,1	28,2	0,8	30	52
16.08.2020	0,4	0,1	8,9	1,1	0,1	0,1	0,2	0,1	23,1	1,9	29	55
17.08.2020	217,4	0,2	2,6	0,6	0,4	0,3	21,7	0,1	164,1	3	29	54
18.08.2020	21,7	0,1	164,3	3	2,7	0,8	0,7	0,1	4,9	0,3	28	63
19.08.2020	2,3	1,1	7,7	0,2	1,3	0,7	8,7	0,2	5,7	1,5	28	60
20.08.2020	22,5	1,3	58,2	2,5	23,9	2,1	11,5	0,5	55,9	1	27	75
21.08.2020	0	0,1	150,1	2,5	2,9	0,9	20	1	136,7	2,9	30	60
22.08.2020	22,7	0,2	0,8	1	27,6	0,5	0,6	0,1	23,9	1,7	29	69
23.08.2020	2,8	0,3	10,8	1,9	0,4	0,5	6,3	0,3	150,4	1,7	29	61
24.08.2020	3,6	0,1	214,2	3,2	4,4	0,9	1	0,3	36,4	2,3	30	63
25.08.2020	1,4	0,2	0	1,1	1	1,1	0,8	0,2	92,2	1,3	28	53
26.08.2020	2,4	0,1	175,9	2,9	2,2	1,2	0	0,1	33,6	2,1	28	67
27.08.2020	0,5	0,2	42	2,4	8,9	0,3	3,6	0,5	37,6	1,9	30	62
28.08.2020	2,1	0,2	282,7	3,4	2,9	1,2	22,3	0,2	36	1,6	28	64
29.08.2020	0,2	0,1	52,3	2,6	7,6	1,2	0,1	0,1	100,5	2,5	31	61
30.08.2020	5,8	0,2	186,2	3,3	3,2	1,6	0,1	0,1	66,7	2,5	28	60
31.08.2020	1	0,6	12,8	1,3	23,4	0,6	11,5	0,6	53,5	2,3	27	67
1.09.2020	4,2	0,9	9,3	2,2	7	1,8	0,8	0,1	3,2	1,5	28	62
2.09.2020	0,3	2,5	148,1	3	26,4	1,8	2	0,2	70,4	1,3	30	67
3.09.2020	3,2	0,2	4	1,7	21,9	0,3	39,7	1,3	49	0,9	30	67
4.09.2020	8,8	2,2	46,6	2,6	27,2	2,5	2,5	0,3	56,7	2,7	30	70
5.09.2020	0,1	0,2	1,8	0,7	0	0,1	0,7	0,2	9,3	2,1	28	62
6.09.2020	0,1	0,2	7	2,8	13,1	0,6	0,4	0,3	105,6	2,9	29	64
7.09.2020	0,8	0,4	21	1,8	1	1,3	0,3	0,2	1,2	1,2	30	61
8.09.2020	0,3	0,1	25,7	2,4	1	1,1	34,5	0,6	1	0,9	29	66
9.09.2020	23,7	0,3	22,1	2,1	0,1	0,1	1,2	0,5	21,3	1,6	31	63
10.09.2020	22,5	0,2	87,2	2,3	2,2	0,6	0,2	0,2	89,6	1,8	29	57
11.09.2020	21,8	0,2	117	2,8	21,9	0,2	2,4	0,1	63,8	0,7	30	62
12.09.2020	0,1	0,1	70,3	2,7	3,2	0,4	0,3	0,2	86	2,8	30	63
average	6,2	0,3	68	2,1	7,6	0,9	6,6	0,3	50,5	1,8	29,3	62,4

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Figures

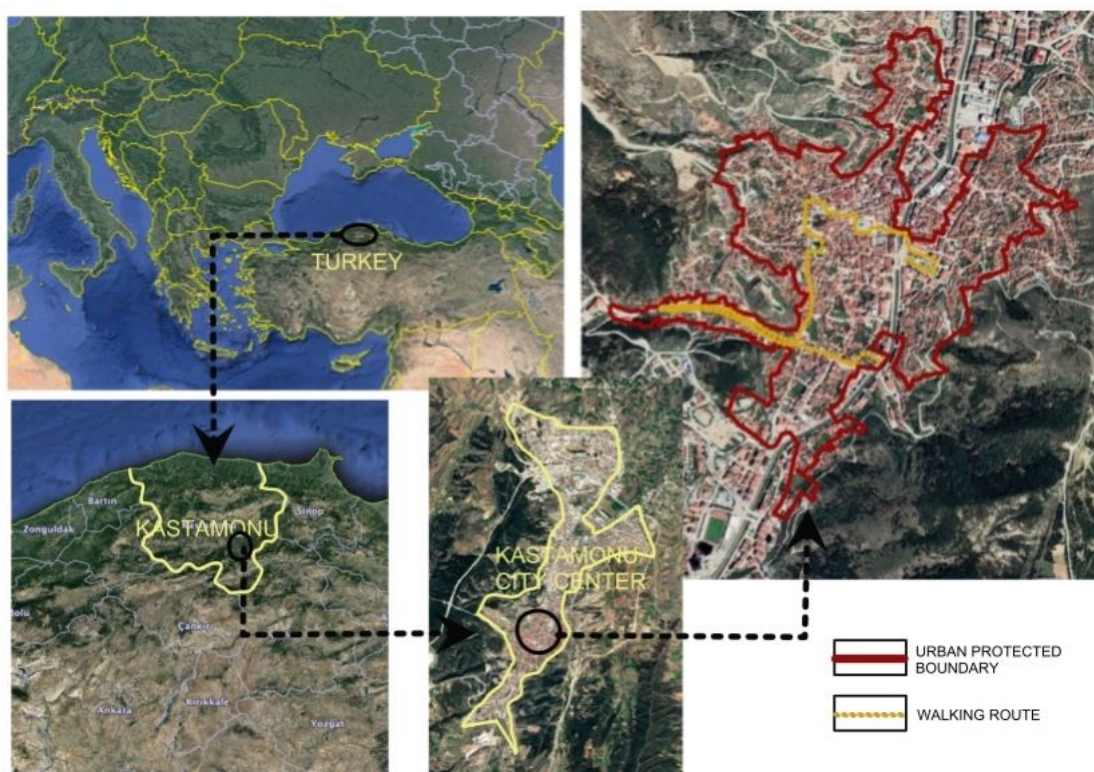
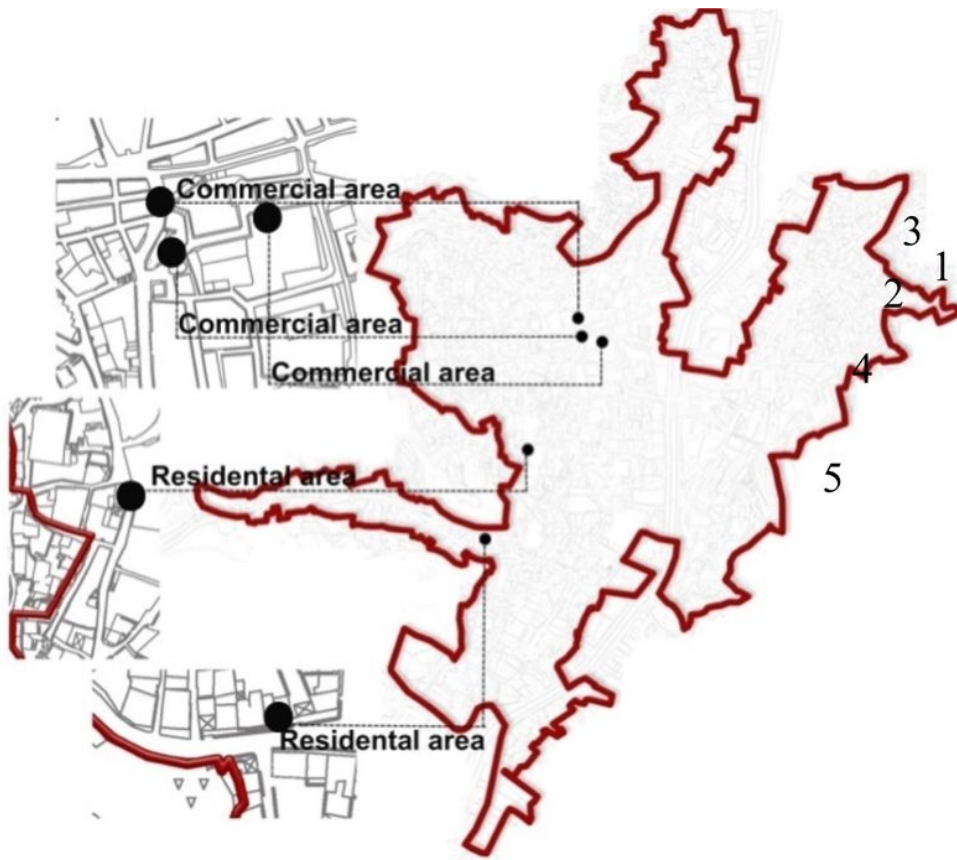


Figure 1

The study area



1	41,37794	33,77384
2	41,3777	33,77338
3	41,37796	33,77326
4	41,37297	33,77062
5	41,37434	33,7652

Figure 2

Smell measurement locations

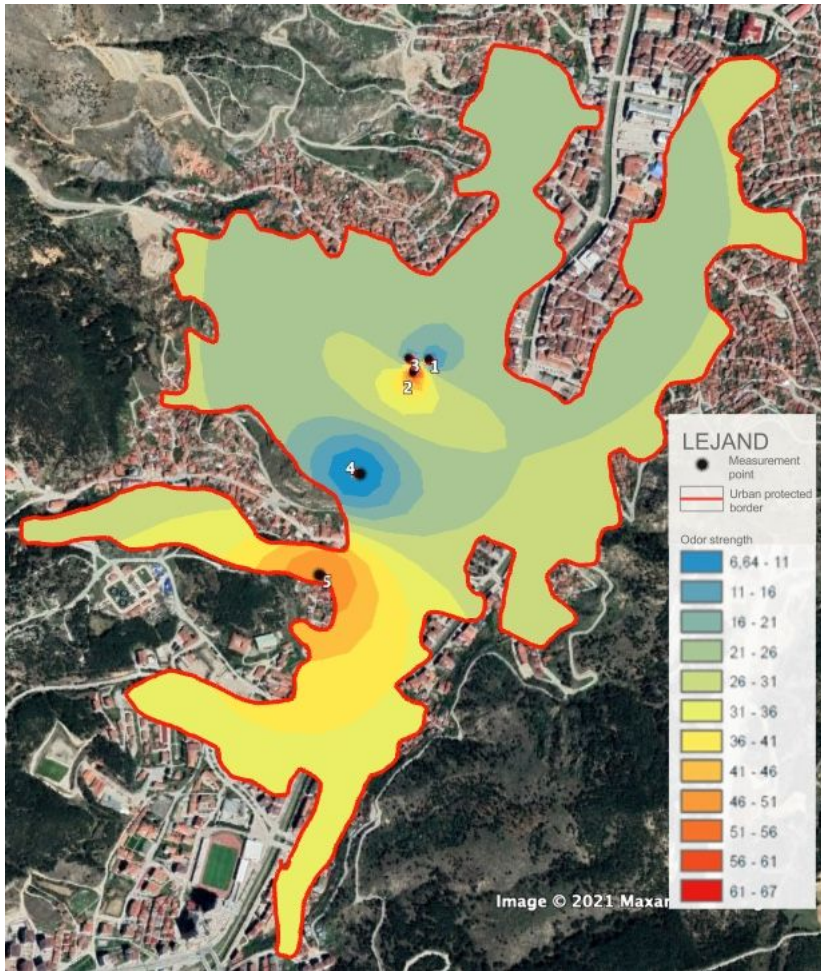


Figure 3

Smell dispersion map developed with the IDW method



Figure 4

Spatial structure of the 1st and 3rd locations

Figure 5

Spatial structure of the 4th and 5th location