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Green buffers near industrial plants, examples in Jefferson County TX

Liv Haselbach[1] · Riwaz Niroula[1] · Mahdi Feizbahr[1]

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Abstract
Green buffers between industrial plants and residential areas have multiple purposes in mitigating air pollution and protecting the environment. This study focuses on providing information on examples of green space development by industries near residential areas in Jefferson County, Texas. One represents a full buffer where residences were totally removed, another is a partial buffer where some residences were removed in a neighborhood and the third represents vegetation of a formerly industrial facility. Additional estimates on benefits of buffer spaces with respect to a pollutant plume are also considered. The study used geospatial and property data from 1966 to 2020. The transition from a residential area to a full or partial buffers highlights possible mitigation of air pollution impacts while serving additional functions, such as boosting stormwater infiltration and improving the aesthetic attractiveness of the area. The transformation from oil tanks to forested space may display the potential for environmental remediation, but not all spaces are suitable for fully forested buffers, as safety and other limitations should be considered. With the analysis of the classic Plume Equation insights can be provided regarding the possible impact of green buffers on ground-level pollutant concentrations. The calculations for atmospheric stability classes A-F and for various stack heights provide an understanding of how different conditions may affect the pollutant concentrations. The presence of a green buffer can play a crucial role in controlling ground-level pollution concentrations and reduce a community's perception of risk.

Keywords Air pollution · Green buffers · Residential · Industrial · Plume

1 Introduction

Jefferson County lies in the coastal plain of Southeast Texas. It has the land area of 1113 mi^2. It is bounded by Orange County to the east and Hardin County to the north, Liberty and Chambers Counties lie to the west, the Gulf of Mexico is to its south and on its east is the Neches River which drains into Sabine Lake, through the Sabine Pass and into the Gulf. Jefferson County consists of flat and low terrain which rises to only about 50 feet from sea level. The average annual temperature is 69°F and average annual rainfall is 53 inches. Beaumont, Groves, Nederland, Port Arthur, Port Neches are the major cities in the County. There are petrochemical industries in Jefferson County which are the backbone of the County's economy. Most of the employment comes from the petrochemical industries followed by shipbuilding, rubber industries, farming, and cattle [1]. A self-reported study showed that there are marked differences in adverse health effects of those studied that live near the major chemical/industrial complexes in Jefferson County compared to a nearby control county with fewer industrial complexes [2]. Based on visits to several areas near industrial complexes in Jefferson County, the authors noticed that many former residences had been removed and the lots turned into green spaces. Could these changes provide buffering from industrial emissions?

Buffered green spaces typically refer to the green belts or vegetation barriers established for environmental reasons and community enhancement. Green buffers between industrial plants and residential areas have multiple purposes in mitigating air pollution, noise pollution reduction, well-being of the residents and protecting the environment. They act as physical barriers, dispersing and lessening spread of air pollutants and reduce the risks to nearby areas by segregating impacts of hazards, contaminated water, soil, or air and mitigating environmental impacts and protecting

✉ Liv Haselbach
lhaselbach@lamar.edu

[1] Lamar University, PO Box 10109, Beaumont, TX 77710, USA

ecosystems. Such green buffer areas may contain trees which help remove air pollution by absorption of gaseous pollutants through the plant leaves. Some pollutants removed are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), lead (Pb), sulfur dioxide (SO_2), and particulate matter (PM). Green Plants can remove pollutants from the atmosphere through dry deposition, which is the process of particles and gases being captured by the surfaces of leaves and branches. During dry deposition, various pollutants, such as nitrogen oxides (NOx), sulfur dioxide (SO_2), particulate matter (PM) can be removed from the air. Once these pollutants are deposited onto surfaces, they can undergo further chemical reactions or be washed away by rainwater, eventually ending up in soils or water bodies [3, 4].

Plant species in buffered areas have been investigated in various research projects. Research in South Korea shows that tree species and planting densities can enhance buffering functions, landscape functions, and habitat functions for the buffer green space along a railway. The authors suggested density standards for multi-layered planting, focusing on tree species such as chestnut, cherry, and Japanese pagoda tree for habitat functions [5]. Other research suggested using plant species that are resistant to noise, screening and exhaust gases, and other pollutants, and maintaining the ecological functions of the forest through multi-layered and edge planting techniques to promote wildlife habitat [6].

Despite the establishment of large-scale buffer green spaces, the number of odor complaints in residential areas near some industries in Korea increased until 2005, indicating that the green space was not tall enough to block the odor effectively and that the tree size and planting density were insufficient to have a significant impact. Analysis of pollutant diffusion and distribution, such as SO_2 and NO_2, revealed that the current buffer green spaces had a limited effect on reducing air pollution [7]. Furthermore, it was found that reducing odor substances through changes in the physical form of green spaces, such as increasing green coverage and connecting fragmented green areas, was difficult to achieve [8]. A reforestation plan for buffer green spaces was established in 2006, and reforestation projects were carried out until 2012. Additionally, since 2006, areas subject to strict emission standards under Gyeonggi Province regulations have been managed, resulting in a gradual decrease in odor complaints to around 100 per year.

Research in China suggests that a buffer distance of 1.5 km could help lessen exposure risks to inhaled pollutants. The study shows that in urban areas, SO_2 and NO_x concentrations decrease more rapidly with distance than in rural areas. High levels of pollutants are still found at 300 m, suggesting a risk to nearby populations. The researchers recommend increasing buffer distances to 1500 m and implementing stricter emission controls [9]. Recent research is on vegetation species that might more effectively aid in removing different air pollutants. The study focused on particulate matter and nitrogen dioxide [10]. A review of vegetation in indoor environments that can remove various volatile organic compounds indicates that more research is needed for outdoor conditions and impacts of human activities [11].

Although many industries and air pollution researchers may be aware of the possible benefits of buffers, particularly vegetated buffers on reducing air pollution impacts, there is little information on how public perception of air pollution and its control might include vegetated buffers. There have been studies on public perception of air pollution risk, but they do not necessarily include information on how communities might reduce the risk with buffer alternatives [12–14].

Thus, there are several knowledge gaps such as: (1) additional research on vegetation species and the various air pollutants they may help mitigate, (2) how decision makers and communities may be informed about the benefits of vegetation with respect to environmental buffers, and (3) the current use of vegetated buffers by industry. This case study seeks to start answering the third knowledge gap for a highly industrialized county in Texas.

Using geospatial and property data from 1966 to 2020, this study focuses on three different examples of green space development by various industries near residential areas in Jefferson County. The first study (1) is on a neighborhood in Beaumont, Texas where many former residences have been acquired within the neighborhood and most are now green spaces. This will be referred to as a partial buffer area. The second example (2) is where an industry in Port Arthur, Texas has acquired an entire portion of a neighborhood and turned it into a buffer space between the industry and other residential spaces. This will be referred to as a buffer area. The final example (3) is of an area in Nederland, Texas that was formerly an industrial space (oil storage tanks) and has now been established as a forested space. Additional estimates (4) on benefits of an established buffer space with respect to the impacts of a pollutant plume are also considered using the classic Plume Equation [15]. The intent of this research is to showcase examples of green spaces that have been created in or near industrial areas in Jefferson County Texas.

2 Methods

ArcGIS Pro, a geographic information system software was employed for the calculations of land area, distance from the industry fence-line and identification of potential buffer zones [16, 17]. The Texas Natural Resources Information System website was used to download Jefferson County maps from the year 1966 and 2020 [18]. Property information, comprising details such as property ID, land area, and acquisition year, was obtained from Jefferson County's CAD Property search website [19].

The year 1966 was chosen as it represents a time when the US baby boom and development in Jefferson County slowed down as can be seen by a flat populations growth over the following several decades and just before the US Environmental Protection Agency was established. The period from 1966 to 2020 then represents this slow population growth, and associated slow change in land development but also represents a time of increasing environmental awareness and regulations [20]. Figure 1 depicts the industrial and residential areas in this portion of Beaumont, Texas in both 1966 and 2020.

By using ArcGIS pro, 1966 and 2020 Jefferson County map files from TNRIS were compared to determine the zones, and modifications in the vicinity of the industry [17]. Using polygon depiction, properties, potential buffer zones were marked which provided an approximate understanding of changes taken place in those years. Multiresolution seamless image database (.sid) files were used for the 2020 map

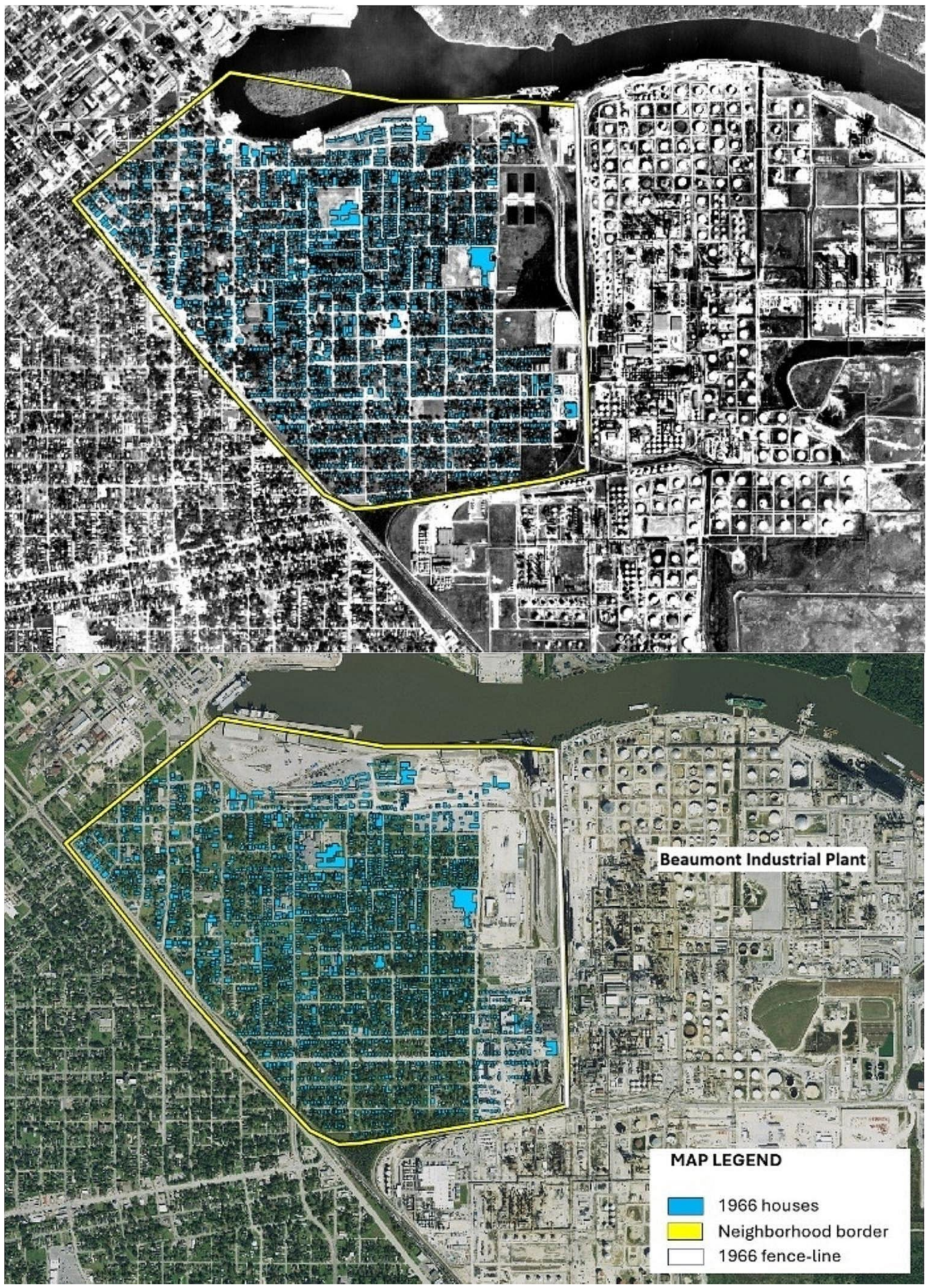

Fig. 1 1966 (top) and 2020 (bottom) Beaumont, Texas neighborhood and industry views with 1966 fence-line marked

and compared to image files of 1966 to identify the changes in these years. To define buffer zones, houses, tanks, blocks and reconstructed areas, polygons were assigned with distinctive colors or patterns.

The potential buffer zones were defined using polygons (.shp) files which portrayed the spatial information in a digital form. The shape files were utilized to emphasize differences between the existing and eliminated properties in the vicinity of the industrial facilities in the years 1966 and 2020. The following sections provide more details of the methods used specifically for the different portions of this research.

2.1 Partial buffer

In the context of this project, defining the neighborhood was a critical step in providing a clear framework for research, analysis, and planning concerning the changed residential areas and buffer zone. The neighborhood's study area was selected mostly based on physical factors and spatial considerations. A natural feature was taken into consideration since the Neches River bordered the neighborhood to its north. A major roadway and M. L. King Jr Pkwy bordered the neighborhood to its west. Downtown Beaumont bordered the neighborhood on the northwest and the industry's 1966 fence-line was to its east.

As previously mentioned, property information, comprising details such as property ID, land area, and acquisition year, was obtained from Jefferson County's CAD Property search website. The Beaumont industry's name was used to search using the "By Owner" filtering option. From individual property data, land area and the year the property was acquired by the industry, was extracted [19]. For properties that were purchased by the industry after 2000, the impervious land area for these lots was determined and the distance from the industry's 1966 fence-line to each purchased lot was calculated.

For those calculations, the 1966 image file was uploaded on ArcGIS Pro [17] and the 1966 fence-line of the industry was marked, also the 2020 image database file was uploaded. The 1996 fence-line was used for the 2020 map [18]. The "Measure Distance" tool on ArcGIS Pro was used to measure the distance from the properties to the 1966 fence-line. When calculating the distance, the initial point of the line was taken as the edge of the property land area nearest the fence-line and the other point was the perpendicular distance to the fence-line from the property. After clicking on both points, a table pop up displayed the distance from the property to the fence-line in miles. The distance data were later added to the excel sheets for all the purchased properties.

To verify the distance from the 1966 fence-line to the properties acquired by industry after 2000 calculated using ArcGIS Pro as stated in the previous paragraph, JCAD 2023 website's "View Map" tab on the top right corner then the "Interactive Map" option was clicked where it popped up a new window for interactive map website [21]. Distance from the fence-line was recalculated by using "Line Measure" tool on that website and matched with the distance calculated from ArcGIS Pro for the properties purchased by the industry after 2000. All the distances matched within a foot. The data of these properties acquired by the industrial complex in this neighborhood in Beaumont, Texas were collected and sorted into categories such as vacant or in-use.

For the purposes of this study, impervious land area from 1966 map of the purchased property was also calculated. Pervious refers to a ground surface which lets water penetrate through it and go down into the soil beneath. Whereas, impervious refers to a ground surface which does not allow water to penetrate through it. Most roads and buildings are examples of impervious surfaces [22]. Working on the 1966 map in ArcGIS Pro, using the "Measure Distance" tool, only the footprints of the houses and pavement were calculated for the properties purchased by the industry for impervious calculation, leaving the rest of each property as pervious/green land area. Length and breadth were measured, and then the areas were calculated for impervious land in square feet [17}. The areas that were changed from impervious to pervious on the purchased properties that are now green space were also collected on a spreadsheet for all the associated properties. In addition, for some properties the areas that went from pervious to impervious were also noted.

2.2 Buffer space

The 1966 and 2020 Jefferson County map files from TNRIS were also compared to determine the buffer zones between an industry near Port Arthur, Texas and neighboring residential areas. A boundary polyline was used in both maps to outline the buffer area whereas rectangular blue colored shapefiles were used to highlight the properties which were present in 1966 but later acquired and deconstructed for a full buffer prior to 2020 [18]. These can be seen in Fig. 2.

More specifically, the 1966 and 2020 image file were uploaded to ArcGIS Pro and the virtual fence-line was noted. The 2020 map's virtual fence-line was referenced using the 1966 virtual fence-line and extending past the industrial facilities constructed after 1966. The "Measure Distance" tool was used to determine how far the properties in the buffer area in Port Arthur, Texas were from the virtual fence-line in a similar manner to the partial buffer method. Rectangular shapefiles were used to mark the properties using ArcGIS Pro. The "Measure Distance" tool was used

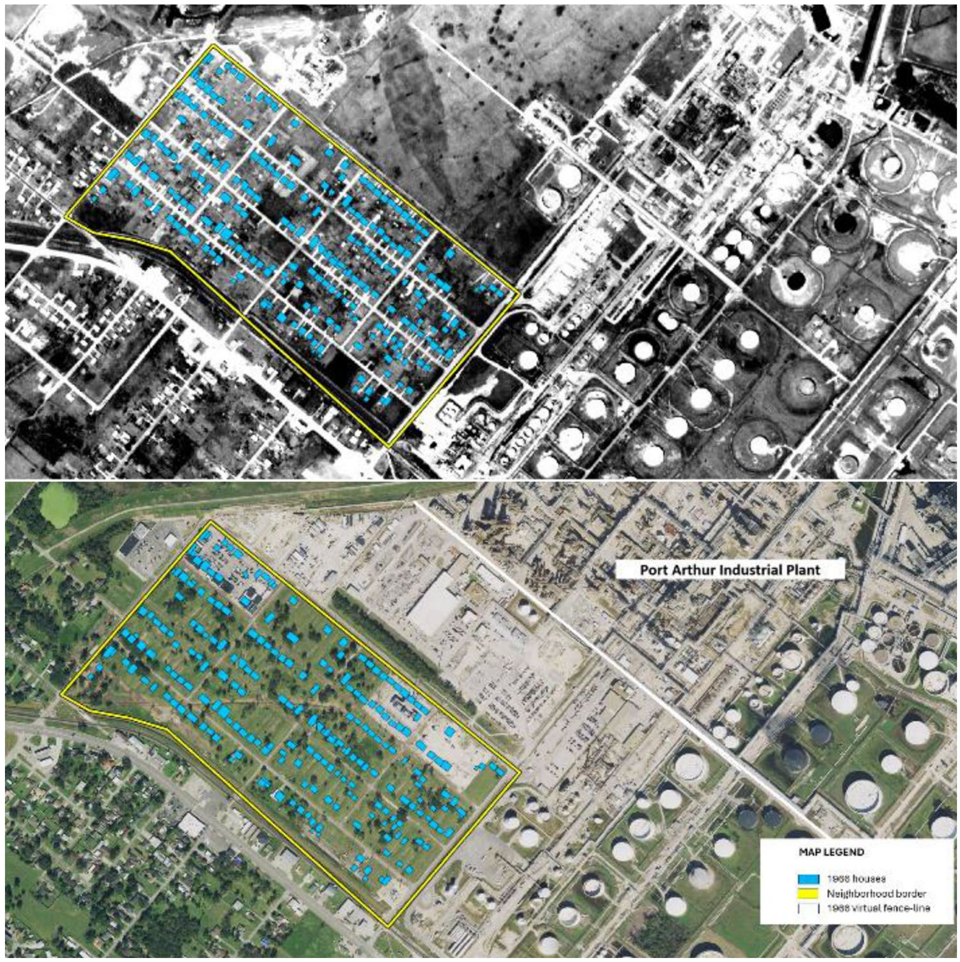

Fig. 2 1966 (top) and 2020 (bottom) near Port Arthur buffer space view

for distance, where the initial point of the line was the point on boundary of the rectangular shapefile/property's land area, and the other point represented the vertical distance to the virtual fence-line. A table that appeared after clicking on both spots showed the distance between the property and the virtual fence-line in feet.

2.3 Forested space

The selection of an area near an industrial facility, which was transformed from a site with oil storage tanks to a forested buffer area was made from the 2020 map which showed a forested area in Nederland Texas, next to a large petroleum tank-field where the tree growth had distinctive circular features that might indicate previous locations of aboveground tanks. The datasets of both the 1966 and 2020 maps within the ArcGIS Pro software were used to find out the changes that occurred between these two years. The 1966 map showed 52 large oil industry storage tanks which were marked using circular shapefiles. However, the 2020 map, showed those once-dominant storage tanks had been deconstructed, and in their place, a woodland buffer had grown, indicating a significant shift in land use patterns. This can be seen in Fig. 3. The "Measure Features" tool in ArcGIS Pro was used to determine the land area of the forested buffer outlined with a polyline shapefile in terms of square feet. The same measuring tool was used to calculate the area of the circular tanks in terms of square feet [17].

2.4 Plume equation

The classic Plume Equation is a foundational mathematical model commonly used to describe the dispersion of pollutants and substances. This equation is based on the principles of fluid dynamics and atmospheric physics. Wind speed, atmospheric stability, stack height, distance from the stack is used to calculate the concentration of plume over time and distance. The equation is generally applied in environmental impact assessment, air quality modeling and industrial safety analysis. Based on the classic Plume Equation, from Figure 3–9 on distance to maximum ground level concentration from the Workbook of Atmospheric Dispersion Estimates, for all stability classes A-F, using various effective stack heights (40 m, 100 m and 200 m) and using distance

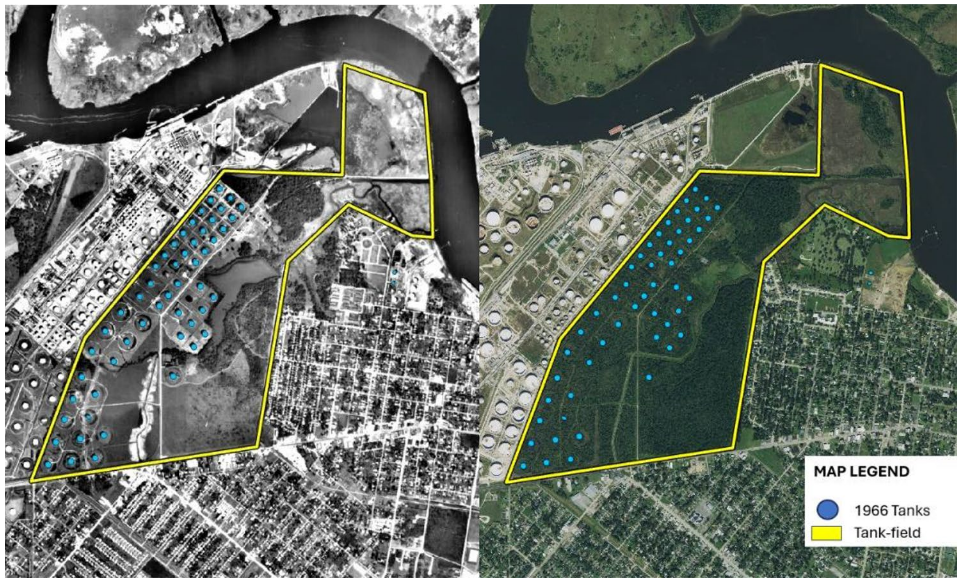

Fig. 3 1966 oil storage tanks (left) and 2020 forested buffer (right)

to the peak on y-axis, "γ" was calculated, which is the ratio of all stability classes A-F to stability class A, that is the parameter to find the peak concentration on the x-axis [15].

Two positive impacts a green buffer might have on ground level concentrations are: (1) the estimated maximum ground level concentration within the green buffer for various atmospheric conditions and (2) for atmospheric conditions where this point of maximum ground level concentration is still estimated to be outside the buffer and hence in a neighborhood, it is useful to understand how that concentration might be reduced. Both questions were explored by using the results of the classic Plume Equation, particularly Figure 3–9 on distance to maximum ground level concentration from the Workbook of Atmospheric Dispersion Estimates [15]. For estimated distance to the maximum ground level concentrations directly downwind of the stack, the figure in the Workbook was used to determine this distance based on various atmospheric stability classifications (A through F) for various effective stack heights. The atmospheric stability classifications range from a strong daytime solar insolation for very low wind speeds (Classification A) where the maximum ground level concentration is estimated to be closer to the stack location, to clear nighttime conditions (Classification F) where a maximum is estimated to be much farther away. Note that for similar effective stack heights, wind speeds and source pollution concentrations, the A classification estimates higher ground level maximum concentrations than the F conditions [15].

Table 1 Summary of properties in Beaumont, Texas acquired in the subject neighborhood by the industrial neighbor between 2000 and 2020

Category	Number of Properties	Sum Lot Areas (sq. ft.)	Nearest distance from the fence-line to a lot (ft.)	Furthest distance from the fence-line to a lot (ft.)
Was house now greenspace	56	418,198	1420	4400
Was house now other use	6	41,625	750	2370
Was vacant then and now (green)	13	129,340	1470	3720
Was vacant then, but now in use	2	6686	955	1060
Total	**77**	**595,849**	-	-

3 Results

3.1 Partial buffer

In all, there were 77 properties that were found that had formerly been residential properties with houses and were subsequently purchased by the neighboring industry. These were further subdivided into the following categories: (1) the house is now gone, and the property is a greenspace, (2) the house is now gone, and the property is used for parking, offices, or other industrial purposes, (3) the lot was vacant in 1966 and remains a greenspace, (4) the lot was vacant but now is used for industrial purposes. The results are summarized in Table 1.

In total 56 formerly residential properties were turned into green spaces, whereas 21 were in use.

Among the 21 of the in-use properties, 13 of them were green spaces then and now, 6 of the properties acquired were still in use for parking or offices in 2020, 2 of the properties were vacant then but used now. Among all the properties, the nearest to the fence-line was just 750 ft. whereas the furthest was 4400 ft away. Almost 420,000 sq. ft. of land area was acquired of which about 140,000 sq ft. of impervious land was turned green by the industry as listed in Table 2. Table 3 shows the properties that were acquired and now are used by the industry and for which the impervious area has increased. The net gain of pervious area from these acquisitions is the difference at slightly more than 100,000 sq. ft. (~2.36 acres).

3.2 Full buffer space

As previously mentioned, the virtual fence-line on the 1966 map was marked and used as a reference in the 2020 map as extended past additional facilities constructed post 1966 as noted in Fig. 2. "Measure Distance" tool was used to determine the distance between the virtual fence-line and the nearest and the furthest property. It was determined that the closest distance was roughly 980 feet, and the furthest distance was about 2420 feet from the industry's virtual fence-line. Additionally, the "Measure Features" tool was used on the map from the year 2020 to calculate the land area covered by the polygon shapefile that had been designated as a full buffer zone near the Port Arthur industry. The results showed that the buffer land area covers about 2,964,000 square feet. There were 228 residential properties which are now gone. In addition to removing the houses in the full buffer a butterfly garden was also installed in the full buffer area as can be seen in Figs. 4 and 5 [23].

3.3 Forested space

The 1966 map in ArcGIS Pro showed that the industrial landscape chosen for this analysis was dominated by oil storage tanks. The footprints of the tanks were marked using circular shapefiles. The "Measure Features" tool was used to compute the area of each of these tanks, which came out to be approximately 11,500 square feet. The same tool was used to calculate the land area of the forested buffer bounded using a polyline shapefile, which came out to be 25,560,000 square feet. There were 52 of these tanks and they covered a collective 598,000 square feet of space. The former tanks seen in the 1966 map have been transformed into a forested buffer sometime prior to 2020.

3.4 Plume equation

Table 4 presents the results of evaluating the classic Plume Equation for several representative effective stack heights, stability classes, distance to the peak and γ. Using distance to the peak vs. γ, for that point to have the maximum concentration, the effective stack height needs to be 300 m (984 ft) for stability class "A", around 120 m (394 ft) for class "B", around 70 m (230 ft) for class "C", around 40 m (131 ft) for class "D", around 25 m (82 ft) for class "E" and around 17 m (56 ft) for class "F". The full buffer's end point is at 2500ft which is around 762 m from the virtual fence-line. For these stack heights, the point 762 m (2500 ft) away will have the maximum concentration for stability class "F", which is $2.5 \times 10^{-4}\ \mathrm{m}^{-2}$ ($0.00269\ \mathrm{ft}^{-2}$) [15]. In general, it is possible to look at Table 4 and develop a series of tables for estimating if the maximum ground-level concentrations will be inside or outside the buffer for various stability classes. It is also possible to relate the maximum ground-level concentrations which fall outside the buffer for all stability classes and to the highest ground-level estimates which adhere to stability class "A", which is denoted by a γ.

From Table 4, one can see that for the 40 m (130 ft) effective stack height, the maximum concentration parameter "γ" is at 0.17 km (558 ft) from the stack, and after 0.42 km (1378 ft) it decreases. For 100 m effective stack height, the maximum concentration parameter "γ" is at 0.45 km (1476 ft) from the stack, and after that it decreases with increase in distance, and for 200 m effective stack height, the maximum concentration parameter "γ" is at 0.60 km (1969 ft) from the stack, and after that it decreases with increase in distance.

4 Discussion

The green buffers in this study were not chosen by spatial analysis but rather from local knowledge of some examples on or near industrial facilities. Spatial analysis methods and links to various spatial correlated data from online sources were then used to develop the results. Geoinformatics could be used to further this work in Jefferson County and develop a more comprehensive overview of green buffers or spaces in relationship to industrial areas. There are many spatial analysis tools that could be used to effect this future endeavor such as tools to find various densities and extents of vegetation. A "buffering" tool in geographic information systems could then be used to define zones around the vegetated areas that could be further analyzed by various criteria for proximity to industry. In reverse, industries could first be spatially located and the "buffering" tool used to define zones to analyze for amounts and distances to vegetation [24, 25]. Comparisons from different years would then also

Table 2 56 Properties acquired by Beaumont industry; impervious footprint removed

Total land area (sq. ft.)	Year sold to Industry.	Distance from the fence-line (ft.)	1966 impervious area (building + paved footprint) (sq. ft.)
6360	2009	2414	1243
6566	2013	2887	2919
6566	n/a	2830	2475
6720	2005	4060	2934
4520	2007	4085	1380
3016	2005	4105	4872
2340	2005	3750	2400
9715	2007	2318	9558
7000	n/a	2407	1313
18,494	2014	2373	2006
4403	2007	2444	1472
1796	2003	2340	2914
6540	2007	3919	3402
6424	2005	3778	2944
6000	2005	1734	2146
12,000	2015	1622	3960
6600	2005	1586	3200
7200	2005	1537	2400
3500	2014	1723	4840
7000	2007	1546	2585
8500	2014	1576	3205
6000	2005	4400	2924
4000	2000	4109	2773
4476	2015	3023	3723
7264	2006	2750	1326
4468	2015	2976	1776
4216	2000	3017	1406
4476	2003	3170	1622
4608	2006	3105	1833
4864	2000	3190	1610
5008	2000	3252	1748
6000	2009	2167	1914
4992	2007	3828	2332
7500	2007	3363	2368
15,000	2005	3093	6816
5000	2005	2734	2409
7553	2005	4399	3160
8250	2006	1714	1558
6250	2014	1450	3410
3750	2009	1821	1632
7000	2015	2790	1591
7000	2015	1772	1440
5096	n/a	1580	1650
14,252	2007	1420	3248
14,000	2004	1663	1360
7000	2005	1527	2464
7000	2005	1481	2516
7000	2007	2092	1225
7000	2015	2507	1640
7000	2017	2364	2509
7000	2020	2179	1204
7000	2007	2147	1683
49,500	2015	2320	1560
6356	2007	1654	1470
6020	2007	1596	1950

Table 2 (continued)

Total land area (sq. ft.)	Year sold to Industry.	Distance from the fence-line (ft.)	1966 impervious area (building + paved footprint) (sq. ft.)
5040	2007	1549	1504
Sum: 418,198		**Min: 1420** **Max: 4400**	**Sum: 139,522**

Table 3 Eight properties acquired by the Beaumont industry, comparing pervious to impervious areas

Total land area (sq. ft.)	Year sold to Industry.	Distance from the fence-line (ft.)	1966 pervious area changed into impervious area. (sq. ft.)
Vacant to Parking			
436	2017	1060	436
6250	2017	956	6250
House to parking/buildings/facilities			
4346	2003	2370	2841
4900	2015	891	2772
4600	2015	750	3027
4500	2017	1052	2940
12,600	2015	955	10,188
10,679	2016	1375	8188
Sum: 48,311		**Min: 750** **Max: 2370**	**Sum: 36,642**

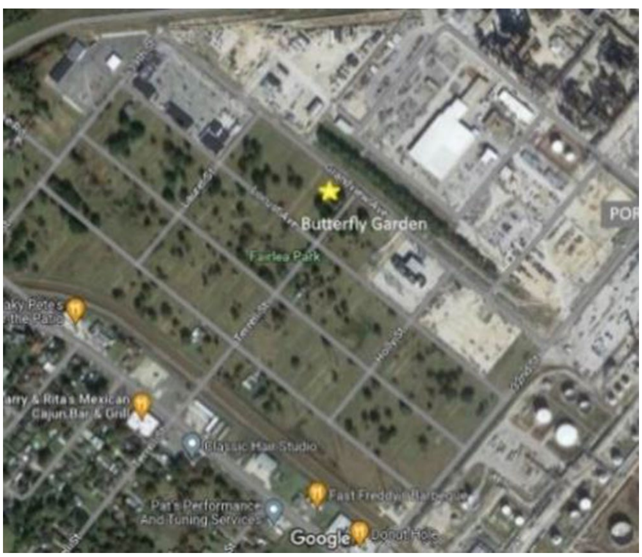

Fig. 4 Full buffer area near Port Arthur, Texas and butterfly garden location

Fig. 5 Photograph of butterfly garden near Port Arthur industrial area

Table 4 Downwind concentration peak for various effective stack heights [15]

Effective Stack Height (m)	Stability Class	γ	Distance to the peak (km)
40	F	0.32	2.60
	E	0.43	1.40
	D	0.54	0.80
	C	0.65	0.42
	B	0.61	0.29
	A	1.00	0.17
100	F	0.17	15.0
	E	0.31	6.0
	D	0.46	3.0
	C	0.83	1.2
	B	0.89	0.7
	A	1.00	0.45
200	F	0.02	85
	E	0.11	22
	D	0.23	9
	C	0.51	2.5
	B	0.68	1.4
	A	1.00	0.6

provide information on temporal development of these vegetated buffers as performed in this research.

One example of how this was performed with respect to public greenspaces for access by pedestrians was performed in a city in Iran. The authors used spatial analysis to locate parks and then a "buffering" tool to develop circular zones around the parks within certain distances that might be accessible by walking within a certain timeframe. Additional spatial analyses found streets and other paths within these zones and connectivity analyses to locate the extents of actual pathway distances. Further analysis of the city and its environs then provided information on areas that pedestrians were serviced or not serviced by these public greenspaces [26].

In the Partial Buffer case, the refinery in Beaumont was first built in the very early years of the twentieth century [1]. During that time period there were little transportation options for most workers, so neighborhoods developed right next to the industrial complex. This was before most zoning codes were enacted and little was known about environmental impacts on health. Thus, the partial buffer was developed in a rather random pattern, with former residential properties bought by the industry as they became available in this later century. The neighborhood has an association which is still active and has a long history [27]. Therefore, a partial buffer option has retained the neighborhood, but does provide some benefits as previously mentioned and as evidenced by the increase in permeable surfaces as noted in Table 2. The partial buffer option is one that might be considered when balancing historical neighborhoods and sense of place while decreasing impacts [28].

In contrast, the full buffer case represents a former neighborhood near Port Arthur Texas that was totally removed prior to a major expansion of the neighboring industry. This is evidenced in Fig. 2 where a large portion of the now existing industrial complex was vacant in 1966 when the houses in the neighborhood were still there. Although the authors are not privy to the various decisions made by the industry leadership and the community leaders prior to the expansion it can be assumed that providing this extensive buffer was probably a condition of the necessary permits. In addition to the benefits that the buffer might provide in case of an emergency at the facility, the analysis of the Plume Equation and the distances to the lower peak ground concentrations farther away as evidence in Table 4 provide some indication of improved air quality outside of the buffered area as compared to what would have been experienced at the former residential sites.

In both of these cases where nearby neighborhoods were changed, a question arises as to what trees might be more or less beneficial for air quality. A US Department of Agriculture (USDA) study summarized some of the positive and negative effects of trees on various air pollution issues. A major consideration is the formation of ozone as many trees can also emit VOCs. The recommendation is that in regions where ozone formation might be an issue is to select trees that are low VOC emitters. Some examples of tree species that are low VOC emitters listed are Fraximus (ash), Gleditsia (honey locust), Malus (such as crab apples), Prunus (which include plums, cherries, peaches, almonds, etc.) and Pyrus (pear). The USDA study also reviewed greenhouse gas benefits of trees, both with direct sequestration of carbon dioxide as they grow and with the potential of decreasing emissions from nearby sources if the trees provide a reduction in the urban heat island effect [29].

The vegetated buffer case does have some similar buffering benefits to the two aforementioned partial and full cases in that the residences to the east of the now forested area have this space between them and the current tank fields, providing distance from emissions and incidents. However, it also provides an additional benefit for possible in-situ remediation of the soil after possible leakages from the former tanks. Trees tend to be the preferred plantings for remediation of petroleum hydrocarbons such as BTEX as compared to grasses. Their long roots tend to cover a larger volume than the smaller root system of grasses [30].

In another previous study [31] plume-based methods were compared to earlier circular style spatial analyses for possible exposure of neighborhoods to toxic releases. The authors performed multiple comparisons of these two methodologies based on the Toxic Release Inventory (TRI) database of the Environmental Protection Agency (EPA) [32] overlaid with spatial census data. The comparative study was performed in 1997 but the spatial research performed herein in Jefferson County indicates that since then industries have made efforts to purchase or renovate parcels for green buffers in or near residential zones. Applications of these plume-based methodologies may better inform these and other industries of focal areas for future land acquisition and buffer implementation.

Consideration should be given to errors on the analyses herein and on future use of spatial analysis for buffer impacts on air pollution and other community concerns such as flooding and safety. Some sources of error are the models themselves such as the Plume model, but also the GIS techniques such as with map overlays and interpolation. There are also data errors such as with the availability of industrial data, or natural variations not detected with the geospatial data accuracy, including uncertainty in boundary locations and topology. However, the aforementioned plume-based model might still be used as a rough tool for decision-making for input on where to locate a buffer and its size and shape [33].

5 Conclusions

The acquisition of houses near the Beaumont industry which ended up with green spaces, may provide numerous environmental benefits including air pollution control and air purification. The impervious land area turned to pervious green spaces might improve stormwater infiltration, reduce surface water runoff, and help in flood control. Apart from its environmental benefits, the partial green space buffer areas may provide a serene environment for the local community members with trees and habitats for birds and animals.

The transition from a residential area to a full buffer zone gives an example of an approach to urban design that might promote sustainability and adaptability. This change highlights an effort to possibly mitigate detrimental effects of surrounding industries on the local environment and community health. The variety of plants within the buffer zone may help to improve air quality by absorbing pollutants generated by the industry and might add to the cleansing of the surrounding atmosphere. The buffer zone might serve several additional functions, such as boosting stormwater infiltration, lowering the risk of floods, and improving the aesthetic attractiveness of the area. A butterfly garden is a particularly charming aspect of this renovated landscape. Furthermore, the butterfly garden serves as more than just a place for butterflies and their migration, it may be a place for employees to enjoy breaks. Another option might be to plant a pollinator garden to aid in agricultural needs. This comprehensive approach to land use not only protects the environment but also improves the lives of those it serves, presenting a compelling model for future urban development that promotes both ecological resilience and community well-being.

The transformation from oil tanks to forested space may provide ecological and environmental benefits. This conversion may display the potential for environmental remediation. The trees in this forested area may trap and purify pollutants and help improve air quality which may help in reduction of harmful emissions from industrial plants. The forested area may also act as a natural infiltration area for rainwater and help reduce erosion and flood. Mainly this forested area may help in soil recovery if contaminated in the past due to leaks from oil tanks. Apart from its environmental recovery it may also provide a habitat for birds and animals and help in ecological aspects as well.

Not all spaces are suitable for fully forested buffers. While forests have additional benefits for the environment, sometimes it is better to have a buffer that has better lines of vision. Grassy buffers can help promote public safety by providing surveillance for crime or trespassing. There needs to be a balance between taking care of nature and making sure the community is safe. In conclusion, all these partial green spaces, the full areal buffer and the forested buffer may contribute to air pollution, contamination and emission control, natural rainwater/storm water infiltration reducing surface runoff and reduced risk of flood, soil contamination recovery and ecological restoration and conservation.

With the analysis of the classic Plume Equation from Figs. 3–9 from the Workbook of Atmospheric Dispersion Estimates, insights can be provided regarding the dispersion of pollutants and possible impact of green buffers on ground-level pollutant concentrations [15]. The calculated values of "γ" for stability classes A-F and for various stack heights provide an understanding of how different conditions affect the pollutant concentration. The presence of a green buffer can play a crucial role in controlling ground-level pollution concentration, depending on stability class, stack height, distance from the stack, and other atmospheric conditions.

The methods used herein or as detailed in the discussion could be used by other researchers to catalog the increase or decrease in green buffers near industrial areas over time. Additional research on the extent of green spaces in Jefferson County and criteria for future decisions on where to locate additional green spaces to aid in environmental and health improvements to the area are also recommended.

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Declarations

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

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