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Utilizing UAV for the Detection of Vacant Urban Spaces: Implications for Sustainable Infill Development

Boş Kentsel Alanların Tespiti için İHA Kullanımı: Sürdürülebilir Dolgu Gelişimi Üzerine Etkileri

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Abstract

Vacant and abandoned land are important sources of endogenous urban development. Ahvaz, one of the largest cities in southern Iran, has undergone significant physical expansion. Consequently, identifying suitable land for new development is essential for urban authorities. This research aimed to identify vacant urban land in Ahvaz using UAV images. The identification process was based on two criteria: "Urban Morphology" and "Distribution Pattern," which guided the extraction of urban vacant lands. The methodology included standardized image processing, categorization of vacant spaces, and statistical analysis to ensure accuracy and reliability. The first step was to identify the location of vacant lands in Ahvaz using images. Next, suitable locations for infill development were categorized into 6 groups based on their number and area. The density and distribution of these spaces were then examined using the index of the shape of the vacant plots and the Kernel function. The findings revealed that the largest area of vacant land was categorized as "barren with vegetation." In terms of distribution patterns, zones 2 and 1 of Ahvaz city exhibited the largest and smallest vacant land areas, respectively. This indicates a correlation between urban development levels and the availability of vacant spaces, suggesting that more developed areas tend to have fewer vacant lands. Moreover, zone 2 had the largest amount of vacant land in the town, followed by zones 8 and 6.

Keywords: *UAV, Vacant urban land, Infill development, Ahvaz city*

Özet

Boş ve terk edilmiş araziler, içsel kentsel gelişimin önemli kaynaklarıdır. Güney İran'ın en büyük şehirlerinden biri olan Ahvaz, önemli ölçüde fiziksel genişleme geçirmiştir. Sonuç olarak, yeni gelişim için uygun arazilerin belirlenmesi kent yetkilileri için çok önemlidir. Bu araştırma, İHA görüntülerini kullanarak Ahvaz'daki boş kentsel arazileri tespit etmeyi amaçlamıştır. Tanımlama süreci iki kritere dayanmaktadır: Kentsel boş arazilerin çıkarılmasına rehberlik eden "Kentsel Morfoloji" ve "Dağılım Modeli". Metodoloji, doğruluk ve güvenilirliği sağlamak için standartlaştırılmış görüntü işleme, boş alanların kategorizasyonu ve istatistiksel analizi içermektedir. Çalışmanın ilk adımda, İHA görüntüleri kullanılarak Ahvaz'daki boş arazilerin yerleri belirlenmiştir. Daha sonra, dolgu geliştirme için uygun yerler, sayılarına ve alanlarına göre 6 gruba ayrılmıştır. Bu alanların yoğunluğu ve dağılımı, daha sonra boş arazilerin şekil indeksi ve Kernel fonksiyonu kullanılarak incelenmiştir. Bulgular, en büyük boş arazinin "bitki örtüsüyle çorak" olarak kategorize edildiğini ortaya koymuştur. Dağılım açısından, en büyük ve en küçük boş arazi alanlarını Ahvaz şehrinin 2. ve 1. bölgeleri içermektedir. Bu durum, kentsel gelişim seviyeleri ile boş alanların mevcudiyeti arasında bir korelasyon olduğunu göstermekte ve daha gelişmiş bölgelerin daha az boş araziye sahip olma eğiliminde olduğunu düşündürmektedir. Ayrıca, 2. bölge şehirdeki en büyük boş arazi miktarına sahipken, onu 8. ve 6. bölgeler takip etmektedir.

Anahtar kelimeler*: İHA, Boş kentsel arazi, Dolgu geliştirme, Ahvaz şehri*

1. Introduction

The intense concentration of the population in cities of metropolises of developing countries has caused horizontal growth of cities. According to the statistical data of the World Bank, between 1960 and 2018, the number of cities with more than one million people increased from 14.14% to 24.01% (The World Bank, 2021); While at the same time, the global increase in urbanization was equal to 21.66 percent. The share of the population in the largest cities has decreased from 17.58% to 16.11% (World Bank Group, 2019). This divergence is particularly prominent in developed countries in Europe and the United States. These show the sprawl development in almost 60 years; consequently, this global problem has caused the destruction of the environment and pressure on the natural ecosystem of the earth in the outskirts of the cities and made the provision of services to city dwellers difficult (Hamidi et al., 2022). So, one of the approaches related to the balanced and logical development of the city is infill development (Arvin & Pourahmad, 2022). In this approach, instead of outward growth, vacant lands within cities are used such as barren, wasteland, brownfields, etc. (Khazaie, 2021).

The city, with all its complexity and interwoven components, in its totality, includes two main components "mass" and "space" and endogenous development can happen in masses or urban spaces. Apart from the things that can be suggested for this model of urban development, the important point is to identify and recognize these areas in different parts of the city. Conventional identification methods are often time-consuming and costly. Therefore, it is essential to use a technique that can identify areas with high accuracy and speed, as well as at a lower cost, that can be used for infill development (Peter et al., 2022). Unmanned aerial vehicles can play a role in supporting sustainable development, including infill development. UAVs can also be used to support infill development in several ways such as surveying and mapping, Environmental monitoring, and existing infrastructure, etc. This information guides the planning and design of new developments more efficiently and sustainably. UAVs are used to monitor and assess the environmental impacts of infill development. This information is important to identify potential areas of concern and inform the development of mitigation strategies. Overall, the use of UAVs in "infill development" and sustainable development more broadly can help address some of the challenges associated with urbanization and promote more efficient and sustainable development practices.

Vacant lots not only make the city look unpleasant but also usually become a place of accumulation of construction debris and household waste (Stewart et al., 2019). The accumulation of construction debris, which in turn leads to the waste piling up of garbage, threatens residents' health, and obnoxious urban landscape and vacant urban land is a significant barrier to sustainable neighborhood development (Chen & Conroy, 2023). Therefore, empty urban lands and brownfields are the prime options for redevelopment. It is currently essential for urban planners and decision-makers to identify and generally obtain locational information from vacant land (Song et al., 2020). However, accurate mapping of vacant lands has implications due to the morphology of urban spaces as it includes various features such as abandoned structures, bare land, vegetation, or a combination of them. Such diversity usually challenges their identification (Xu & Ehlers, 2022). Even when using high-resolution remote sensing images, this goal is difficult to achieve. In general, and from the aspect of typology, vacant urban land can be placed in four broad categories (Figure 1).

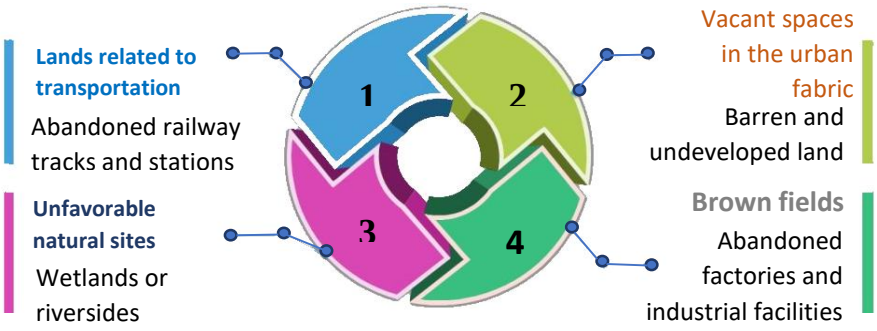

Figure 1. Typology of urban vacant land (Newman et al., 2018)

Transportation-associated land: land and spaces related to transportation systems, including railways, highways, and other roads. Natural sites: located within built-up areas, these sites have not been used due to their physical/environmental constraints. They include drainage areas, wetlands, hillsides, steep slopes, riverbanks, and rivers. Unattended areas and reserve parcels: these sites are empty and inactive and look like leftover spaces within the urban fabric. They very often feature vegetation but are not parks or gardens.

Some of these sites are already earmarked for future expansion/development. Brownfield sites: land or premises previously used and currently underused. Reusing such a site may be complicated by addressing with existing structures or contamination. Typically, there are derelict buildings or structures on site. Previous uses include industry, mining, military activities, agriculture, or commerce (Xu & Ehlers, 2022).

Examining the physical development of Ahvaz city shows that during the past decades, 58% of the physical development of the town was based on demographic changes and 42% was due to horizontal growth, also Ahvaz has greatest rates of population growth among large cities in the country. The industrial nature of the town has attracted migrants from different parts of the province and a cultural point of view, some of the citizens still have a higher birth rate than the national level, and for this reason, the population growth will continue in the medium-term future (Ahvaz, 2018). Therefore, to accommodate this population, new lands are needed for residential purposes. Vacant lands in the inner parts of the city can be one of the important opportunities to place new development. The current research aimed to develop a comprehensive method for identifying vacant urban spaces in Ahvaz using UAV photogrammetry. This approach involved a multi-step process that included image acquisition, processing, and analysis to ensure that the identified spaces were suitable for infill development.

2. Theoretical foundations

This section starts by presenting a brief overview of the different definitions of vacant land and measuring the morphology and distribution pattern of vacant urban lands.

The term vacant land is broad and diverse, but it is usually defined as under-utilized lands including bare soil, derelict land, abandoned buildings and structures, brownfields, green fields, uncultivated land, or marginal agricultural land, and recently razed land. In general, there are two representative views on the meaning of urban vacant land (UVL) to date. The first, presented by the American Planning Association, is that UVL refers to land not used for any purpose or without any buildings or other physical structures (Davidson & Dolnick, 2004). According to the second view, UVL refers to unused or abandoned land, including land that is currently unused and without any buildings, and land with buildings that have been abandoned or deserted (Nemeth & Langhorst, 2014; Kim et al., 2015). Moreover, the Chinese government established the concepts of “vacant land” and “idle land” in land management practice. The National Standard of Current Land Use Classification in China defines vacant land as a land use type referring to the unused land within an urban, village, or industrial and mining area. According to the Measures for the Disposal of Idle Land released in 2012, idle land is state-owned land which has been supplied for construction but has not reached the prescribed development intensity (Ministry of Land and Resources of the People’s Republic of China, 2012). In the concepts compared above, vacant land is a positive term with no uniform definition, while idle land is a normative one that reveals policy intervention in land use. Here, a definition of UVL is presented from a positivist perspective.

From a positivist point of view, urban vacant land is unused urban land within a developed urban area, urban planning area, or urban administrative district (Song et al., 2020). From this perspective, note that an unused status with no current human activity is the key criterion for designating land as vacant land. The vacant land is not limited to land that has not been developed and constructed upon, but also includes abandoned or deserted land which has been developed with buildings, structures, and ancillary facilities (Tu et al., 2024). However, protective land and green infrastructure, such as parks and green spaces which are developed for recreation or landscape are excluded from vacant land (Anderson & Minor, 2018). Wild green spaces with no artificial management, such as wild grassland along roads or rivers within urban areas, fall within the definition of urban vacant land.

To identify the vacant lands of the study area in different evaluated classes, two macro indicators "morphology" and "distribution pattern" of vacant lands have been used.

3. Data and research method

The data obtained from aerial photography of May 2019, Unmanned Aerial Vehicle (UAV) by Shahid Chamran University, along with secondary documents. To produce a detailed map of vacant spaces suitable for infill development, the UAV images were first standardized using Agisoft PhotoScan. This process involved creating a point cloud and generating an ortho-photomap, which was then imported into ArcGIS for further analysis. The subsequent steps included identifying target areas, designing flight paths, and establishing ground control points to ensure the accuracy of the data collected. The following steps were taken to prepare the aerial images from the drone:

First identification, flight design, ground control points, and marking were designed. In the second step Ground mapping operations included creating a ground navigation station, and determine the location of the main stations and control points. In the third stage, flight operations were carried out pre- and post-flight controls, unmanned bird navigation, and receiving collected data.

Finally, data is processed through aerial triangulation, point cloud filtering, ortho-photomosaic production, control geometric correctness and output conversion comprising drawing and cartography and creating a spatial database (Majidizadeh et al., 2023). To achieve the research goals, it was realized by extracting the indicators of urban vacant spaces such as the morphology and distribution pattern of these spaces. To perform the required analysis, first the location of vacant lands of Ahvaz were identified using images and then the suitable locations for infill development were classified into 6 groups, their number and area assigned. In the following, by using the index of the shape of the vacant plots and the Kernel function, the density and distribution of the mentioned spaces were examined, and their map was produced.

3.1 Measuring the morphology of vacant urban land

As the typology indicates, the morphology of vacant land on images varies between man-made structures, bare soil, vegetation, or a mix (Xu & Ehlers, 2022). The morphology of the mentioned sections is a function of criteria such as the area of vacant plots, their average area, the number of empty blocks, and finally the shape index of empty blocks in the city, which is obtained from Equation 1 and Equation 2:

$$Auvl = s / n \quad (1)$$

$$Siuvl = (0.25 \times p)/\sqrt{s} \quad (2)$$

Where A is the average area of empty blocks; s is the area of an empty block; n is the number of empty blocks; Si is the shape index of empty blocks and p is the diameter of empty blocks.

3.2 Assessment of the distribution pattern of vacant urban land

The second indicator for identifying vacant urban lots is the distribution pattern of these lots. For the purpose of determine the pattern of distribution of land and vacant plots, initially, shares of parcel and area of UVL were used to measure the UVL occurrence probability: Equation 3 and Equation 4.

$$Rp = n\_uvl/n\_lu \quad (3)$$

$$Ra = s\_uvl/s\_lu \quad (4)$$

Where Rp is the proportion of UVL parcel number to total land parcel number; n_uvl is the number of UVL parcels; n_lu is the total number of whole land parcels; Ra is the proportion of UVL area to total land area; s_uvl is the area of UVL; and s_lu is the total land area. Kernel density estimation, a nonparametric method that reflects the degree of spatial aggregation of observed variables by using two-dimensional smooth estimation surfaces (Xu & Gao, 2016), was then used to estimate UVL density

3.3 The study area

Ahvaz City the center of Khuzestan province with a population of 1,262,581 people (Hosseini et al., 2024), is the seventh most populous city of Iran (Sajjadian & Daman, 2018), which is located in the southern part of the country, as seen in Figure 2.

Ahvaz is considered one of the most extensive cities in Iran. In recent decades, this city has experienced significant growth in terms of population and the size of the city due to socio-economic developments. Ahvaz metropolis includes eight urban zones that are administered by 8 municipalities (Table 1). In 1976, the area of Ahvaz was nearly 3,700 hectares. After a decade, in 1986, the size of the city reached 6900 hectares (Bahadori, 2020). With the change in the scope of the master plan, the size of the urban area changed to 8,615 hectares, In 1991. and the size of the town between 1996 and 2011 was 10,257 and 12,266 hectares, respectively. In 2012, due to the separation of Zone 5 from Ahvaz and its joining to the new city of “Kut Abdollah”, the size of the city decreased to 10,709 hectares (Arvin & Zanganeh, 2020). Finally, according to the assessments from the Ahvaz Municipality Planning Department, the area of the city is estimated to be more than 18,800 hectares (Ahvaz, 2023).

According to the comparison of the number of plots and the area of empty blocks in Ahvaz and the ratio between the two, listed in Table 2, it can be seen that barren lands with vegetation and barren lands without vegetation are the most with 2.95 and 1.23, respectively. These lands have the lowest ratio between the area and the number of investigated lands. Therefore, in barren lands with vegetation, we see the most and in barren plots without vegetation,

we see the smallest dimensions and area. One of the reasons for this may be the reason that barren lands without vegetation are usually between built blocks and are ready for development. Since the ratio of the area to the number of empty plots of the city (average area) is greater than unity and equal to 1.89, it can be concluded that the area is a more important indicator of the number in any category of evaluation of the empty plots of Ahvaz city.

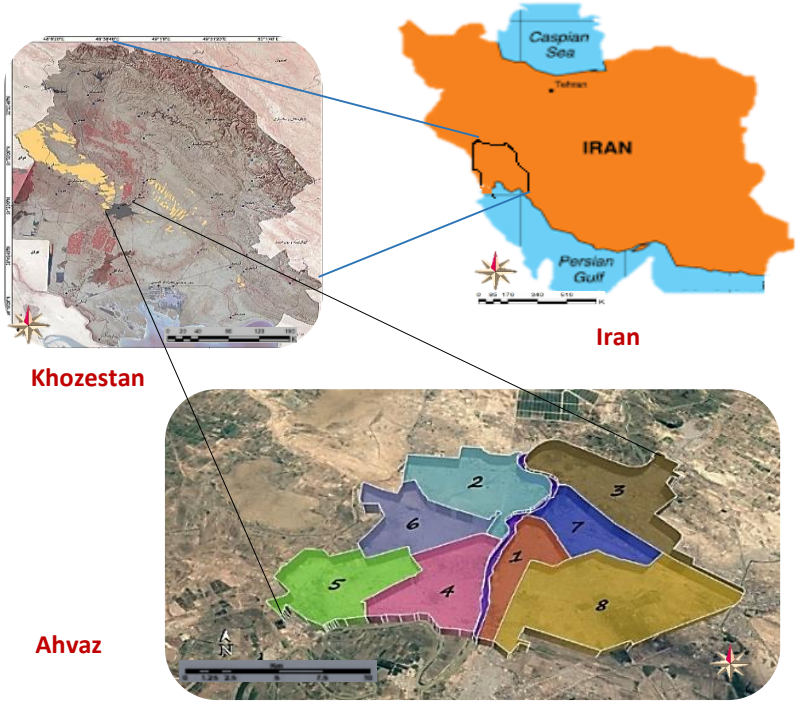

Figure 2. Location of Ahvaz city and its eight zones

Table 1. General characteristics of the eight zones of Ahvaz City (Ahvaz, 2023)

Regions	Area (ha)	Percentage of Total Area	Population of 2018	Estimated population in 2023	Percentage of the total population in 2023	Population density in 2023 (people per ha)
1	1106.6	6	13942	148583	12	135
2	2113.08	16	197274	114317	9	39
3	1318.36	18	176167	187735	15	59
4	2527.09	12	153313	163380	13	65
5	2154.74	10	105477	112402	9	52
6	2110.53	11	165110	175951	14	83
7	1718.71	10	146218	155819	12	91
8	3098.11	17	191802	204394	16	66
Total	*18806.4*	*100*	*1184788*	*1262581*	*100*	*67*

4. Results

4.1 Typology of vacant land in Ahvaz city

Vacant urban lands of Ahvaz can be classified into different types according to land cover, land use, and land ownership. Based on land cover, the vacant land of Ahvaz is divided into 6 categories such as barren with vegetation, wetland around Karun, barren without cover, barren with shrubs, and vegetation in combination with buildings and vegetation (Figure 3).

Based on land use, urban non-passage spaces can be classified into two categories 1) empty residential land and 2) empty industrial land. According to the type of ownership, lands include Private, Public, endowment, Cooperative, and Mixed ownership.

4.2 Morphology of vacant land of Ahvaz

After preparing the images and applying Equations (1) and (2), it was found that the amount of vacant land in Ahvaz city based on land cover is equal to 372 plots with an area of 701.7 hectares as seen in Figure 4. As shown in Table 2, the largest number of vacant lands was obtained from the category "barren without cover" with 106 plots, while the largest size of vacant land with 256.9 hectares belonged to "barren with vegetation". Also, the lowest amount with 28 empty plots and 65.2 hectares belongs to the class "barren with shrubs". In general, barren lands (including: barren with vegetation, barren with shrubs, and barren without cover) with a total of 446.2 hectares, occupy the majority of Ahvaz's vacant land in terms of coverage. The ratio of the number of empty plots of land to the total city plots (urban mass) is only less than 3%, while the ratio of the area of empty plots to the total area of the city is more than twice the ratio of the number and about 7.5 percentage.

Figure 3. Vacant lands of Ahvaz city based on coverage: 1) barren with vegetation, 2) wetlands around Karun river, 3) barren, 4) barren with shrubs, 5) vegetation in combination with buildings, 6) vegetation

4.3 Distribution pattern of vacant land in Ahvaz city

The distribution of the classified lands and the area of its eight zones were analyzed to evaluate more closely and examine the distribution pattern of vacant urban land in Ahvaz (Table 3). As shown in Table 3, the most and the least empty plots of land in Ahvaz with 123 and 12 belonged to zones 2 and 1 respectively. Because Zone 1 is located in the central area of the city, the small number of vacant plots seems reasonable.

The least quantity of vacant land seems to be found in more developed areas. In other words, the relationship between the development of different parts of the city and the amount of vacant land is an inverse relationship. However, even though Zone 2 is the most developed part of Ahvaz City, the presence of a high number of vacant lands is the result of annexation of the new and undeveloped neighborhood "Kian Shahr" in recent years. The ratio of the area of vacant plots to the total urban area of zones 2 and 1 is 11.97 and 2.62 hectares, respectively.

As seen in Figure 5, The highest and least average area of empty plots with 2 and 0.67 hectares are located in zones 6 and 5, respectively. The total average area of the city is equal to 1.88 hectares, which indicates that the empty lands are mostly outside the current built area. In terms of the average values of the shape index, zone 2 is still the leader with 1.95, while in terms of this index, zone 3 has the least number with values of 1.28.

The largest number of vacant lands in Ahvaz were identified in zones 2, 8, and 4, respectively, while the least are found in zones 1, 7, and 5. Regarding area, zone 2 is still the first rank of vacant land in the city, and zones 8 and 6 in the next. By examining other data in (Table 3), it is clear that Zone 2 of Ahvaz Municipality is not ranked first only in the index of the average area of vacant blocks. Also, this zone ranks fourth and second in terms of the number and total area of city blocks.

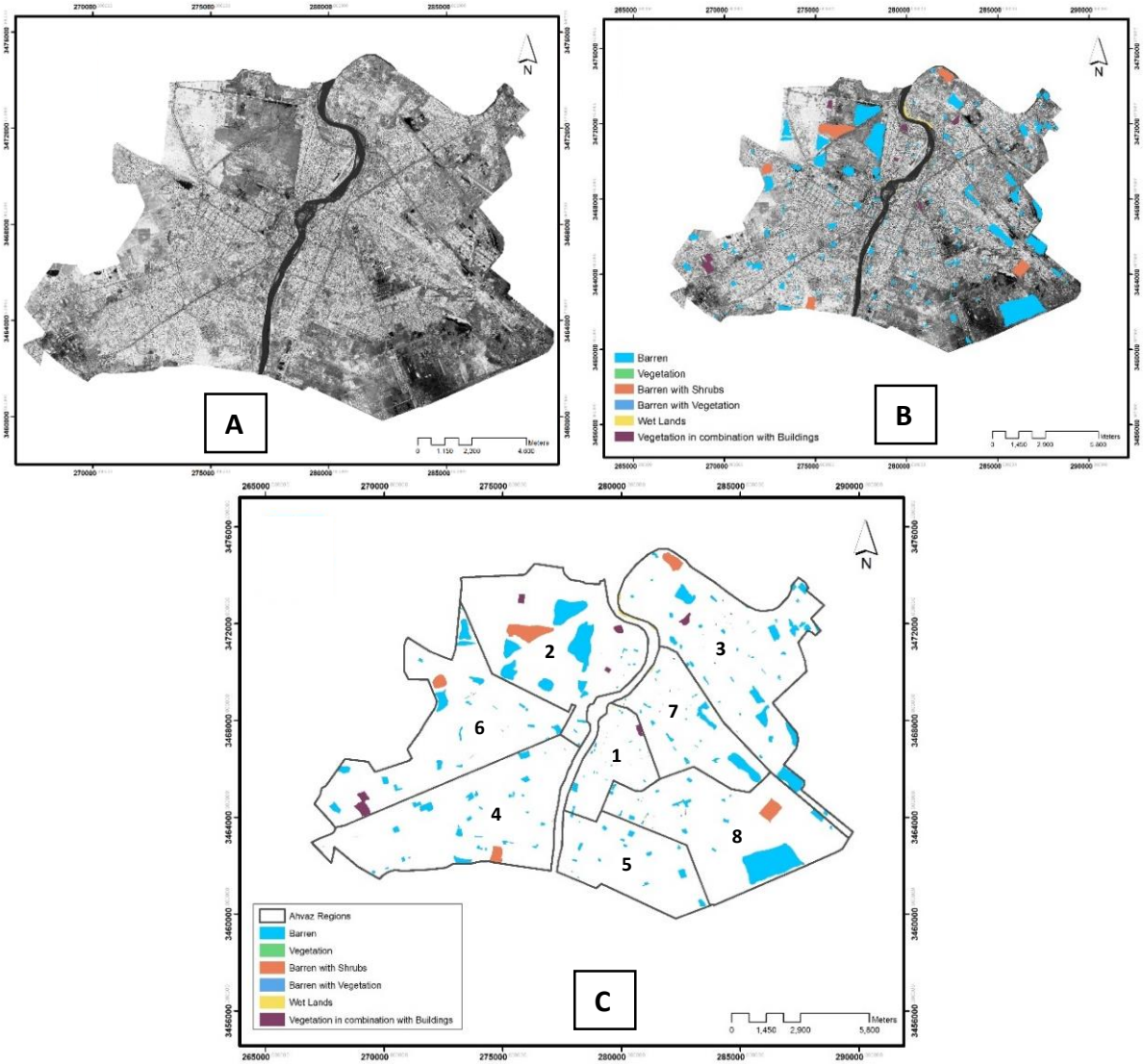

Figure 4. Vacant land in Ahvaz based on land cover: A) mosaic images, B) vector and raster image, C) vacant land map of Ahvaz

Table 2. Types of empty land in Ahvaz city based on land cover

	Number of parts	Area of parts (ha)	Average area of vacant block (ha)	Probability of Occurrence(%)	
				Ratio number of empty plots to total number of plots	Ratio area of empty plots to the total area
Barren with vegetation	88	259.6	2.95	0.76	2.76
Wet lands around Karun	48	79.3	1.65	0.36	0.84
Barren without vegetation	106	131.4	1.23	0.79	1.39
Barren with shrubs	28	65.2	2.32	0.21	0.69
Vegetation in combination with buildings	35	68.9	1.97	0.26	0.73
Vegetation	67	97.3	1.45	0.5	1.03
Total	372	701.7	1.89	2.79	7.45

Table 3. Morphological characteristics of vacant urban land plots in the 8 zones of Ahvaz

Zone	Total number of blocks	The total area of blocks (ha)	Number of blocks	Area of empty blocks (ha)	The average area of vacant block (ha)	Probability of Occurrence(%)		Average of Shape Index
						The average area of vacant block (ha)	The ratio of the area of empty blokes to the total area of the city	
1	1378	726.34	12	19.6	1.63	0.87	2.69	1.32
2	1471	1549.56	123	185.5	1.50	8.36	11.97	1.95
3	1839	1343.61	34	39.4	1.15	1.84	2.93	1.28
4	1601	1090.18	49	55.3	1.12	3.06	5.07	1.35
5	1592	913.66	32	21.5	0.67	2.01	2.35	1.48
6	1072	1000.91	34	68.2	2	3.16	6.81	1.65
7	1414	1157.21	19	31.7	1.66	1.34	2.73	1.39
8	2941	1631.06	69	69.5	1	2.34	4.26	1.31
Total	13308	9412.53	372	701.7	1.88	2.79	7.45	1.35

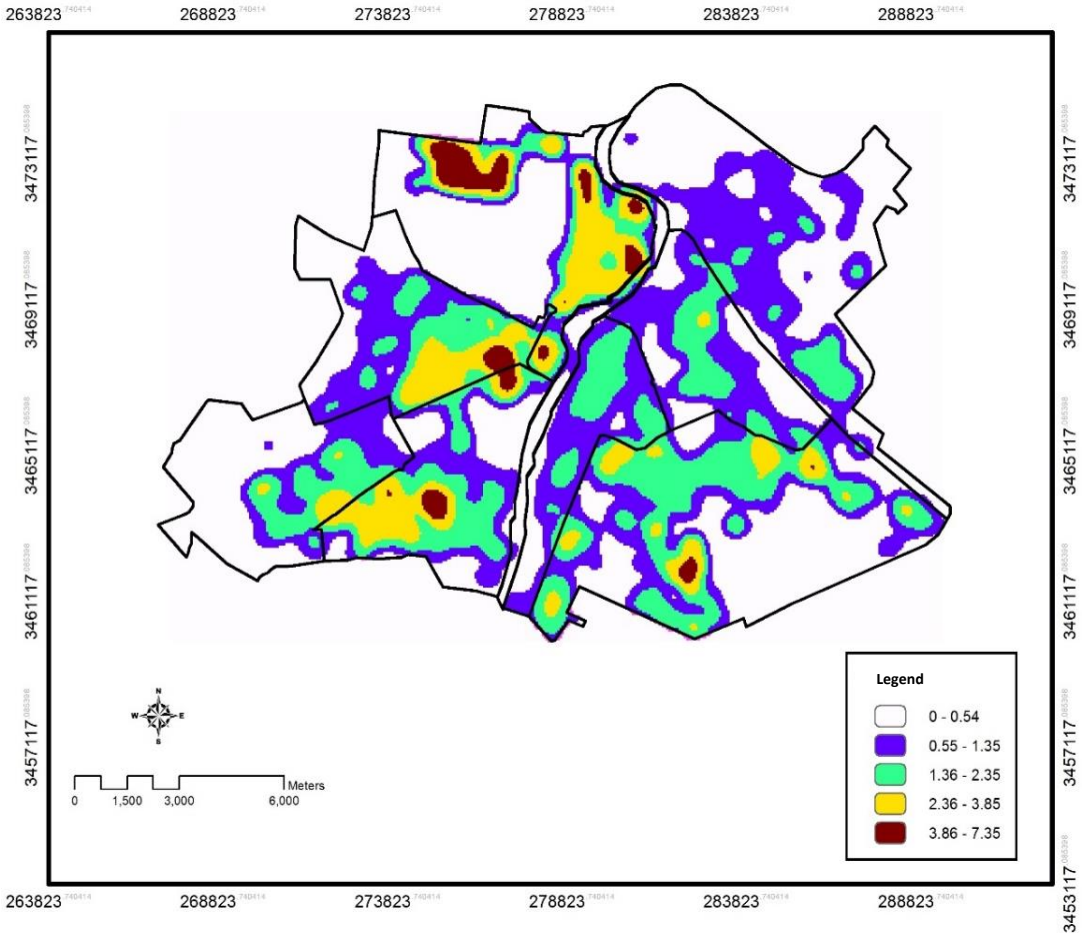

Figure 5. Distribution pattern of vacant lands in Ahvaz based on the average shape index and using Kernel

By comparing the three key indicators of the research (the ratio of vacant plots to the total city plots, the ratio of empty area to the total area of the city, and the average values of the shape index) and by examining the eight zones of the city, it was found that the 5th zone of Ahvaz municipality has the most harmony and homogeneity in terms of the indicators. In this context, zones 3, 7, and 1 are in the next places. From this point of view, zones 2, 6, and 4 have the least homogeneity, as seen in Figure 6.

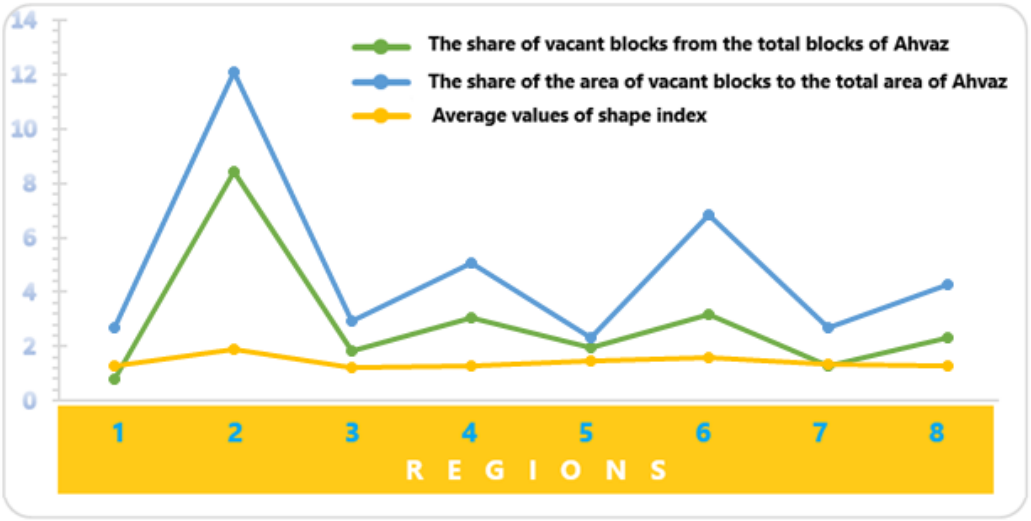

Figure 6. Comparison chart of three key research indicators

4.4 Verification of Results

To establish the reliability of the identified vacant lands, a comprehensive verification process was undertaken. This included systematic ground truthing through field visits, wherein researchers meticulously compared the mapped data with actual conditions observed on-site. This assessment involved evaluating the accuracy of the identified vacant spaces against empirical observations, thereby ensuring the integrity of the data.

Furthermore, advanced statistical analyses were conducted utilizing shape indices and Kernel functions to rigorously evaluate the density and spatial distribution of the vacant lands. These analyses provided quantitative metrics to confirm that the observed patterns were statistically significant, thereby reinforcing the validity of the findings and their implications for urban planning and development.

5. Conclusion

The lack of land for housing construction in developing countries is a prevalent issue exacerbated by rapid urbanization. This study highlights the potential of infill development in utilizing vacant urban spaces, particularly in Ahvaz, where over 372 vacant plots covering more than 700 hectares were identified. By employing UAV technology for accurate mapping, the research not only provides a framework for identifying underutilized lands but also emphasizes the importance of sustainable urban development practices. The findings advocate for the strategic use of these vacant lands to accommodate population growth while minimizing environmental impacts, thus contributing to more efficient urban planning. With more and more people living in urban areas, agricultural and natural areas are being increasingly built over, causing land needed for natural habitats and food production to be lost. At the same time, rapid urbanization has resulted in fragmented urban development and the abandonment of infrastructures, meaning that many metropolitan areas have become vacant land indicated by their unused, underused, derelict, or abandoned situation. Sustainable urban development makes the reuse, redevelopment, or recycling of such areas a key strategy for reducing land consumption and combating urban sprawl.

One of the solutions to face this problem is infill development in unused vacant spaces in the urban mass. Identifying these spaces is often associated with obstacles and difficulties such as time and cost.

The use of traditional and field methods to identify vacant land in the city and also considering the area of 20 thousand hectares of Ahvaz city cannot be efficient. Moreover, the existence of unused spaces in the center and outskirts of urban masses also makes the problem more complicated. Current research on vacant land is mainly approached from an urban planning perspective the objective of identifying the vacant lands of Ahvaz with the ability to be used in the infill development using drone areal images. To achieve this goal, two major indicators of the morphology of empty urban land and the distribution pattern of empty spaces in the city of Ahvaz were used.

The results of the research showed that out of the total number of 13308 urban plots and blocks in Ahvaz, 372 are vacant spaces that can be used for infill development. This number includes an area of more than 700 hectares from the area of about 9412 hectares of Ahvaz city. In general, the number of vacant spaces is 2.79% of the total number of plots and 7.45% of the total area of Ahvaz urban mass.

Based on land cover and regarding to the six classes of research, the largest number with 88 cases and an area of 259.6 hectares, includes 2.76% of the vacant plots of the city. The vegetation layer combined with the building, with 35 cases and an area of 68.9 hectares, was the least covered case with 0.73 hectares.

Most of the plots and vacant lands are located in zone 2 in the northwestern area of Ahvaz, which has the highest development rating of the city due to the annexation of the Kianshahr area to the urban fabric and this area of the town in the recent years. Zone 1 is located in the central part and has the least number of vacant lands where there are the oldest structures of Ahvaz.

From a spatial point of view, the city of Ahvaz can be divided into two parts by the river of Karun. The western part including zones 2, 4, 6, and 5 has the highest number of vacant plots which could be used for infill development (as seen in Figure 5). While in the opposite part, which includes zones 3, 1, 7, and 8 with a total area of 4,858.22, having a larger area has a smaller number of vacant plots in the western part of the river.

By analyzing the data and the discussion, the research recommended the following proposals: 1) The vacant lands of the research area from the point of view of land use and ownership should also be calculated and compared with the findings of this study. 2) By calculating the capacity of identified vacant lands, their population potential should be calculated from different aspects. 3) Utilizing GIS and the involvement of factors such as access to the highway, identified vacant lands should be prioritized for infill development (as seen in Figure 6).

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