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Exploring the heterogeneity of the street pattern of informal settlements on agricultural lands in Giza Egypt

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Abstract

Given the dominance of informal settlements on the agricultural land, within the Egyptian context, highlights the importance of studying and understanding them quantitatively. Although a lot of studies have quantified them according to their sizes, densities, and their rates of growth; the study of their urban morphology is still qualitative. As a first step, a previous study quantified the main features of the street network of Giza informal settlements and revealed an inconsistency within the street pattern of such settlements. This study, as a second step, is an attempt to explore this inconsistency and, ultimately, reveal some of the complexity of the urban morphology of the informal settlements in general, and of those occupying agricultural lands in specific. By adopting a cross-sectional approach, a cluster analysis technique has been conducted to 38 quasi-randomly selected sample points (locales), representing Giza informal settlements at the city-level. Results show that, within the similarities and differences of the main features of the street network, four distinguished street patterns are identified, which reflects the complexity and heterogeneity within informal settlements of the same typology and, hence, highlights the need for re-evaluating the stereotypes of the informal settlements.

Keywords: Street Pattern; Street Network; Informal Settlements; Agricultural Land; Informal Urbanization; GIS

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1. Introduction

Egypt is facing a rapid informal urbanization that has reshaped the form and nature of Egyptian cities over the past decades (UN-Habitat, 2015). As a result, informal settlements have prevailed as the most common pattern of the Egyptian urban growth (El-batran and Arandel, 1998; El-Hefnawi, 2005; Kipper, 2009; Sejoune, 2009). It is estimated that about 40–50% of Egypt's urban population, and over 20% of the total population, are living in informal settlements (Hassan, 2012). Moreover, the UN-Habitat (2015) has stated 37.5 % of the total urban mass in Egypt as informal settlements, where this percentage increases to 95% in the Egyptian villages. According to GOPP (2012), informal settlements constitute approximately 40% of the Greater Cairo Region (GCR) residential areas, covering a total area of 22,500 acres, with population density rates reaching 800 persons per acre.

Based on their proliferation and urban morphology characteristics, informal settlements in Egypt are classified into four main typologies[1]: 1) informal settlements on agricultural lands, 2) informal settlements on desert state lands, 3) deteriorated medieval city core and, finally, 4) deteriorated pockets of urban poverty (O'Donnell, 2010; Sims, 2003). Among these typologies, the most prevailing one is the informal settlements occupied on agricultural lands; where 90% of informal settlements in GCR were found to be developed on (83% were developed on a privately-owned agricultural land, and 7% on a state-owned agricultural land), while the remaining 10% were developed on desert lands (GOPP, 2011; GOPP, 2012; Sims, 2011). In this respect, informal settlements on the agricultural land are widely known as a distinguished prototype. With the exception of the organic narrow streets of the core villages, the main street layout of these informal settlements is mostly determined by the former agricultural land and irrigation network and, hence, it is mainly identified by its straight narrow routes (usually 2-4 meters), which are perceived as a cohesive pattern distinguishing such settlements (GOPP, 2011; Sims, 2011).

Given the dominance of informal settlements on agricultural lands, within the Egyptian context, highlights the importance of studying and understanding them quantitatively. Although a lot of studies have tried to quantify them according to their sizes, densities, and their rates of growth (Barada, 2006; Hassan, 2012; GOPP, 2011; GOPP, 2012; UN-Habitat, 2015; World Bank, 2007); the study of their urban morphologies is still qualitative (GTZ, 2010; O'Donnell, 2010; Shehayeb, 2009; Sims, 2003; Sims, 2011). In this context, an important component of the urban morphology is the street network (Nasreen, 2014). Where streets are illustrated as links, and intersections are illustrated as nodes; street network could be simplified and seen as a schematic layout of those informal settlements (Louf and Barthelemy, 2014). Respectively, by studying their street networks; their urban morphology could be determined (García-Villalba, 2014; Kamalipour, 2016; UN-Habitat, 2012), and the processes of their proliferation and development could be captured (Louf and Barthelemy, 2014).

Correspondingly, a previous study has focused on computing and assessing the street network of Giza informal settlements, one of the cities of GCR, as an initial attempt to quantify the street connectivity of those

[1] However and as a trail to prioritize its interventions, the government has redefined the slums in 2009 according to the severity of risks on the residents of these slums. Accordingly, informal settlements have been categorized into two main groups: "unplanned" and "unsafe" areas. In this context, informal settlements on agricultural lands are considered as unplanned areas.

settlements at the city level (Elfouly, 2017). Whereas the main results showed that those informal settlements are poorly connected; with extremely low connectivity values compared to the required, one of the significant results highlighted inconsistency and irregularity in the pattern of the main features of the street network and, hence, further investigation was recommended. Consequently, this study is considered as a second step, building on the former study, towards exploring the heterogeneity within the street pattern of informal settlements on agricultural lands and, hence, revealing some of the complexity of the urban morphologies of the informal settlements in general, and of those occupying agricultural lands in specific. Accordingly, same study area and same data gathering methods of the former study were adopted in order to, ultimately, reach cumulative findings which could enrich the general understanding of such typology quantitatively.

In this respect, this study is divided into four main parts: the first part discusses the main urban features of the informal settlements on agricultural land in the Egyptian context, with the focus on the street network. The second part gives a brief description of Giza informal settlements, and the main characteristics of their street networks, moreover, it discusses the research methods used. As the third part represents the main results, the fourth and final part formulates the discussion and conclusion.

2. Background

Informal urbanization of the agricultural land was the result of the general urbanization of the Egyptian cities themselves, combined with a horizontal extension of core villages surrounding the cities, which have been overtaken by the urban expansion (Sejoune, 2009; Sims, 2011). It mainly started during the 1960s, when the first peripheral urbanization process took place. The centralization of government investments and businesses, along with the negligence of the rural development, encouraged the internal immigration seeking a better quality of life (El-Shenawy, 2016). With a significant increase of the rural-urban immigration to cities, especially to GCR; the proliferation of informal settlements began by the gradual encroachment of the agricultural land in the western (Boulaq AlDakrour, Warrak AlHadr, Mounira) and northern (Shobra AlKheima, Matareya) fragments of the city. Despite the good productivity of those agricultural lands, farmers were driven to sell them; as their sale for building purposes was more profitable than the revenues from farming back then (Arandel and Batran, 1997). This process was developed by private actors without any consideration to formal legislation, especially those prohibiting the conversion of agricultural lands into urban uses (World Bank, 2007). Moreover, due to the severe shortage in the formal housing supply, informal settlements became the solution to the housing needs of the majority of both middle and lower classes (Arandel and Batran, 1997; Osman et al., 2016). According to their own regulations and norms, informal settlements on agricultural lands have grown over a long period of time to become the most common settlements in the Egyptian cities. It has been noted that, between the 1970s and the 1990s, almost 80% of the housing supply in GCR was built informally (Piffero, 2009).

Generally, the process of building on the agricultural land has begun by purchasing and informally subdividing it into smaller plots, which were gradually converted into housing units without building permits (Gouda, 2013). Being non-compliance with the planning legislation, the resulting layout was shaped by scattered decisions, taken by many individuals, which was usually limited to the scale of the agricultural plot itself (El-batran and Arandel, 1998). Tailored to the original shape of the agricultural land, the main characteristics of such layout are mostly identified by the relatively small sub-divided housing plots (usually of a rectangular shape), with no designated spaces for either services or infrastructure connections, and with minimal outdoor spaces left for access and thorough movement (El-Hefnawi, 2005; UN-Habitat, 2012; UN-Habitat, 2013; 2016). Streets, in this context, are multi-functional; they are the channel of mobility, communication, social interaction, informal commerce, economic productivity, and cultural activities (UN-Habitat, 2012; UN-Habitat, 2013; 2016).

Figure 1. Informal Infill between Giza Core Villages
(Source: Sims, 2011)

With the exception of the organic narrow streets of the core villages, the main street layout is mainly driven by the irrigation networks (GTZ, 2010); where the former-irrigated agricultural plots are separated by small irrigation channels. Those channels are converted to local routes upon converting those plots into housing units (Amer, 2015). Contextually, the prevailing street pattern is mainly formed of straight narrow routes (usually 2-4 meters) (GOPP, 2011; Sims, 2011), which could be determined as the infill between existing village settlements [Figure 1] (Sims, 2011). As for the housing conditions, buildings are generally in a good condition, permanent type (of reinforced concrete frame and infill red brick walls), yet with an over-time increasing densification causing a serious overcrowding issue (GOPP, 2011; Sims, 2003; Sims, 2011). The average building height is usually 6-8 floors, and some buildings rise to exceed the 12 floors; forming a very compact pattern (Shehayeb, 2009).

However, the result of the informal development process is the overall poor quality of life in such settlements; as inhabitants suffer from the poor provision of public services and utilities, insufficient street networks, lack of public spaces, and the general overcrowding high-dense environment. On the other hand, the proliferation and expansion of those settlements have led to the deterioration of the surrounding agricultural areas, as well as the loss of a valuable resource (El-Hefnawi, 2005; UN-Habitat, 2012).

3. Methods and materials

3.1. Study area

Giza, one of the cities of the GCR and the capital of Giza governorate, is situated on the west bank of the Nile river opposite Cairo city (Giza-Governate, 2002). Accommodating more than 2 million inhabitants on 44 km^2 of Giza city (GOPP, 2011), informal settlements on agricultural lands have reached 87% of Giza urban expansions (Barada, 2006), occupying more than 62% of the total area of Giza city [Figure 2] (GOPP, 2011). In this respect, most of Giza locality units[2] "sheyakha" are totally informal (unplanned) to the extent that the planned ones are becoming the exception (AUC, 2014); resulting in perceiving Giza city as an "informal city" more than being planned.

According to a previous study on Giza informal settlements, main features of the street network were measured (Elfouly, 2017). In this context, four measures were deployed: the proportion of land allocated to streets (LAS), street density (SD), intersection density (ID), and connected node ratio (CNR)[3]. LAS and SD represent the streets, while ID and CNR represent the intersections within a street network. Values were found to be extremely low compared to the recommended for sufficient connectivity: 12% instead of 30% for LAS, 34km/km^2 instead of 20 km/km^2 for SD, and 475 int/km^2 instead of 320 int/km^2 for ID, whereas CNR (0.85) relatively matched the recommended value (> 0.75). This implies that dead-ends within the existing street network are not the main factor of the poor connectivity unlike the other measures; especially the extremely high no. of intersections which, in some cases, exceeded 700 int/km^2: a clear manifestation of the urban informality sub-division processes. Moreover, unlike literature, street network measures were neither consistently nor strongly correlated; whereas those measures showed a strong correlation in the formal planning practice, they were relatively uncorrelated in that study: ranging between 0.1 and 0.3, LAS, SD, and

[2] The locality unit is the smallest administrative geographical unit and, hence, the smallest officially identified unit in the general and economic census in Egypt.

[3] CNR refers to the number of street intersections divided by the no. of intersections plus cul- de-sacs, in which a higher number indicates relatively fewer dead ends, and higher connectivity.

CNR showed very weak correlation. While as for ID, there was inconsistency in its relation with other measures; from a positive weak correlation with SD to a negative weak correlation with LAS and CNR. This highlights the fact that those measures did not regularly assign the same level of connectivity within the locales; where only 3% of the locales were in the same quartile on all four measures, and 37 % were in the same quartile for three measures, while the rest 60% were in the same quartile for only two measures. These findings, of the former study, have provided an entry point for addressing the issue of the heterogeneity of the street pattern of the informal settlements on the agricultural land; which is to be investigated in this study.

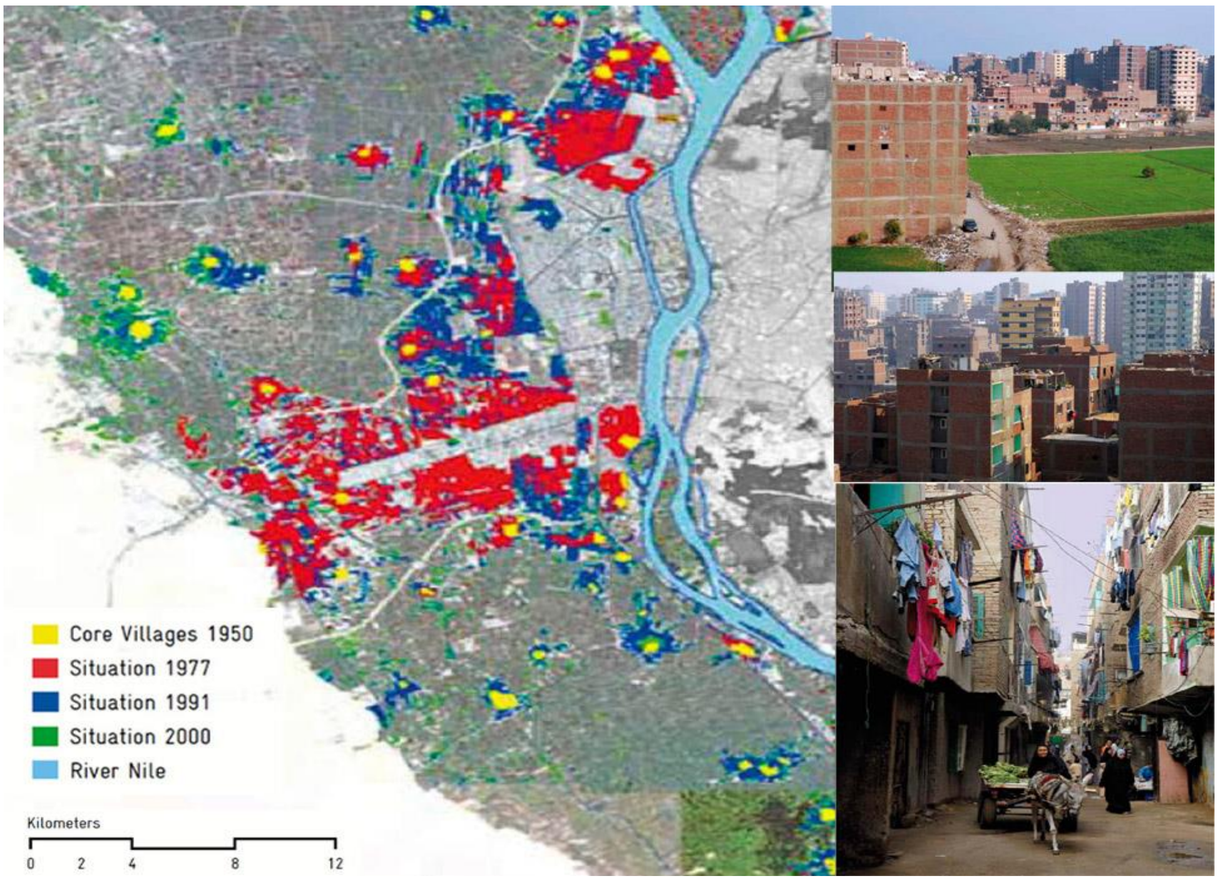


Figure 2. Informal Urbanization on Agricultural Lands in Giza city (Source: author after Kipper, 2009)

3.2. Methods

The aim of this study is to explore the heterogeneity of the street pattern of the informal settlements on agricultural lands at the city level. Accordingly, adopting a cross-sectional approach (Neuman, 2014), and depending on a quasi-random spatial sampling technique, 10-hectare locales (sample points) were selected (UN-Habitat, 2016); by excluding the planned locality units in Giza city, and randomly selecting the locales in the informal (unplanned) locality units; one sample per an average-sized locality unit (400 acre), and two samples for large locality units (≥ 900 acre), of total 38 locales [Figure 3a]. The boundary of each locale was determined by including the streets along the entire perimeter of all blocks within the locale, together with those clipped by the circular 10-hectar buffer [Figure 3b].

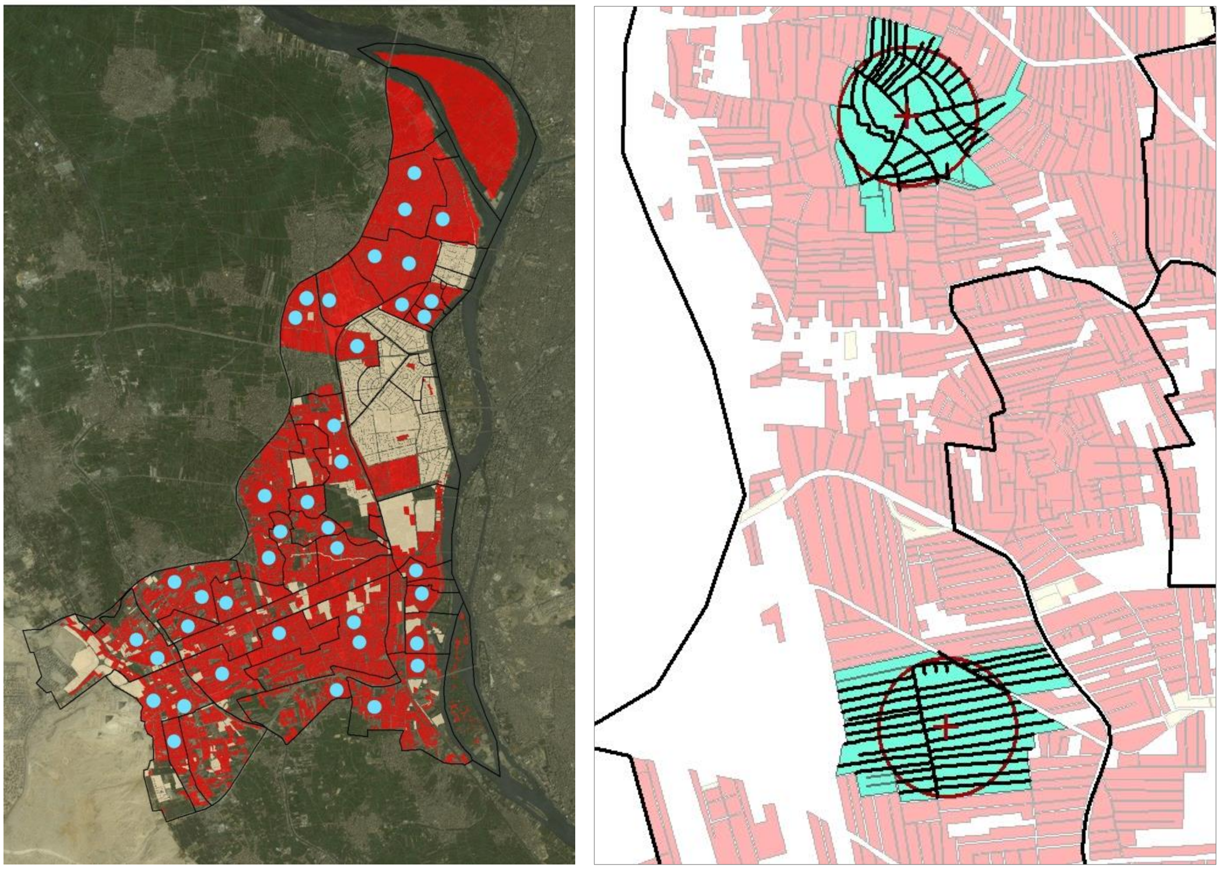


Figure 3a. The distribution of the 10-hectare locales representing Giza informal settlements

Figure 3b. The 2-sample locales of Saft Al-laban; a large locality unit in Giza

(Source: Author)

Depending on the GIS spatial analysis methods, and using ArcGIS program, data of street networks were extracted for each locale (LAS, SD, ID, CNR)[4] from the geospatial data of Giza Governorate developed during the preparation of the strategic plan of Giza (GOPP, 2011). Then by using Microsoft Excel and SPSS, cluster analysis; a multivariate exploratory technique, was employed (Hair et al.,2010), and data were statistically analyzed to fulfill the aim of the research.

[4] This data, initially computed in the previous study (Elfouly, 2017) was deployed for further analysis, in order to explore the street network heterogeneity and, hence, reach cumulative findings.

4. Results

As being normally distributed a prerequisite for any clustering analysis (Hair et al., 2010), the dispersion of data for the street network features has been tested; based on a Shapiro-Wilk's test ($p>0.05$), and a visual inspection of their histograms [Figure 4], normal Q-Q plots, and box plots, it has been found that data was approximately normally distributed: with a skewness of 0.648 (SE= 0.383) and a kurtosis of -0.043 (SE= 0.750) for LAS measure; and a skewness of 0.006 (SE= 0.383) and a kurtosis of 0.326 (SE= 0.750) for SD measure; and a skewness of 0.185 (SE=0.383) and a kurtosis of -0.714 (SE= 0.750) for ID measure; and a skewness of -0.091 (SE=0.383) and a kurtosis of -1.223 (SE= 0.750) for CNR measure.

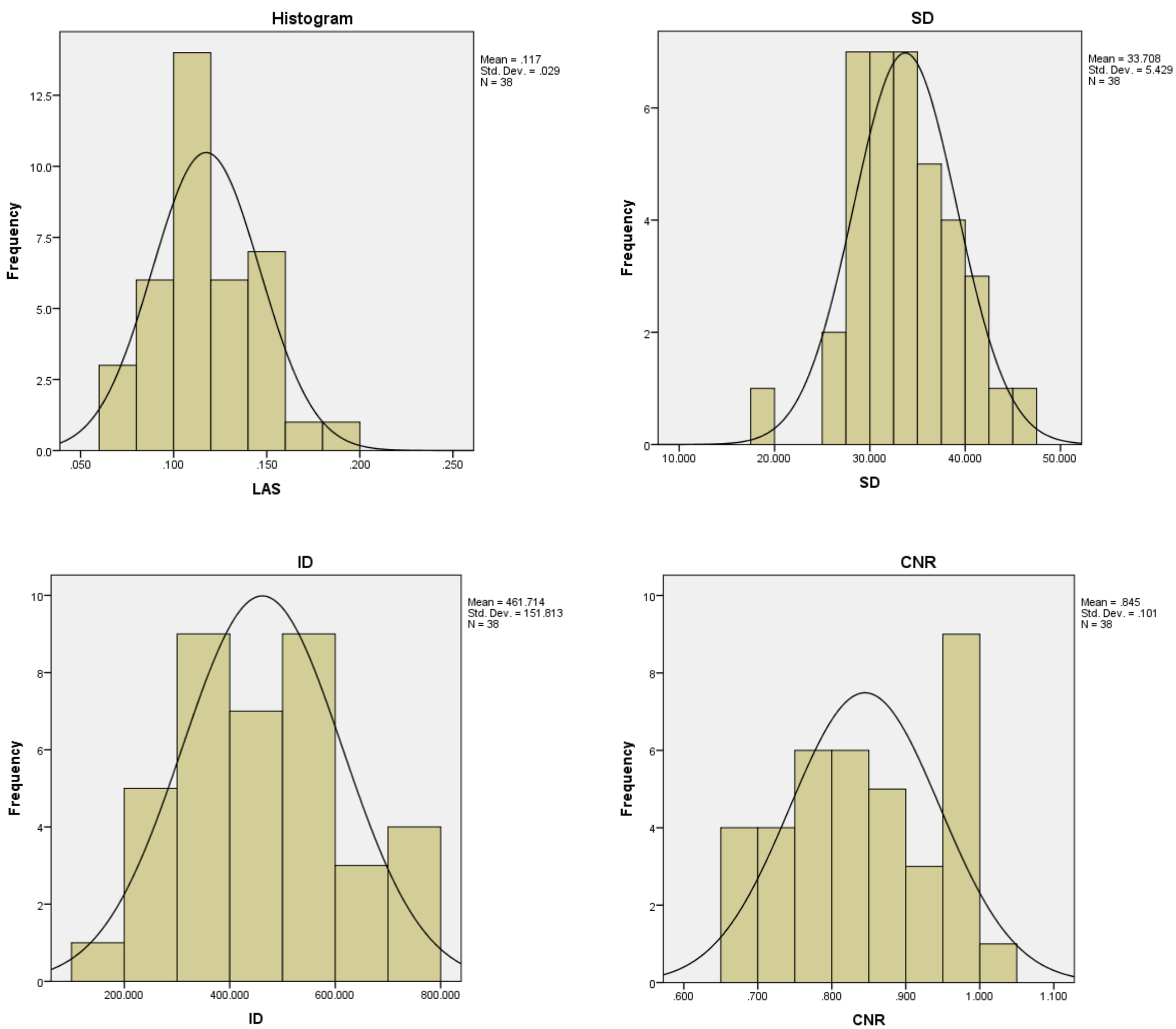


Figure 4. Distribution of the data of the street network features (LAS, SD, ID, CNR) (Source: Author)

Applying a simple hierarchical clustering method on the data of the street network features (LAS, SD, ID, CNR), the locales were arranged in clusters, and a dendrogram was obtained. At an intermediate level, four main clusters were identified in which street patterns were best represented [Figure 5].

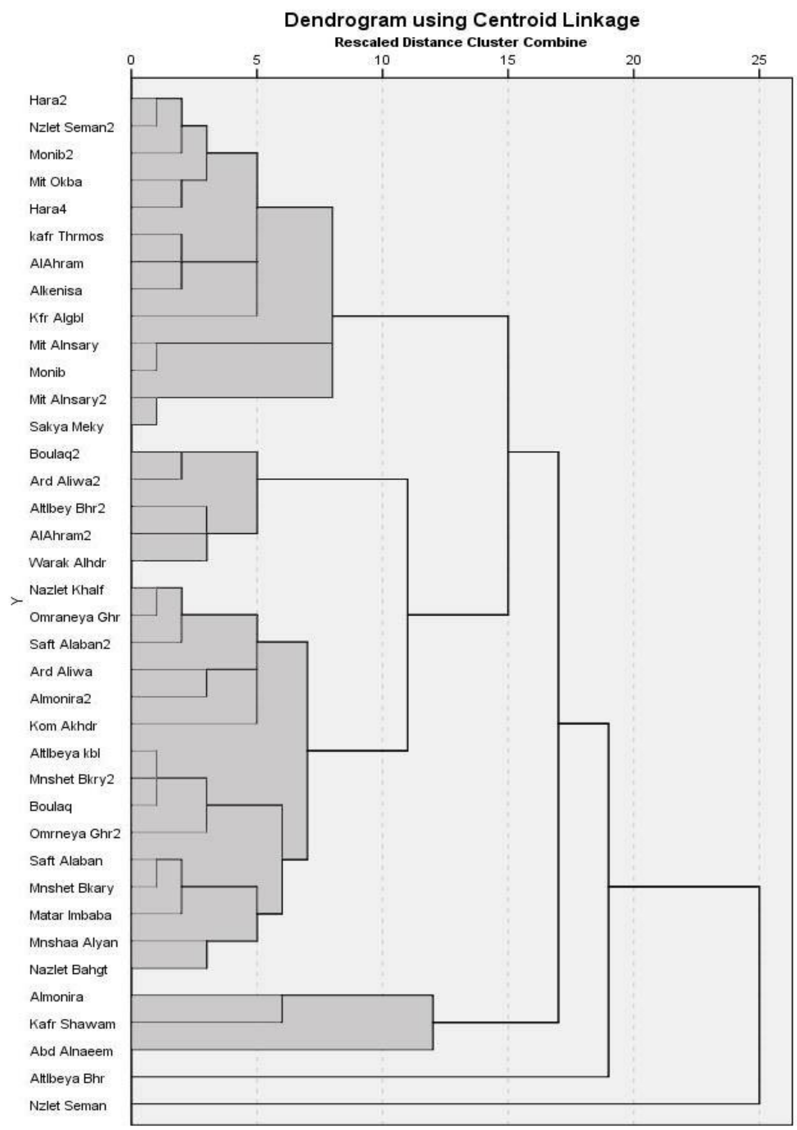


Figure 5. The dendrogram of a hierarchical cluster analysis (Source: Author)

After excluding the outliers (n=2), the resulting clusters showed high internal homogeneity (within cluster), and high external heterogeneity (between-cluster), where the main street features of each cluster could be recognized as follows [Figure 6]:

- Cluster (1) represents locales (n=13) of relatively high values regarding street and intersection densities (SD, ID), and at the same time, of relatively low values regarding the street area and the connected node ratios (LAS, CNR).
- Cluster (2) represents locales (n=5) of relatively low values regarding all street network features.
- Cluster (3) represents locales (n=15) of relatively low values regarding street and intersection densities (SD, ID), and at the same time, of relatively high values regarding the street area and the connected node ratios (LAS, CNR).
- Cluster (4) represents locales (n=3) of relatively high values regarding all street network features.

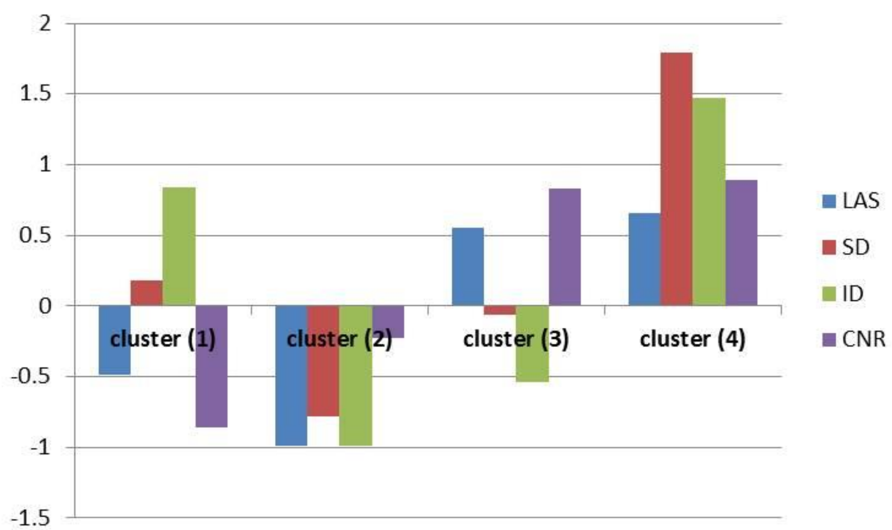


Figure 6. Clusters characteristics according to the street network features (Source: Author)

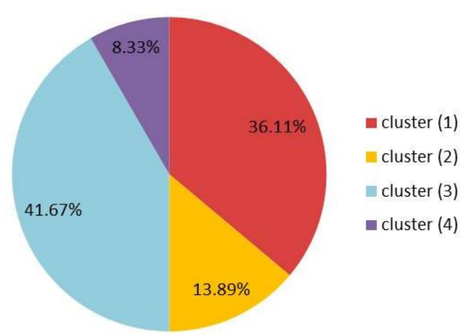


Figure 7. The frequency of the cluster groups (Source: Author)

As shown in [Figure 7], it has been found that the most frequent cluster group is no.3 (41.67 %), followed by cluster no.1 (36.11%), then cluster no.2 (13.89%) and, finally, cluster no.4 (8.33%) with the least frequency compared to the other clusters.

Moreover, by analyzing the satellite images of Giza city (core villages 1950-1977-1991-2000) and sorting the locales according to their initial proliferation within these images, it has been found that there is a significant correlation between the resulting cluster groups of the informal settlements (according to their street network pattern) and their initial proliferation (r=0.6, $p < 0.01$) [Figure 7].

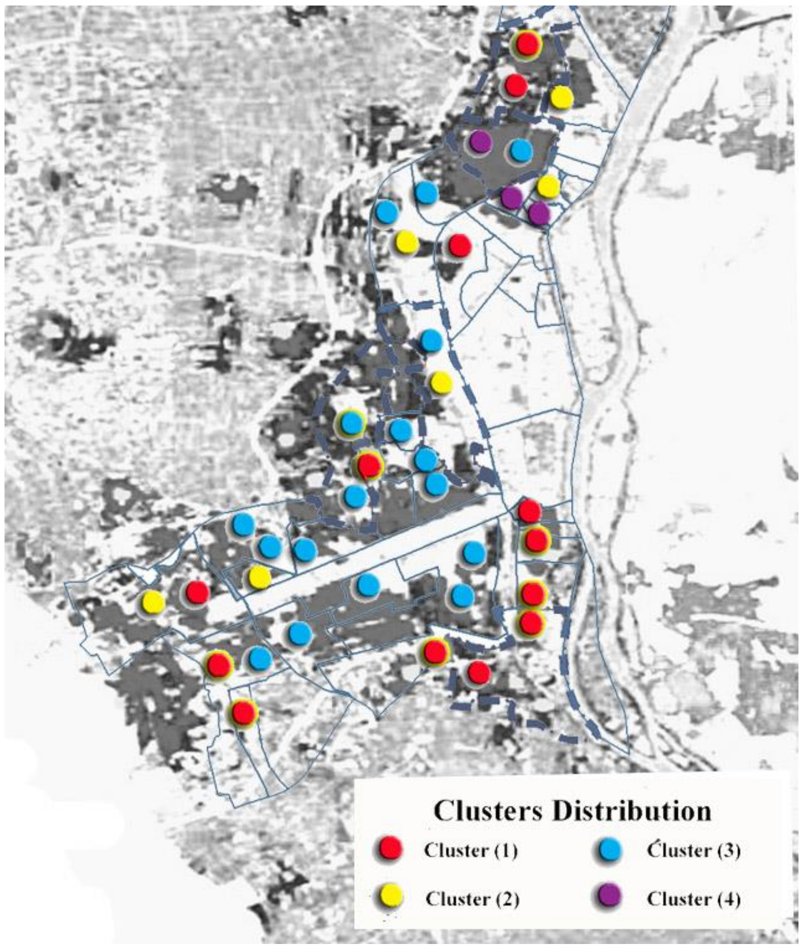


Figure 7. The distribution of the four main clusters of the street network within Giza informal settlements (Source: Author)

5. Discussion and conclusion

This study is an attempt to explore and quantify the heterogeneity of the street pattern of informal settlements on the agricultural lands at the city-level. Although being widely perceived as a distinguished prototype, with a cohesive street pattern, a previous study has highlighted an inconsistency within the main features of the street network of such settlements (LAS, SD, ID, CNR). Accordingly, the aim of this study was mainly to investigate this inconsistency quantitatively. Comparing the previous qualitative studies with the main findings of this quantitative study; it has been found that the former perception of the informal settlements on agricultural lands as a typology of a homogeneous street pattern is inaccurate and that it comprises much more complexity than just being of rectangular-shaped blocks and narrow straight streets: the former qualitative description of such typology [Figure 8].

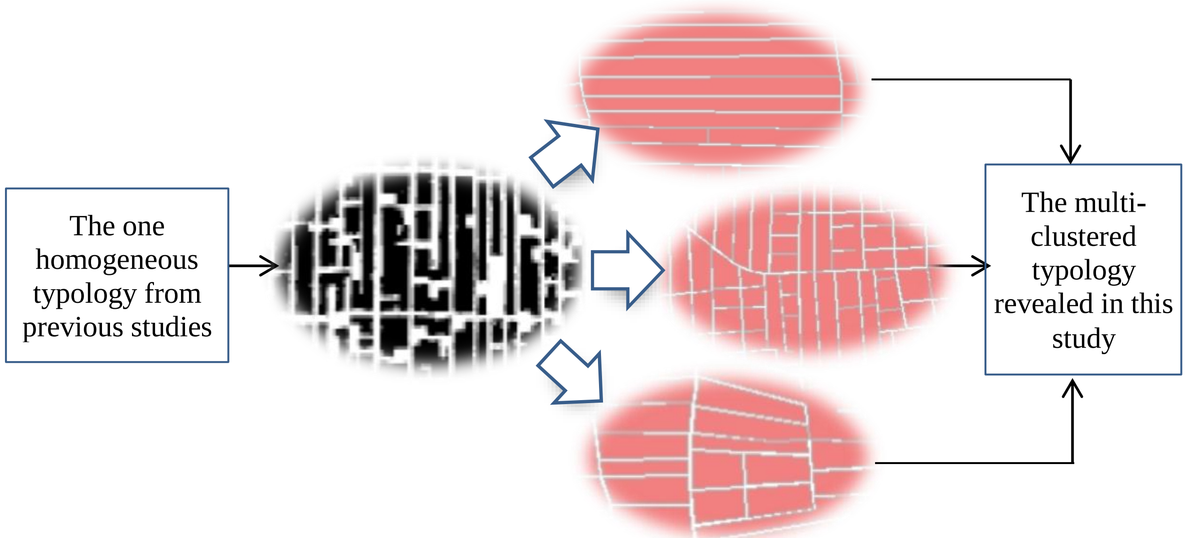
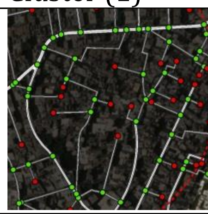
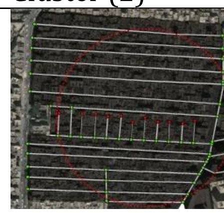
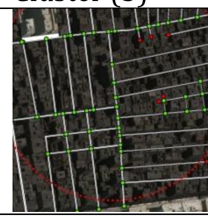
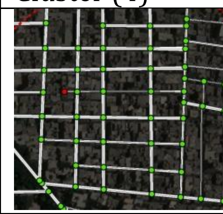


Figure 8. From one homogeneous to multi-clustered typology of the informal settlements on agricultural lands (Source: Author)

As per the hierarchical cluster analysis conducted in this study, and based on the similarities and differences of the main features of the street network within those settlements; four distinguished clusters were identified: one representing the street pattern of the core villages, and the other three clusters representing the street patterns originally shaped by the agricultural land plots and the irrigation networks [Table 1]. These clusters could be considered as the preliminary sub-groups of the typology of the informal settlements on the agricultural lands.

Cluster (1) represents the narrow organic street pattern of the core villages with numerous dead-ends (CNR= 0.75), 10% as an average value of LAS, and relatively high values of SD and ID (35 km/km^2, and 590 int/km^2 successively). Whereas the other three clusters represent the narrow straight street patterns, with fewer dead-ends, evolved from the irrigation networks; those three clusters reveal internal differences: cluster (2) represents the longest block length (210 m), and at the same time has the least values of LAS, SD, and ID (8%, 29 km/km^2, and 310 int/km^2 successively). Meanwhile, cluster (4) represents the shortest block length (80m), and relatively has the highest values of LAS, SD, and ID (14%, 44 km/km^2, and 685 int/km^2 successively). However, the main prevailing street pattern is represented in cluster (3) where the average block length is 170m, and the average values of LAS, SD, and ID are 13%, 33 km/km^2, and 380 int/km^2 successively.

Table 1. The main features of the sub-groups of the prototype of the informal settlements on agricultural lands

	Cluster (1)	Cluster (2)	Cluster (3)	Cluster (4)
				
Percentage of land allocated to Streets	10%	8%	13%	14%
Streets length	35 km/km^2	29 km/km^2	33 km/km^2	44 km/km^2
Intersection Density	590 int/ km^2	310 int/ km^2	380 int/ km^2	685 int/ km^2
Connected Nodes Ratio	0.75	0.82	0.92	0.93
Average Street width	3 m	2.9 m	4 m	3.2 m
Average block length	125 m	210 m	170 m	80 m
Average block size	3180 m^2	5000 m^2	4000 m^2	1700 m^2

Moreover, it has been noted that these resulting clusters are significantly correlated with the initial proliferation and development phases of the informal settlements (r=0.6, p < 0.01); as cluster (1) mainly represents the core villages detected in 1950, and cluster (4) mainly represents settlements initially detected in 1977. However, both cluster (2) and (3) represent settlements from different proliferation phases. In this respect, the proliferation process could be considered as a factor, among other factors, which influences the final layout of the street network of informal settlements on agricultural lands. However, the definite impact of the informal urbanization and the proliferation processes on the street layout needs further research.

Generally, informal settlements are the manifestation of multi-dimensional factors, and of extremely complicated urban morphologies, that a representation of the schematic street patterns could hardly capture all their complexities; a limitation of the evolved clusters. Yet, by exploring their street heterogeneity, and classifying them into distinguished clusters (sub-groups), this study is considered as an encouraging step towards re-evaluating the stereotypes of the informal settlements and deepening our understanding in a systematic and quantitative way. In this respect, the resulting clusters obtained in this study should be seen as a preliminary classification of informal settlements on agricultural lands. However, depending only on the main features of the street network, a further investigation is needed; where those primary clusters could be more developed by analyzing and integrating the other dimensions of the urban morphology (the urban form, building types, frontages, spatial activities …) to, ultimately, establish a multi-layered classification of informal settlements on agricultural lands; the most prevailing typology within the Egyptian context.

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