**The Impact of Urban Sprawl on the Agriculture Lands in Greater Cairo**

# Abstract

Urban sprawl is the expansion over the limited fertile land. Urban sprawl stresses the agricultural resources and in return, influences food security.This study explores the influences of urban sprawl on the agricultural lands in Egypt through a case study in Greater Cairo, namely Giza governorate (Tersa district). It aims to develop a framework that links urban sprawl with its impact on agricultural activities. The study is carried out throughout qualitative and quantitative field study as well as analyzing irrigation water samples to evaluate irrigation water quality. The research affirms that urban sprawl led to losing about 19 percent of Tersa’s fertile agricultural lands between 2007 and 2017. Farmers working in the remaining fragmented agricultural lands face many challenges in traditional farming practices. As a result of polluted irrigation water, the remaining agricultural lands are losing their soil fertility and crop type has changed from edible vegetable crops to fodder crops.

Keywords: urban sprawl; fragmented agricultural lands

# Introduction

The world faces an unprecedented rate of urbanization nowadays. More than 50 percent of the world’s population lives in high densely populated areas with different urbanization levels (UNDESA, 2014). Though urbanization is taking place in both developed and developing countries, urbanization rate occurs at a rapid pace in developing countries and causes significant pressure on the limited available resources in these countries (UN-WWAP, 2015).

Agricultural lands on the outskirts of urban communities play a vital role as being ecosystem services providers. They supply nearby urban regions with clean air, water, soil, and food. Additionally, they act as buffer areas that lessen the negative impacts of the urban systems on the environment. They are considered transitional regions between natural habitats of rural areas and urban landscapes. (Doygun, 2009).

Urban sprawl is linked to the shrinkage of the adjacent surrounding agricultural lands (Shalaby, Ali, & Gad, 2012). Encroachments over agricultural lands is usually a profit-oriented process accompanied by ineffective land use (Du, Shi, & Rompaey, 2013). This is mainly due to the low revenues of farming compared to the high profits gained from building activities. Besides, population increase plays a significant role in speeding the process of urban sprawl over the agricultural lands (Khamis, Ali, & Hahn, 2015; Soares, Ramos, & Fonseca, 2011). In their global projections of urban expansion leading to loss of agricultural lands through comparing the cropland and crop production loss, Bren d’Amour and colleagues (2016) showed that Egypt, in particular, Greater Cairo Metropolitan Region (GCMR) is among the most threatened areas with high probability (>75 percent) of being converted into urban areas by 2030 (Fig. 1 and 2).

According to the results in Bren d’Amour et al. (2016) study, urban growth will lead to 1.8 up to 2.4 percent loss of the global productive agricultural lands by 2030. About 80 percent of these agricultural lands, prone to sprawl, concentrate in Asia and Africa and have almost double the productivity of other global lands (Arunpandiyan, Aarthi, Vidyalakshmi, Rj, & Devi, 2015; Kharel, 2010; Uttara, Bhuvandas, & Aggarwal, 2012). Thus, urban sprawl is a significant threat for agricultural lands; which in the long run, influences the ability to produce food and fibers leading to food security problems. Furthermore, because of the loss of many peripheral agricultural lands for sprawl development, the remaining lands work intensively to produce food and sustain the needs of the large urban residents (Eko, 2012).

Population growth and rapid urbanization, especially in developing countries, are expected to increase the stress on agricultural lands’ productivity and increase the difficulties that farmers face in agricultural practices (Gumma, Mohammad, Nedumaran, Whitbread, & Lagerkvist, 2017). According to Larson, Findeis & Smith (2001), there are indirect influences on the remaining agricultural lands and agricultural activities besides the direct impact of sprawl over agricultural lands in the form of loss of fertile lands. Urban sprawl makes it more expensive and hard to cultivate in the traditional ways.

Farmers face many problems such as increased pressure on available water resources, unbearable spillover from the adjacent urban area, and crop yields deterioration. In some regions, they may suffer from lack of support of machinery dealers and agricultural inputs suppliers and the increased taxation accompanied by the urban lifestyle. Another significant indirect effect is the increase in agricultural costs, which decreases the profitability of sustaining agricultural production (Larson, Findeis, & Smith, 2001).

## Urban sprawl in Egypt

Egypt’s population inhabits only 5 percent of its land area, with about 95 percent of its 92 million population residing on Nile Delta (“The World Factbook — Central Intelligence Agency,” n.d.). In 2014, Egypt was ranked the tenth country on the global urban agglomerations, with more than 55 percent of its population residing in rural areas (CAPMAS, 2017).

Part of the most productive agricultural land in the world is located in Egypt’s Nile Delta (Fig. 3.). Almost 60 percent of these lands are cultivated (FAO, 2011). Agriculture is a leading contributor to the Egyptian economic growth, accounting for nearly 15 percent of the country’s GDP. About 55 percent of the population in Egypt relies on the agricultural sector for their livelihood. In 2010, agriculture generated about 36 percent of Egypt’s total employment (Karajeh et al., 2011). In 2012, Egypt’s total agricultural lands were estimated to be 37503 x 106 m2 (8.92 x 106 Feddans), representing about 3.7 percent of Egypt’s total land area (Hereher, 2013), besides the contribution to Egypt’s total employment dropped into 32 percent. Between 1952 and 2002, Egypt has lost about 294 x 107 m2 of agricultural lands due to urbanization (Alfiky, Kaule, & Salheen, 2012). Moreover, the political instability during the three years succeeding in the revolution of January 25th, 2011 led to considerable encroachments upon agricultural lands. These infringements over the agriculture lands in the Nile Delta were estimated to be about 215 x 106 m2 up to 63 x 107 m2 (Gouda, Hosseini, & Masoumi, 2016). Sims, D. (2012) asserted that the rate of unlicensed informal building activities after January 25th, 2011 has risen by 2.5 times than the rate before January’s revolution.

The highest rate of these encroachments was concentrated in Greater Cairo and the Nile Delta. GCMR is one of the largest metropolitan cities in Africa (18th largest metropolitan area globally), it witnessed unmatched urban sprawl rate concentrated over the fertile agriculture lands (“Egypt-Urban Issues – UN-Habitat,” n.d.). Khamis, Ali, & Hahn (2015) highlighted in their study that nearly all of Cairo’s urban expansion took place on fertile and productive agricultural lands.

Despite the rapid sprawled process in the area of GCMR, no studies have attempted to develop a framework that links urban sprawl with its impact on agricultural activities within the Egyptian context. The current study attempts to develop this framework by exploring the influences of urban sprawl on agricultural activities between 2007 and 2017 a small county representing Giza governorate (Tersa district) in Egypt.

# Method of Assessing Urban Sprawl

This study attempts to explore the links between urban sprawl and agricultural activities through assessing the changes in the different dimensions of farming activities, including crop type, agricultural land’s productivity, and local and national food security. The study relied mainly on conducting a field study in the fragmented agricultural lands of the selected study area. The fieldwork included interviewing 30 farmers in their farmlands, and 50 residents in areas of different urbanization stage such as residents from existing urban areas before 2007, and residents in areas that were agricultural lands and wholly transformed into urban areas.

The questionnaire used in the farmers’ interviews covered the various dimensions of the agricultural process, which urban sprawl may have influenced according to the literature review. These dimensions included land ownership, irrigation, crop type, laborers, fertilizers, machinery, livestock, and productivity. Changes caused by urban sprawl were assessed through a comparison between the current status of the defined dimensions (2017) and its retrospective status in 2007. The questionnaire included questions on work duration in farming activity, the area of their owned or rented agriculture land, type of cultivated crops, land productivity, method of irrigation, number of other farm laborers working with them, type and amount of the consumed fertilizers, the available livestock and machinery, the effect of urban sprawl (surrounding buildings) on their traditional farming practices and the steps they followed in order to adapt to or deal with these influences. Besides, a sample from the residents in the surrounding buildings was qualitatively interviewed regarding their reasons to move to their current residence over agricultural land in Tersa and the availability and accessibility to infrastructural services, including water and sewage system.

Parallel to this, in-depth interviews were conducted with governmental representatives from the Ministry of Agriculture and Land Reclamation and the local governmental unit of Tersa to collect official data about the history of agricultural activity in Tersa since 2007. Water samples were collected from the water canal and three different underground water pumps of average 17-meter depth. Water was sampled according to standards and methodologies instructed in EPA (Decker, 2013). Samples were sent to Soil, Water & Environment Research Institute (SWERI) in the Agricultural Research Centre for chemical analysis according to APHA standard methods and Walkley-Black1986 method, whereas the bacteriological analysis was done according to Difco manual 1985. Each sample was analyzed twice to ensure repeatability and reproducibility. Results consequently are compared with the FAO, WHO irrigation guidelines, the Egyptian law for protecting Nile River and water surfaces (Law 48/82) and the Egyptian code for reusing wastewater (ECP 501/2015).

# Study Area

GIS and remote sensing data for the lost agricultural lands in Greater Cairo Metropolitan Region (GCMR) were assessed. This assessment revealed that Giza governorate was the governorate that experienced the most significant percentage of lost agricultural land among GCMR’s three governorates. This result confirmed (Osman, Divigalpitiya, & Arima, 2016) the conclusion that Giza faced severe corrosion of agricultural lands and environmental problems.

Markaz Al-Jizah is a local administrative unit subdivided from Giza governorate. It was the district that suffered the most significant percentage of lost agricultural land in Giza as shown in Table 1. Fig. 4 presents the land cover of Markaz Al-Jizah in 2007 while fig. 5 presents its land cover in 2017 showing the influences of sprawl on the available agricultural lands (Google Earth, 2018). Markaz Al-Jizah is subdivided into districts and administrative units that all faced different percentages of urban sprawl (Table 2). Some districts were excluded from selection for the research study due to their small total surface areas such as Tamouh, Bany Youssef, Shabramnt, and Mit Shamas. Secondary data collected showed social and political preferences in some districts, which accordingly were excluded from the selection process. For example, some parliament members live in Abou Al-Nomros; accordingly, the district undergoes special treatment in terms of the provided services.

Tersa is a relatively small county located at the north of Markaz Al-Jizaha between latitude 29°58'50"N & 29°57'00"N and longitude 31°10'50"E & 31°13'10"E. Tersa’s total surface area is 651 x 104 m2, its population increased from 21324 in 2007 to 23644 in 2015 (CAPMAS, 2018). Tersa, was selected for the study due to the large relative percent of fertile agricultural land lost under urban sprawl compared to its total surface representing urban sprawl in Giza. Tersa lost about 127 x 104 m2 of its agricultural land area under urban sprawl. These lost arable lands were mainly contributing to local food production.

Fig. 6 and Fig 7 present Google Earth images of Tersa in 2007 and 2017, where the green line represents Tersa’s outer borders. In fig. 7, the pre-existing urban areas that were already there in 2007 are enclosed in yellow borders; accordingly, the remaining urban cover represents the areas where sprawl takes place over (Google Earth, 2018).

Despite the rapid pace transformation in the land cover, Tersa is still predominately a rural village. Transportation to Tersa is accessible through public transportation; however, the inner transportation within Tersa is challenging and relatively costly. El-Munib metro station is the nearest station to reach Tersa; it is almost 6900 meters between El-Munib and Tersa’s main street “Tersa El-Omomi” (Fig. 8). Microbus or tuk-tuk can be picked up to reach Tersa El-Omomi. However, tuk-tuk is the only transportation method to go through the side and inner streets of Tersa.

Although tuk-tuk is available all the time in the main streets, it is hard to find one strolling in the inner areas due to the condition of the streets (narrow and unpaved roads). It is also not affordable for daily use, especially to reach inner areas such as El-Konayesah; almost 6100 meters from El-Munib and 4200 meters from Tersa El-Omomi. Tuk-tuk fare costs EGP 20-25 from Tersa El-Omomi to El-Konayesah, which is considered expensive to be used daily by all family members. Magdy Sayed, an employee, mentioned that he walks daily for 40 to 50 minutes from his house near El-Konayesah to El-Munib station then he picks up a microbus or subway to his work. The further areas from Tersa El-Omomi, the less accessible and less affordable to pick up a tuk-tuk.

The closer residential areas to Tersa El-Omomi, the easier and more accessible to means of transportation. Fig. 9 presents the residents responses about the easiness of transportation in Tersa through 2007 and 2017. Most of the surveyed households stated that the mobility within Tersa is currently difficult in terms of accessibility and affordability, especially the residents of the inner sprawled areas. However, the situation in 2007 was harder in terms of availability. About 65 percent of the surveyed households who reported the difficulty the transportation in 2007, referred this to the absence of any means of transportation within Tersa and that they used to walk or use livestock as means of transportation.

Fig. 10 shows fragmented agricultural lands (5131 m2) located in the North and North East of Tersa where part of the research study was conducted (Google Earth, 2018). These lands are confined within constructions and buildings and become isolated from other agricultural lands due to urban sprawl. Buildings surrounding these agricultural pockets were not existing in 2007. Residents of these buildings included farmers and non-farmers who moved recently to this area (5 to 10 years). About 66 percent of the sprawled residents have initially been living in Tersa itself in the pre-existing urban areas. Low prices of the agricultural lands and low renting prices in the inner parts of Tersa compared to higher renting prices in Tersa Al-Omomi is the main reason that led to sprawling over the inner agricultural lands in Tersa. The remaining one-third of the sprawled residents came from other parts of Giza governorate, Upper Egypt and other urban governorates seeking job opportunities or because of marriage. There is apparent tension between farmers and non-farmers dwellers because of the residents’ practices that significantly influence the farming activity. Fig. 11 presents the complete transformation of one of the agricultural areas (17477 m2) in Tersa that faced illegal encroachments between 2007 and 2017. Roads are informal, muddy, and unpaved. All buildings are in red brick with very primitive infrastructure services. More than 80 percent of the residents rely on underground water pumps for water access and use inferior quality septic tanks.

# Results of the Field Study

The General Manager of the land improvement department in the Ministry of Agriculture and Land Reclamation of Egypt reported through the in-depth interview that: “The nature of the farming activity in Tersa has transformed due to urban sprawl and the resulted pollution.” The total agricultural land in Tersa and El-Munib was 6,749,400 m2 in 2004. Abu Al-Nomros water canal feeds the main water stream in Tersa “Tersa El-Omomia” water canal, which subdivides into three branches. There were two drainages in Tersa, which are: Bukbashy on the eastern side and El-Konayesah on the western side. The salinity and alkalinity of Tersa’s soil were appropriate for producing a wide variety of vegetation such as wheat, maize, vegetables, fruits, and forage. However, the water and soil quality deteriorated through the successive years.

The following subsections present the results of the field study. It starts with the results of the water quality analysis as water is the most crucial element in the agricultural process, followed by a discussion of other essential agricultural elements, namely ownership, laborers, agricultural cooperation organization, crop type, and livestock.

## Water quality

The practices of the sprawled urban residents and the poor quality of infrastructure (sewage system and septic tanks) profoundly affected the quality of water resources in Tersa, leading to contaminating drinking water and irrigation water resources. Residents throwing garbage in the water canal, also, the failure of the sewage system led to the contamination of the water canal and stressed the available underground water. Complaints of the surveyed households in different locations in Tersa included water mixed with sewage, impurities, smelly, abnormal color, and sour taste. Almost all responses confirmed that the water is mixed with sewage and impurities. Even households who rely on underground water pumps face the same problems. Mohamed Abu El-Mwaheb, a resident, pointed out that most of the residence in Tersa suffer from renal failure and hepatic disease due to the polluted water. All these problems increased significantly in 2017 compared to responses about 2007.

Water and irrigation system is a primary element in the agricultural process. Availability, accessibility, and the quality of the water resource are essential parameters to achieve the targeted crop yield. Most of the previous studies investigating causes of urban sprawl indicated that the lack of proper sewer systems in the settlements built due to sprawl is the main reason behind deteriorating the water quality (Al-Kharabsheh & Ta’any, 2003).

Other behaviors contributed to the degradation of water quality, such as overuse of pesticides and throwing dead animals and garbage in the water canal. Many farmers experienced the blockage of irrigation machinery by garbage while pulling up water from the water canal. As a result of the previously mentioned reasons, farmers had to change the source of irrigation. Ten years ago, all farmers used to irrigate their farmlands from Tersa Al-Omomia water canal and its branches; while currently, all surveyed farmers use underground water pumps to irrigate their lands. Table 3 presents the analysis results of the collected water samples from the water canal and underground water pumps (average depth: 17 m) compared to the Food and Agriculture Organization (FAO) irrigation water quality guidelines and the Egyptian law 48/82 for protecting the Nile River.

Plants need essential elements to support healthy growth and other different vital processes such as photosynthetic process and osmotic adjustments; however, the presence of these elements in higher concentration levels leads to growth disturbance, toxicity and affects the crop yield. Higher levels of sulfates, ammonia, chemical oxygen demand (COD), biological oxygen demand (BOD), and bacteriological strains are a clear indication of water contamination from the sewage system.

* All water samples have a high concentration of total dissolved solids (TDS) exceeding the Egyptian law 48/82; also electric conductivity (EC) of all samples shows slightly to moderate use restriction according to FAO guidelines. These results indicate a slightly high salinity level that may consequently affect the soil salinity. Accumulation of salts in the plant roots leads to a reduction of the crop yield; the salinity problem can be solved through leaching below the root depth
* Sulfate concentrations exceed the Egyptian law limit in all water samples. The high concentration of sulfates affects the soil salinity, decreases the plant and toxic to cattle
* All water samples have a slightly high concentration of chloride (Cl-), which lies in the moderate usage restriction section according to the FAO guideline. High concentrations of chloride lead to chloride toxicity. Chloride moves through the transpiration stream and then accumulated in the crop leaves. If chloride exceeds the tolerance limit of the crop, it causes injuries such as crop burns, dryness of leaf tissue and leads to yield loss.
* The concentration of magnesium exceeds the limits of the FAO guideline in all water samples except pump 1. High concentrations of magnesium in water affect the soil infiltration rate. Magnesium cations act slightly like calcium; whereas magnesium is absorbed by the soil with a higher degree than sodium but slightly less than calcium. Accordingly, sodium adsorption rate (SAR) may be damageable in water with Ca/Mg ratio of less than 1 (magnesium dominated water) (Rahman & Rowell, 1979).
* All water samples contain manganese concentration (Mn) exceeds both: FAO guidelines and Egyptian law 48/82, which increases the toxicity level of water and makes it unsuitable for long-term irrigation. Accumulation of heavy metals is hard to be removed. It leads to damage to vegetation tissue and these, in turn, become severely harmful to humans and animals who feed on these crops.
* The concentration of ammonia ions (NH3-) in the water stream is noticeably very high, exceeding both: the FAO guidelines and the Egyptian law 48/82; ammonia concentration of the three underground water exceeds the Egyptian law limits. High concentrations of ammonia are a clear indication of water contamination with sewage wastewater. Whereas nitrate (NO3-) concentration lies in the slight to moderate restriction use range of the FAO guideline, and all samples exceed the Egyptian law limits. Both ammonia and nitrates contribute to the total nitrogen concentration. Nitrogen is a naturally needed nutrient for stimulating vegetation growth; however, high concentrations of nitrogen in water will act like excess use of fertilizers. Excess of nitrogen will lead to overstimulation growth, poor quality crops, and delayed maturity.
* Naturally, COD, BOD, Coliform bacteria, Salmonella, and Shigella bacteria are not detected in water used for irrigation. The highly detected level of COD and bacterial forms in the canal is another indication of the contamination of water with sewage, which makes the water source is unsuitable for irrigation. Due to this contamination, the water canal of Tersa goes under the category wastewater. According to the World Health Organization (WHO) and the Egyptian regulation; the maximum concentration for Fecal Coliform in water for agricultural uses is 1000 cfu/100 ml. The bacteriological analysis of the water stream sample shows high risk if being used, not only for the cultivated crops but also for the workers and farmers exposed to this water. In this case, the water should undergo treatment levels to comply with the Egyptian code (ECP 501/2015) before reusing water in irrigation. The Egyptian code indicates four levels of treatment with different efficiencies to reach the minimum accepted physical, chemical, and biological characteristics of water. The code also determines the proper uses for treated wastewater according to the treatment level. The treatment levels mentioned in the code are A, B, C and D, where the treatment A-level is the highest efficient involving the treatment of raw wastewater in the treatment station besides implementing additional treatment operations in the agricultural site while D-level is limited to the primary treatment processes including strainers, sand removal tanks, and oil removal tanks.

The code prohibits using untreated municipal wastewater in any agricultural purposes. Moreover, it is prohibited to reuse treated municipal wastewater –regardless of the level of treatment- in cultivating raw eaten vegetables or export crops, it is prohibited to use D- level treated municipal wastewater in the cultivation of any vegetable crops, fruit crops, field crops or medicinal plant crops. Additionally, it is prohibited to use B, C, and D- level treated municipal wastewater in irrigating green surfaces of educational institutes, public and private parks.

## Cultivated land and land ownership

Based on the GIS and remote sensing images in 2018, the estimate of agricultural land loss in Tersa under urban sprawl between 2007 and 2017 is 19.43 percent. The expansion over peripheral agrarian lands decreased their spatial extent and fragmented the land leading to reduced average patch sizes (Fig. 12). Nineteen farmers of the thirty surveyed farmers currently cultivate smaller area than the area they used to cultivate ten years ago (Table 4). Eleven lessees cultivate smaller area mainly because their landowners sold part of the agricultural land for urban uses, or the rising renting costs significantly.

## Laborers

The Demand for farming workers varies with the agricultural seasons. Workloads and working hours are the highest during planting and harvesting seasons. However, urban sprawl over the agricultural lands reduced the need for farm workers and pushed many workers to leave the farming activity. Most of the surveyed farmers currently cultivate their farmlands by themselves and their families. About 21 farmers (70 percent) stated that they do not need more labor force with them due to the small farmland area while the remaining nine mentioned that they need more labor force (Fig. 13), yet, they do not find farming workers easily as most of them abandon agricultural practices for other jobs mainly related to construction work. A landowner indicated that “Agricultural workers leave farming activities and go for construction works, and this scarcity of labor resulted in raising the wages of the available worker.” He added that: “workers were very flexible ten years ago; they used to work in the farmland in return to any amount of money for the full day.” The average farming workers’ wage in 2007 was EGP/day 30-35 from dawn to dusk (about 12 working hours). Considering the rise of living costs besides the condition of farming workers opting out of farming practices, the wage of labors who still working in the agricultural activities in Tersa reaches EGP/day 100 from 8:00 to 13:00 only (6 working hours).

## Agricultural cooperative organization

The agricultural cooperative organization plays a vital role in empowering and supporting farmers by supplying them with essential inputs for agricultural production. The cooperatives also provide a wide range of services that sustain the farming activity, including improved market accessibility, technologies, and required information. Notable reduction of the total agricultural area and the increased sprawling rate for urbanization led to marginalizing the role of agricultural cooperative in Tersa. The amount of the subsidies provided to farmers is defined based on the area of their agricultural land; however, these subsidies were noticeably reduced in 2017 in comparison to the amount provided for the same cultivated area in 2007. Regarding providing subsidized fertilizers; the agricultural cooperative currently does not cover the share of land lessees compared to the situation in 2007, where subsidized inputs were provided to both landowners and lessees. Additionally, the subsidies share of landowners is reduced compared to the amount they used to receive in 2007. Eight out of twelve (58 percent) landowners reported that the amount they receive is insufficient; five of them currently cultivate smaller area compared to the area they used to cultivate in 2007, and they still need to buy extra amounts of fertilizers due to the soil degradation (Fig. 14).

Changes in irrigation water quality have significantly affected the fertility of the soil. As a result, many farmers had to change fertilizer type through conversion into more effective chemical fertilizer instead of depending on livestock dung only. Others had to increase the quantity of fertilizers compared to the amount they used to consume for their land ten years ago, keeping in consideration that all of them cultivate the same or smaller area than before. Fig. 15 shows that all farmers are using chemical fertilizers such as nitrates and urea and 19 of the 30 farmers combine these chemical fertilizers with livestock dung.

Besides, the agricultural cooperative used to provide the farmers with the required machinery free of charges. The machinery included irrigation machines, plows, and tractors. Currently, all the surveyed farmers rent the needed automated machinery. Since the renting fees include the fuel needed for the machine, increased fuel prices affected the renting fees of machinery.

The surveyed farmers complained about the weakness of control and follow up on behalf of the agricultural cooperative association and the governmental authorities. Many landowners maintain the use of their land ownership documents to receive their share of the fertilizers, seed, or pesticides, and then they sell it in the black market even after they have sold their land or have constructed over it.

## Crop type

Based on the in-depth interviews conducted with local governmental authorities and quantitative surveys; the agricultural land in Tersa used to have a good quality of fertile soil suitable for cultivating many types of crops. Ten years ago, farmers used to cultivate different kinds of vegetables such as tomato, onions, cabbages, eggplant, zucchini, etc., fruit crops such as grapes, and mango and field crops such as wheat and maize. Farmers used to provide food and livestock production to their local area. Deterioration of water quality, reduced soil fertility and the presence of residents in the surrounding neighborhood of the agricultural lands led to a total shift in the agricultural products in Tersa. All farmers shifted into fodder crops such as alfalfa and sugar maize (Table 5). Water contaminated with sewage negatively influenced the soil quality, jeopardized its productive capacity and no more supported the healthy growth of vegetables.

Furthermore, sprawled neighbors harass farmers with vandalism, they steal and devastate crops. Farmers stated: “Children take off plants while playing, and we never plant maize or vegetable, surrounding residents will steal what we cultivate.” Only one of the surveyed farmers cultivate his enclosed 7 Kirat, equivalent to 1225 m2, owned land with a variety of vegetables for his family consumption using an underground water pump.

Farmers were asked about agricultural productivity in terms of profitability. No doubt that the profitability of vegetable crops is higher than the profitability of fodder crops in the long term. Though the profitability of fodder crops is also high due to its short cultivation cycle, farmers believe that agricultural productivity decreased compared to its level 10 years ago the recent increase of prices of the inputs of the agricultural process. This include high prices of seeds, fertilizers, fuel, machinery besides the decreased support provided to farmers of Tersa in the meantime.

## Livestock

Raising livestock is an integral agricultural activity and a considerable contributor to the development of rural areas. Livestock business usually reinforces the sustainability and consolidates the economic viability of farming systems. However, the development of livestock also lost the concerned authorities’ support. Through 2007, the governmental authority used to provide health insurance and free health care services for livestock, which no more takes place in 2017. Mutual tensions between farmers and non-farmers neighbors included complaints from sprawled urban residents about the odor and noise of livestock.

On the other hand, farmers complained about the surrounding residents harassing the animals, stealing them, or stealing their products. They also noticed a deterioration of livestock health and productivity, mainly due to the contaminated drinking water. As a result, the developing livestock sector in Tersa remained in a limited scale where the majority of farmers stated that they sell their livestock dairy production on a minimal scale within Tersa, whereas few reported that they only use it for family consumption.

# Discussion

Urban sprawl noticeably affected Tersa in different ways, where it has direct and indirect impacts on agricultural lands. Fig. 16 represents the proposed framework that attempts to link urban sprawl with agricultural activities on the bases of the results of the current case study of Tersa within the Egyptian context.

The framework classifies the impacts of urban sprawl in two categories

1. Direct impacts of urban sprawl, these include:

Encroachment over fertile agricultural lands where Tersa lost nearly 19 percent of its fertile agricultural land as indicated through the high-resolution remote sensing images and confirmed by the conducted field visits. This accordingly led to the formation of poorly served residential areas that were clearly observed through the poor quality of the available infrastructure services including poor quality of the constructed communal sewage systems, unmanaged disposal of the septic tanks and sewage failure problem leading to deteriorating the available water resources used for agricultural purposes.

1. The indirect impacts of urban sprawl are represented in the impacts influencing the remaining fragmented agricultural lands and the negative impacts on the farming practices
   * Farmers were forced to convert into using underground water for irrigation instead of relying on the water canal
   * The contaminated irrigation water forced farmers to change the cultivated crop type into fodder rather than cultivating edible crops that they used to cultivate ten years ago

* The presence of the residential buildings around the agricultural lands increased tension between farmers and the surrounding sprawled residents and formed another reason that pushed into crop type conversion. This tension was manifested in acts of vandalism, stealing crops and livestock, and throwing municipal wastes in the water canal
* Due to decreased in farming activity in Tersa; the governmental and institutional support, services and subsidies provided to farmers decreased significantly
  + Many farm-workers opt-outs of the farming activity to other off-farming jobs; accordingly the wages of the labor force increased
  + Alterations of the crop type reduced the contribution to fulfilling the local food needs within Tersa accordingly food prices increased

# Conclusion and Recommendations

Though urbanization nourishes the economy and contributes to the growth of countries, it can lead to pernicious consequences if not managed and controlled appropriately. This research aimed to study the impacts of urban sprawl on the fragmented agricultural lands in an administrative village named Tersa, representing the urban sprawl in Giza, Egypt. Despite the presence of enacted laws in Egypt that incriminate building on agricultural lands, there are no deterrent actions or controlling mechanisms to prevent such illegal activities, so looking at the bigger picture, Tersa’s case represents a small example being repeated on the macro-level all over GCMR and Delta. Accordingly, urban sprawl is a significant threat to national food security.

Additionally, the impacts of urban sprawl cut across the environmental, social, and economic pillars of sustainable development. Thus, urban sprawl influences progress towards sustainability. Controlling urban sprawl requires an integrated multidimensional strategy to achieve sustainable urbanization. On the macro-level, there is a significant need for accurate and scientifically based projections for urban growth. These projections allow the identification of the areas (districts or counties) at high risk for urban sprawl. This early deduction permits early interventions to manage and deal with the negative impact of urban sprawl.

For the particular case of Tersa, on the research level, it is recommended for future research projects to study and collect more water, soil and crop samples for chemical and bacteriological analysis, in order to track the pollution resulted from urban sprawl. Concerning water stream samples, it is advised to analyze the following parameters: E.Coli, Fecal Coliform, Salmonella and shigella due to high contamination with the sewage system.

A Sustainable action plan can be established to solve the negatively influenced system in Tersa and turn the situation over into a more sustainable community. 1) Examining and repairing the sewage infrastructure system in Tersa is highly required to prevent further contamination as the available infrastructure system represents a real threat to groundwater. 2) It is also advised to establish a treatment program for the point sources of contamination in the water canal in Tersa to enable the proper regular use of the available water; which may include constructing hydroponic basins and implementing a biological treatment program. 3) Raising awareness between residents and farmers is a major step in order to clarify and limit the risk resulted from exposure to the contaminated water service. 4) Irrigation machines should be supported by screens to prevent machinery blockage by garbage. 5) It is crucial to prepare proper farming practices adaptation strategy and a training program to the farmers of the remaining fragmented agricultural lands based on the current situation they are facing. Adaptation strategy should include using suitable fertilizers with less nitrogen content due to the high saturation of ammonia and nitrates (high total nitrogen content) in the water used for irrigation and introducing simple organic farming techniques such as the suitable time for yield harvesting to allow a suitable gap between last irrigation and harvesting time. 6) It is also essential to increase the support provided to farmers and protect their right to farm in a comfortable environment, also, to enhance social cohesion and connectivity through creating a beneficial relationship between farmers and the surrounding urban inhabitants to reduce the tension complaints raised between both sides.

**Data Availability**

Some data, models, or code used during the study were provided by a third party (Fig.1 and Fig.2), Some data, models, or code generated or used during the study are available from the corresponding author by request (Fig.3, Fig.4, Fig.5, Fig.6, Fig.7, Fig.8, Fig.9, Fig.10, Fig.11, Fig.12, Fig.13, Fig. 14, Fig. 15, Fig. 16, Table 1, Table 2, Table 3 and Table 4, Table 5)

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**List of Tables**

**Table 1.** Percent of areas lost in Giza governorate due to urban sprawl from 2007 to 2017 (Centre of Sustainable Development- AUC, 2018)

|  |  |  |  |
| --- | --- | --- | --- |
| District | Area of district (m2) | Area lost due to encroachment (m2) | Percentage of land lost (2007-2017) |
| Al-Jizah | 13652 x 104 | 1617 x 104 | 11.84 |
| Al-Badrashin | 13318 x 104 | 1247 x 104 | 9.36 |
| Imbabah | 36089 x 104 | 3375 x 104 | 9.35 |

**Table 2.** Districts in Markaz Al-Jizah with the highest percentages of lands lost under urban sprawl between 2007 to 2017 (Centre of Sustainable Development- AUC, 2018)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **City/village** | **District area**  **(m2)** | **Area lost due to encroachment (m2)** | **Percentage of land lost** |
| **1** | Tamouh | 165 x 104 | 58 x 104 | 35.01 |
| **2** | Bany Youssef | 68 x 104 | 18 x 104 | 26.16 |
| **3** | Al-Harraniya | 637 x 104 | 158 x 104 | 24.76 |
| **4** | Shabramnt | 243 x 104 | 59 x 104 | 24.42 |
| **5** | Mit Shamas | 265 x 104 | 63 x 104 | 23.73 |
| **6** | Zwyet Abou Mosalem | 829 x 104 | 167 x 104 | 20.11 |
| **7** | Tersa | 651 x 104 | 127 x 104 | 19.43 |

**Table 3.** Analysis of the collected water samples compared to the FAO guidelines and the Egyptian law 48/82

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameters | Unit | Pump 1 | Pump 2 | Pump 3 | Water canal | FAO guidelines | | | | | Egyptian guidelines  Law 48/82  “Article 49” |
| Degree of restriction on use | | | | |
| None | Slight to Moderate | | | Severe |
| pH |  | 7.50 | 7.50 | 7.20 | 6.80 | Normal Range 6.0 – 8.5 | | | | | 6.5 – 8.5 |
| TDS | mg/l | 883.0 | 1177.0 | 1030 | 1295.0 | < 450 | 450 – 2000 | | | > 2000 | 500 |
| EC | dS/m | 1.38 | 1.84 | 1.61 | 2.02 | < 0.7 | 0.7 – 3.0 | | | > 3.0 | n/a \*\* |
| CO3-2 | meq./l | - | - | - | - | 0 – 0.1 | | | | |
| HCO3- | meq./l | 4.72 | 5.19 | 5.66 | 5.94 | 0 – 10 | | | | |
| SO4-2 | meq./l | 6.16 | 9.94 | 7.95 | 6.51 | 0 – 20 | | | | | 4.2\* |
| Cl- | meq./l | 4.24 | 4.92 | 4.41 | 7.12 | < 4 | 4 – 10 | | | > 10 | n/a |
| Ca+2 | meq./l | 5.00 | 7.89 | 9.47 | 5.53 | 0 – 20 | | | | |
| Mg+2 | meq./l | 4.52 | 5.20 | 5.29 | 5.43 | 0 – 5 | | | | |
| Na+ | meq./l | 5.48 | 6.80 | 3.07 | 7.80 | 0 – 40 | | | | |
| K+ | meq./l | 0.11 | 0.14 | 0.18 | 0.82 | 0 – 2 | | | | |
| SAR |  | 2.51 | 2.66 | 1.13 | 3.33 | < 3 | | 3 – 9 | >9 | |
| NH3+ | mg/l | 1.82 | 1.05 | 1.19 | 26.6 | 0 – 5 | | | | | 0.5 |
| NO3+ | mg/l | 8.87 | 10.15 | 6.51 | 15.68 | < 5 | 5 – 30 | | | > 30 | 2 |
| P | mg/l | 0.002 | <1.5 | <1.5 | <1.5 | 0 – 2 | | | | | 2 |
| Fe | mg/l | 0.167 | 0.197 | 0.107 | 0.388 | 5.0 | | | | | 0.5 |
| Mn | mg/l | 0.966 | 1.255 | 1.351 | 0.606 | 0.2 | | | | | 0.2 |
| Zn | mg/l | 0.047 | 0.04 | 0.07 | 0.061 | 2.0 | | | | | 0.01 |
| Cu | mg/l | 0.029 | 0.026 | 0.025 | 0.049 | 0.2 | | | | | 0.01 |
| B | mg/l | 0.066 | 0.060 | 0.077 | 0.104 | < 0.7 | 0.7 – 3.0 | | | > 3.0 | 0.5 |
| COD | mg/l | Not detected | | | 65 |  | | | | | 10 |
| BOD | mg/l | 18 | 6 |
| Total coliform | cfu/ml | 272 x 103 | n/a |
| Fecal coliform | cfu/ml | 154 x 103 | 1000 (cfu/100 ml) |
| Salmonella & Shigella | cfu/ml | 41 103 |  |
| \* Originally 200 ppm in the law 48/82 | | | | | \*\* No available data about these parameters in law 48/82 | | | | | | |

**Table 4.** Cultivated agricultural areas in 2017 compared to the area 10 years ago and land ownership

|  |  |  |  |
| --- | --- | --- | --- |
| Current cultivated agricultural land | Total respondents | Owner | Lessee |
| n=30 | n=12 | n=18 |
| Smaller area | 19 | 8 | 11 |
| Same area | 11 | 4 | 7 |

**Table 5.** Cultivated crops in 2007 and 2017

|  |  |  |
| --- | --- | --- |
| Cultivated crops | 2017 | 2007 |
| n=30 | n=30 |
| Vegetables | 1 | 30 |
| Fodder | **29** | 0 |