INSIGHT INTO THE METABOLISM OF URBAN FOOD SYSTEM FLOWS FOR SUSTAINABLE DEVELOPMENT: THE CASE OF CAIRO, EGYPT.

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Abstract:

Food and nutrition security remain one of Egypt's fundamental challenges for development and human welfare. Cities need food; they are bound to nature by their appetite. Yet, as urban dwellers, we take feeding our cities and what it takes for our urban food system to function for granted. The paper is to analyze the food system in terms of its functioning actors, inputs and flows, the broader super systems that direct its behavior and the generated outcomes. Taking Cairo as a case study, an insight into the metabolism of Cairo's urban food system and the functioning and relationships among its different flows can help contribute to its sustainable development through planning and managing its complexity. Six vital food system flows were identified: land, water, energy, goods, capital and employment. The paper is to examine the flows using flow maps and Sankey diagrams to visualize the system's transfers accompanied by spatial maps, with an in depth focus on the land flow and how it relates to the city's spatial development; giving insight in terms of the system needs, losses and gains and actors partnership; to target inefficiencies and potential synergies and illustrate planning proceedings that place food higher in the urban agenda.

Keywords:

Food Insecurity, Urban Food Systems, Sustainable Development, Urban Metabolism, City Flows

Introduction

Food security has been acknowledged internationally as a basic human right and governments are obliged to work on asserting this right for every individual. A joint report by the WFP and CAPMAS in 2011 on the status of poverty and food security in Egypt highlighted an increase in food insecurity levels to reach 17.2% (13.7 million) of the Egyptian population and the numbers have been in continuous increase since then. Several drivers have contributed to the rise of the Egyptian food insecurity levels, ranging from environmental drivers as the loss of agricultural lands and soil quality, to socio-economic drivers as growing urban populations, multi-dimensional poverty and inefficient marketing systems, to managerial drivers as inadequate governmental policies and crippling subsidy programs. This has driven Egyptian

households to apply severe coping strategies to their food consumption that led to further deterioration in the nutritional and health status of the Egyptian community; having long-term negative effects, most notably in the aspects of health, education and productivity [1]. The paper is to start with illustrating the transformations in the role that food played in our urban communities through the years, followed by an in depth explanation of what constitutes an urban food system in terms of the system activities, actors, flows, broader systems and outcomes and concluding with the empirical part, taking Cairo as a case study to gain insight into the metabolism of its urban food system, with an in depth focus on the land flow and its spatial consequences on the city.

Integrating local food systems into urban settings: World trends

Cities need food, they are bound to nature by their apetite and the act of feeding cities plays an important role in shaping cvilizations. An examination of urbanization through food can help us achieve a better understanding for our cities, to build, feed and dwell in them in a better and a more sustainable way [2].

Pre-industrial cities

It is of no coincidence that agriculture and cities came to existence roughly about the same time; from the start cities and agriculture were bound together and depended on each other. The first cities were designed adjacent to their productive hinterlands with restricted size and population depending on how much their productive land can offer [3]. Choosing the right sites for their new cities and observing their surrounding natural conditions was essential to ensure the capacity of their cities to support life. The world's famous public spaces: the Athenian Agora and the Roman Forum were originally food markets, situated at the heart of their cities, whose significance and accessibility allowed them to accommodate further cultural and political uses over the time, in a mix of food, philosophy and politics, a relationship that was repeated globally over the years [4]. Examining the plan of a pre-industrial city may look irrational with its crocked streets and lack of clear geometrical shape, but studied with regards to food it makes perfect sense. Tracing the influence of food on it; clearly carved into its anatomy; with markets located at its heart around which the city's urban life revolved and roads leading to them like arteries. These markets were considered the places where the countryside came to the city and witnessed how the city relied on its countryside. City dwellers of the past could not ignore the role that food played in their lives; it was all around them present in everything they did [2].

Industrialization and land use models

Previously, food and the land that provided it determined where cities were chosen to be built and how far they could grow; with the industrial revolution and the advancements in transportation, now cities could be built anywhere and by any size, removing all the constraints that linked cities to their rural hinterlands and held back urban sprawl and increasing the gap between the feeders and the fed. Cities sprawled away from central urban areas into low density, single-use, and car dependent developments segregated from one

another. This low density development accounts to faster rates of urbanizing lands on the expense of productive farm lands and other natural areas, in a process known as ‘Suburbanization’ [5]. This has had its great effect on food trade, converting to a new urban typology where commercial uses are segregated from other uses as well; in what is known as ‘Supermarket Urbanism’. Supermarkets impact on city centers was immediate, killing local shops off and extracting the commercial and social life out of city centers, a trend marking the death of the public space. Suburbs are all about the private ownership of your house, garden and car and supermarkets are extending these notions to the urban space as well. It converted what was once a public sociable place to a private introverted one. The decline of the role of food markets in cities has had its costs; markets are vital to cities, they bring upon awareness to what it takes to sustain life in cities. Supermarkets added problems to food distribution; previously through corner shops and local markets, food could reach every part of the city through a sufficient distribution network. With the closing of local shops, many areas especially those of low income are left without any source of fresh food, in what is known as food deserts. Cities have been disconnected from the notion that we still rely on our surrounding natural geography to feed us and this has to do with the discrete and invisibility of the process and challenges that takes food to reach us [6].

Attempts to Reform: Reconciliation of Urban and Rural

Reform attempts to reconcile the city and the countryside have been going on for decades; connection with nature is rooted in our biology and is fundamental to our wellbeing [7]. The drawbacks of industrialization lead to the creation of a new type of utopias. In 1902 Howard published ‘Garden Cities of Tomorrow, proposing a garden city that would combine the best of both the town and country; through a network of small, self-sufficient city-states; where five sixths of the area of each city was devoted to food production. He intended for his garden city to be self-sufficient in terms of employment, agriculture and industry [8]. Le corbusier’s ‘Villa Raduise’ in 1924 with a segergated circulation system and tall buildings that freed up ground space to access nature [9]. A utopian model for the American suburb was derived by Frank Lloyd Wright in 1932; ‘The Broad acre City’. His vision was creating spaces that were a mix of urban and rural areas, where agriculture stands as an equal to traditional development through a series of farm units, garden schools, roadside markets, and dwelling places [10]. However, the integration of urban agriculture in cities didn’t find its way through architects’ utopias; its spread came from the urban dwellers themselves who saw it as their salvation in acute conditions; as a safety net to provide food and income in times of unemployment and food shortages. In London during both world wars, the food shortages lead to campaigns promoting local food production in homes and public areas as allotment and community gardens During the 1980’s, the collapse of the Soviet Union forced millions of Russians in urban areas to start growing their own food in the urban peripheries, turning St. Petersburg to the urban farming capital of Europe and drove the citizens of Havana, Cuba to takeover empty lots, patios and rooftops to farm, trying to feed themselves; where urban agriculture was declared a national priority. The cities of London, St. Petersburg and Havana bear witness that cities, even if they were designed at first to be dependable on others for food, can work their way to self- sufficiency. Thus, food has helped shape our environments,

and still does. Cities should have emphasis on food systems and connect what are on our plates with the land where it was grown and the farmer who produced it. Plenty of cities nowadays are starting to apply food systems as an agent for urban renewal and sustainable design; acknowldging the power of food to change [2].

Urban Food Systems

Food is considered as a complex adaptive system; in that it's dynamic, consists of multiple interconnected elements and self- organizes corresponding to learnt experience. Food system is defined as: *'i) all the activities related to the production, processing, distribution, consumption and disposal of food, ii) all the factors affecting its activities: the environment, actors, infrastructures and institutions, iii) the outcomes of these activities that contribute to food security and a range of socio-economic and environmental issues'* [11], as shown in Figure 1. Food systems have long been regarded as rural rather than an urban issue, lacking the same magnitude as other urban systems. However, food systems contribute to city's local economy, public health and quality of life and are directly connected to other urban systems as land use, transportation and economic development. Food systems need to be managed in a sustainable and resource efficient way for future generations. This complex task cannot be realized by purely functional or economic perspectives but rather rereading the city as an ecosystem; where flows of material and energy cross; shifting urbanization from laying out locations to a dynamic process of connecting and coupling flows to close cycles, reduce losses and generate economic prospects. The insight into the city's urban metabolism can become a valuable planning instrument for its sustainable development [12].

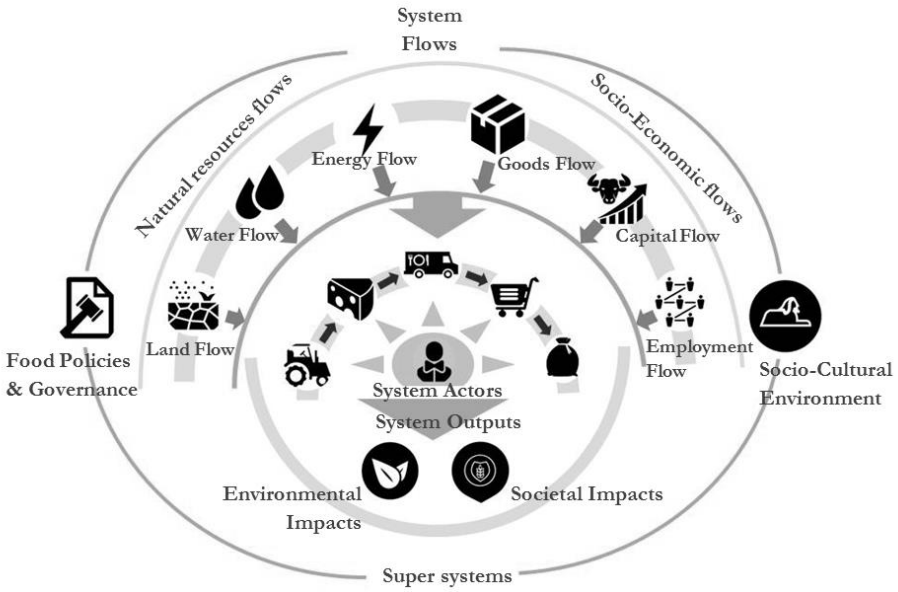

Figure 1 Urban Food System, Source: Authors

Food system Activities

A Food system consists of a group of subsystems that can be broken down into five elements: [13].

1. Food production is the sum of activities used to produce food. It can be classified into: rural and urban production. Urban agriculture provides empowerment especially to underserved neighborhoods, in terms of providing local organic food, job skills and income.

2. Food processing is the process of adding value to raw food to increase profit margins and maintain long life spans. Food processing can contribute significantly to the local economy. Food processing requires land, energy, transportation and infrastructure.

3. Food distribution: involves the transporting, sorting and marketing of food products from producers to consumers. It can be performed through wholesaling or alternative food distribution models that are cost efficient, sustainable and less polluting as farmers markets, roadside stands, farm to school and restaurant models.

4. Food consumption is defined as the process by which individuals and societies acquire and utilize food. Food retail provides potential for revitalizing neighborhoods in large commercial centers and small neighborhood streets where the community comes together.

5. Food waste includes activities as: composting, recycling, land filling and food recovery. Food waste is the final step in the food chain and is a determinant of achieving a sustainable food system**.**

Food system Actors

Food system actors can be classified as: [14].

1. Consumers and citizens form a large and diverse group and are crucial actors in shaping food systems through their demand.

2. Food service and retail companies range from large, medium and small sized enterprises and can operate on local levels as small scale and family owned businesses or global levels as international brands in competitive markets.

3. Government's role in food systems varies according to their national context; in liberalized economies, governments have a regulating and facilitating role, where in state controlled economies; they take part in and sometime control food production and retailing. In both contexts, governments have large influences on the way food systems are managed through financial (taxes, tariffs and subsidies) and legislative regulations.

4. Non-governmental actors and civil society have a wide range of objectives as food security, health and nutrition, environmental conservation and resource management.

Food System Flows

For an insight into the metabolism of urban food systems; six vital food system flows were identified as shown in Figure 2, with description of what constitute each flow and how they relate to cities spatial development.

- Natural resources flows: Food system activities are critically dependent on a diverse array of natural resources as land, water, energy, and biodiversity. The relative share of the use of these resources varies across the food system chain from production to waste [14].

1. Land Flow: Land is an essential component in food systems; it relates to the city's spatial development through activities as production lands, food industries, food warehousing

and retail activities and landfill sites. Although these activities contribute to cities livelihood and food security, they are under increasing pressure of conversion due to increasing land values and decreasing agricultural economic spin-off. Conscious land zoning is needed to protect and integrate food system practices in cities development plans [15].

2. Water Flow: Water is an essential resource across the various stages of the food system and vast amounts are especially needed in production activities.

3. Energy Flow: The use of fossil fuels varies across food systems, from limited use in traditional food systems to being applied intensively in all food system activities in modern food systems; from production to harvesting, processing and transportation of food. Modern food systems are highly dependent on large inputs of cheap resources, which can be environmentally degrading. Planners need to regulate food system activities to be resource efficient, with minimal waste, pollution and environmental degradation [14].

- Socio-Economic Flows: The socio-economic flows of the food system are concerned with the generated trade, capital, income and job opportunities from the functioning system.

4. Goods Flow in the food system is divided into goods that are locally produced or imported; they can be consumed as raw commodities, processed commodities, saved as surplus for the coming year and lost commodities due to spoilage and damage during transmission. The percentage of each use depends on the type of the commodity. The generated waste from these commodities is either recycled or lost to disposal. Planning needs to work towards achieving improved infrastructure and services to provide better food exchange and provisioning conditions, by shorter and strengthen connections between producers and consumers and including food system outlets as a factor in cities transport planning to decrease food costs, city congestions and pollution [15].

5. Capital Flow: Capital input into the food system directs how resources, goods and services are organized within a food system. Capital flow is divided into expenses required for the operation of the food system activities as labor wages, goods purchase, services and commodities expenses and revenues generated from these activities [1].

6. Employment Flow: Food systems play a large role in providing local economies with employment opportunities in the food production sector as farmers and animal breeders, industrial jobs in the food processing sector and in food retail, service and catering sectors.

Food Super systems

The food system functions within larger super systems that direct the system's behavior;

1. Food policies that influence food systems include both policies directly related to food systems as food subsidy and food safety regulations and policies indirectly related to food systems as public health, trade and investment policies and environmental regulations.

2. Food Governance includes the formal functions of governments and non-state actors as the private sector and civil society within the surrounding socio-economic context.

3. The Socio- cultural environment of a food system includes the set of shared preferences, and norms that sets affects the decision making of individuals and societies [14].

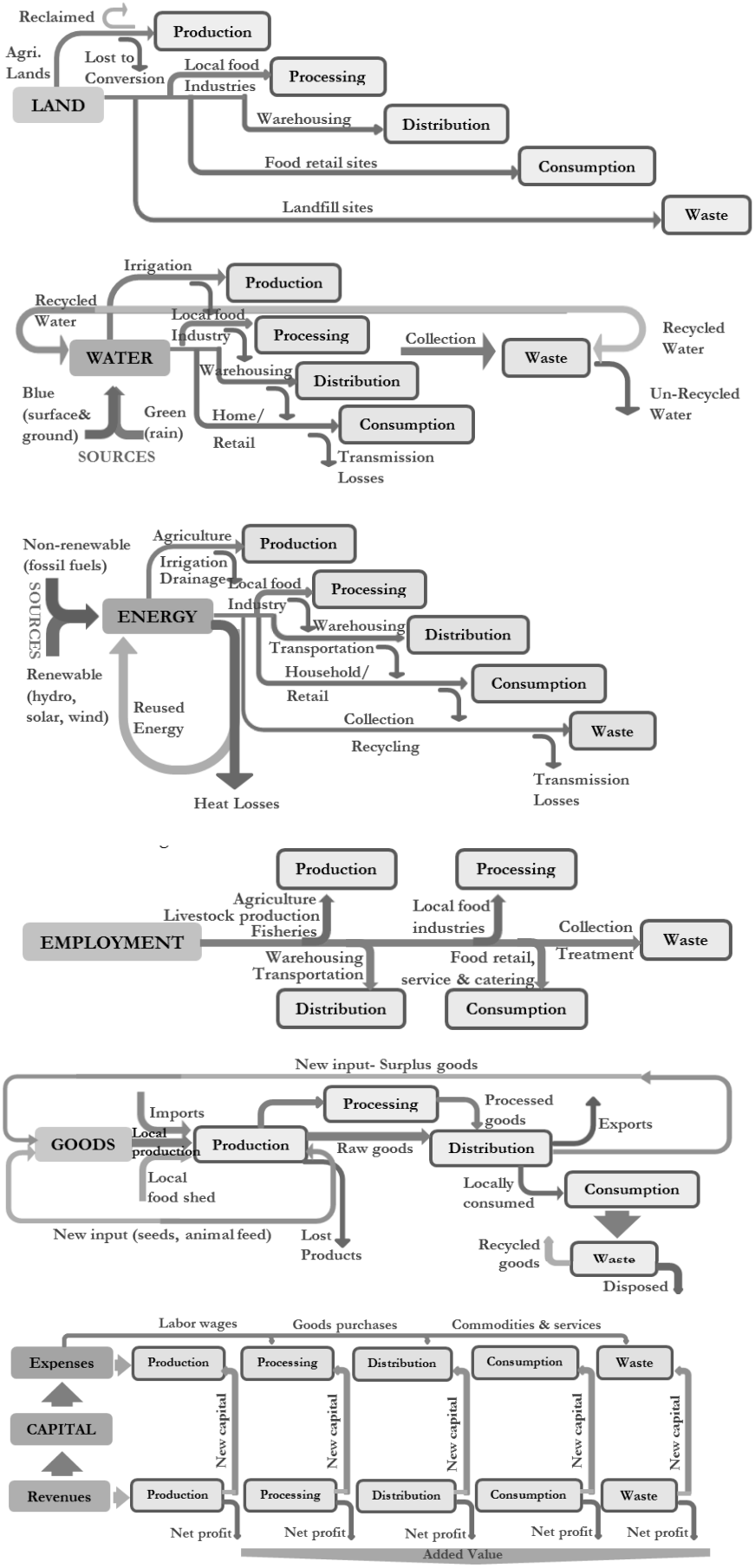

Figure 2 Urban Food System Flows, Source: Authors

Food System Outputs

Food system activities result in a number of outcomes that can be classified into:

- Environmental outcomes that impact natural resources as land use, water availability, biodiversity loss and GHG emissions, these impacts feedback again to natural resources that are needed inside and outside the food system and affects the resources capacity to provide a continuous resilient base of supply leading to food security challenges.
- Societal outcomes concerning how food is accessed; related to food security and hunger aspects and how it is utilized; related to health and nutrition aspects [14].

Insight into the metabolism of Cairo's urban food system

Research Methodology

- Thinking in flows for sustainable urban development: in an attempt to provide insight to how Cairo's urban food system functions and how applying the principles of urban metabolism can contribute to its sustainable development; the paper is to provide an in depth focus on Cairo's food system land flow as an example. The Flow and its consequences is to be examined to determine the fields of inefficiencies and look for potential synergies that can be turned to future opportunities and how they relate to the city's current spatial development. To help achieve a more comprehensive understanding; the analysis was done on two scales; the national scale represented in Egypt and the regional scale represented in Cairo governorate. The national scale is to be used as a frame of reference to help understand the volume of contribution that Cairo's food system shares on the national level.

- Mapping Flows: The research is going to use 'Sankey diagrams', a specific type of flow diagrams, used to visualize the transfers, efficiency and nature of losses within a system. The principles that regulate Sankey diagrams are: the substance within a flow is constant; the amount of substance going into the flow equates the amount coming out of it, but can change form within the flow and the width of the flow line is proportional to its flow quantity or contribution within the system [16]. In order to unify these flows into quantities that could be related and compared to each other, the units will be converted to percentage format. The six defined flows will be analyzed according to the five main activities that constitute an urban food system consecutively. The produced Sankey diagrams will be accompanied by overlaying the examined flow on spatial maps of the study area-Cairo- to illustrate their spatial consequences and help achieve a more comprehensive understanding.

Data Collection

1. Food Production in Land Flow: the research used CAPMAS annual report for agricultural and livestock production to calculate the designated land for food production. According to Landsat satellite data, the loss of agricultural lands due to urban sprawl in Cairo from 1973 to 2006 amounted to 136.75 km2, which equates to 980 feddan per year and relatively Egypt loss to conversion amounts to 39244 feddan per year [17].

2. Food Processing in Land Flow: To calculate the designated area for local food industry, the research related CAPMAS annual report for industrial production data on the no. of employees working in food related industrial facilities with Neufert guidelines which stated that the average required floor space per employee in industrial facilities is 10m2.

3. Food Distribution in Land Flow: using CAPMAS annual report for warehousing and reviewing the report's stock volumes showed that food products cover a share of 32% in Cairo governorate and 34.5% on the scale of Egypt. The area designated for warehousing was calculated through its volume capacity, assuming a height of 5m for the facilities.

4. Food Consumption in Land Flow: CAPMAS annual report for retail and wholesale trade divides food retail facilities into wholesale hypermarkets, retail variety stores and small shops. Applying Neufert guidelines for commercial buildings: hypermarkets were set an average area of 2000m2, variety stores at 500m2 and small shops at 280m2.

5. Food Waste in Land Flow: The CAPMAS annual report for environmental statistics states that Cairo has 5 landfill sites, whereas Egypt has 52 landfill sites, with an average area of 55 feddan per site. Comparing the generated volume of organic to non-organic waste showed that organic waste account to 44.8% of the total waste in Cairo and accounts to 55% in Egypt and hence an approximate area of the land required for food waste was estimated.

The previous food system land data for both Egypt and Cairo were estimated and collected as shown in Table 1 and used to derive the land flow analysis as shown in Figure 3. The land flow spatial consequences were deducted as shown in Figure 4, the specified processing and retail lands are meant to indicate the local food industry and food retail activities locations and not the exact allocated area; as such data was not available and the exact allocated area has been calculated in the previous table.

Data Interpretation

From the above analysis it can be deducted that: Production lands and specifically lands designated for agricultural production constitutes the highest share for land needs in the food system on both the national and governorate levels; 99.6% and 75% respectively. However, Cairo has lost a large sum of its agricultural lands to urban conversion; 4.3% of the land input as shown in Figure 3. Most of the governorate's old agricultural lands can be found along its borders but rarely in the urban center. New agricultural lands amount to a larger share than old agricultural lands, they can be found in new urban communities to the east of the governorate. However, most of Cairo's production from these lands is fruit crops as shown in Figure 3; which means that the governorate relies heavily on imports from its neighboring governorates and abroad to fulfill its needs. Private land ownership also amount to a large share on both the national and governorate levels; 92.15% and 42.8% respectively; where agriculture in the area is mostly characterized by small farm holdings with an average size of about 1.5 hectare [17].

Industrial clusters are mainly allocated to the south and east of the governorate as shown in Figure 4; where private industries account to larger shares than public industries as shown in Figure 3. Warehousing facilities mostly belong to the public sector. The land designated for food consumption activities account to 23.7% of the governorate's food system land use.

Studying the distribution of commercial services in the governorate's urban center and older districts shows better distribution through corner shops and small variety stores in a mixed use setting, rather than the dominant shopping complexes in new urban communities segregated from residential areas; as shown in Figure 4; that may result in uneven distribution; creating food deserts. Cairo official landfill sites are distributed mainly along the peripheries of the city as shown in Figure 4; however unofficial random disposal sites can often be found around the city. The land sites are designated for mainly dumping and not for composting or recycling activities that rarely takes place within the governorate. Studying Cairo's Food system land use in relation to its unplanned areas shows that many of the unplanned areas are located on former and in proximity of agricultural lands; which indicates the exploitation of agricultural lands by unplanned growth. In addition, most of these areas are located in segregation from the food retail and processing activities, which indicates the lack of adequate coverage of food services in these areas; attributing to their food insecurity. Cairo's food system land share accounts to only 0.2% of Egypt's food system land share; which indicates the governorate's insufficiency in local production and dependency on food imports. The lands designated for food system activities within Egypt accounts to 6.5% of its total area and within Cairo governorate to 3.5% of its total land area; indicating that the spaces acquired by food activities in cities accounts to a considerate share of their areas and demands more consideration in the planning agenda.

Table 1 Collective Food System Land Flow Statistics, Source: Authors

Land Flow	Cairo		Egypt	
	Area (Feddan)	Percentage (%)	Area (Feddan)	Percentage (%)
Total Sys. Land Use	**25995**	**100**	**15679347**	**100**
Production	**19124**	**75**	**15627637**	**99.6**
Old agricultural lands	8753	34.1	15443297	98.4
New agricultural lands	9391	36.6		
Lost to conversion	980	4.3	39244	0.25
Livestock domestication			145096	0.95
Field Crops	2399	9		
Vegetables	486	1.87		
Fruits	15207	58.47		
Livestock domestication	380.8	1.36		
Lost to conversion	980	4.3		
Public Sector	11126	42.8	1128913	7.2
Private Sector	8370.4	32.2	14448518	92.15
Processing	**102.67**	**0.39**	**606.25**	**0.4**
Public Sector	10.1	0.04	126.6	
Private Sector	92.57	0.35	479.65	
Distribution	**74.75**	**0.28**	**1275.6**	
Consumption	**6162**	**23.7**	**48546.5**	
Wholesale	2050.85	7.9	9507.5	
Retail	4111.18	15.8	39039	
Public Sector	1309.78	5.1	3938.7	
Private Sector	4852.25	18.6	44607.8	
Waste	**151.2**	**0.58**	**1281.3**	

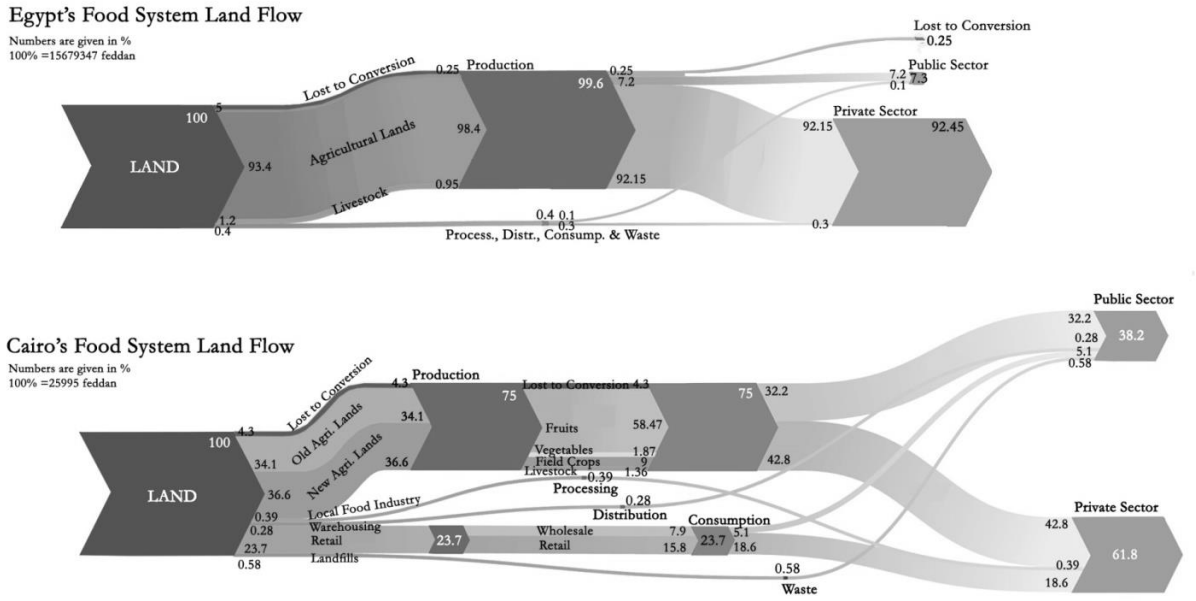

Figure 3 Egypt & Cairo Food System Land Flow chart, Source: Authors

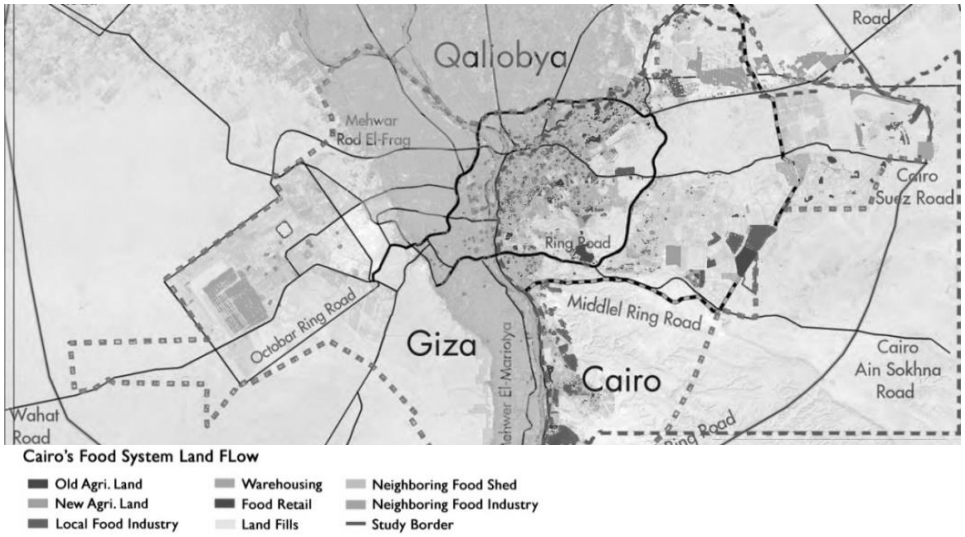

Figure 4 Cairo's Food System Land Use spatial allocation, Source: GOPP, modified by authors

Conclusion

Studying Cairo's urban food system from an urban metabolism perspective via studying its material and energy flows was used to give an insight in terms of the system needs, losses and gains and public-private partnership; to target inefficiencies and look for potential synergies. Taking the land flow as an applied example showed that in terms of needs, production constitutes the highest share for land needs in the food system. However Cairo suffers from extremely limited arable land area; where most of the governorate's agricultural lands are located in the peripheries and rarely in the urban center. This results in the governorate being highly dependent on imports; where domestic food production is unable to satisfy its growing demands. Thus integrating urban agriculture practices in the city's development plans can provide many benefits; where urban agriculture has the potential to provide empowerment especially to underserved neighborhoods, in terms of providing local organic food, job skills and income. In terms of system losses and gains, Cairo lost large

sums of its agricultural lands to urban conversion and although food systems activities contribute to cities livelihood and food security, they are under increasing socio-economic pressures to lose their rights in the city. Conscious zoning and land use policies are needed to protect these agricultural resources. Planning should also work to strengthen and shorten supply chains and directly connects producers to consumers; for more cost efficient and sustainable food provision. Planning can also work towards cutting down food system's waste stream by integrating food composting and material recycling into waste management and connecting food outlets as restaurants and grocery stores with food aid organizations to sustainably regulate food surpluses. In terms of public and private partnership; private land ownership in the food system accounts to the larger share; where agriculture in the area is mostly characterized by small farm holdings, which may hinder the ability to work towards an integrated crop plan that satisfy the needs of its citizens, which is evident in how most of Cairo's production from private lands is fruit and recreational crops. Thus, the food system needs to be examined in its totality; taking into consideration the physical, economic and social aspects that accompanies its functioning and placing it higher in the urban agenda.

References

1. CAPMAS. (2014). Annual Statistical Reports. Cairo: CAPMAS.
2. Steel, C. (2008). Hungry City: How food shapes our lives. London: Vintage Books.
3. Morris, J. (1994). History of urban form: before the industrial revolutions. London: Routledge.
4. Rykwert, J. (1976). The idea of a town. Faber and Faber.
5. Muller, P. (1995). Transportation and Urban Form: Stages in the Spatial Evolution of the American Metropolis. New York: Guilford.
6. Diamond, J. (2005). Collapse: How societies choose to fail or succeed. New York: Viking.
7. Wilson, E. (1984). Biophilia. Cambridge: Harvard university Press.
8. Howard, E. (1902). Garden Cities of Tomorrow. MIT Press paperback edition.
9. Corbusier, L. (1987). The City of Tomorrow. New York: Dover Publications.
10. Wright, F. L. (1958). The Living City. New York: Horizon Press.
11. HLPE. (2014). Food losses and waste in the context of sustainable food systems, Rome.
12. Sijmons, D. (2014). Urban by Nature. Rotterdam: IABR.
13. Jones, P. (2005). Collaborative food system assessment, San Francisco.
14. UNEP. (2016). Food Systems and Natural Resources. The International Resource Panel.
15. Cassidy, A. (2008). The Planner's Guide to the Urban Food System. University of Southern California School of Policy, Planning, and Development.
16. Zhang, K. (2016, June 13). Why Procurement Professionals should use Sankey Diagrams.
17. Hereher, M. (2012). Analysis of urban growth at Cairo, Egypt using remote sensing and GIS. Natural Science, Vol.4, No.6, 355-361.