Urbanization Impact on the Water and Food Security and Assessment of Wheat Production and its Irrigation Water Requirements Using CROPWAT Model in IRAN: A Case Study of City Tehran

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ABSTRACT: In the modern world, the equal allocation of amenities amongst the society individuals has been affected by the phenomena of Urbanization and urban development. Tehran, the capital of Iran, is always the main destination of migrants from all over the country because of its dominant modernistic urban attractions. The latest official national census in 2006 showed that during 1921 to 2006, in the last 85 years, Tehran’s population has multiplied by 37 and its area has multiplied by 100. This rapid Urbanization has replaced a huge area of agricultural land, fertile arable land. In addition, Tehran total water consumption with an average annual growth rate of 23.1 percent reached to more than 990 million cubic meters in 2008 which all of these elements emphasis on a much more sustainable consumption pattern requirement and more attention to the Tehran’s water and food security. For instance, in this research for the first time indicated that the domestic production of wheat in Tehran city just covers 6% of Tehran’s population wheat requirement while it consumes 25% of water consumption of Tehran city.

Keywords: Urbanization; Tehran; Water security; Food security; Water consumption and Wheat.

INTRODUCTION: Urbanization is a global phenomenon which is occurring rapidly in many less developed countries. It is expected that most urban growth occurs in Asian countries related to two main factors, unplanned rural to urban migrations and natural increase of population (excess of births over deaths) for these reasons there are near 300 cities with a million inhabitants and most of these are in the developing world. The growth rate of these cities was 10-fold between 1950 and 1990. Some of these cities, such as Abidjan, Amman, Dhaka, and Harare, are now defined as megacities with 10 million inhabitants.1

Urbanization process has intensified sharply in the early of the twentieth century. Available statistics appear that more than half of the world 6.6 billion individuals live in urban areas, swarmed into 3% of the earth’s land area.2 The extent of the world populace in urban zones was less than 5% in 1800, it raised to 47% in 2000. And it’s anticipated to reach 65% in 2030.3 However, more than 90% percent of future populace development will be concentrated in cities in developing countries and a huge rate of this population will be destitute. In Africa and Asia where urbanization is still in its infancy (40 percent), both are predicted to be 54% urban by 2025.4,5 Quick urban development is responsible for numerous socioeconomic and natural changes. Its impacts are emphatically related to the worldwide issues. Today, the relationships between human societies and their natural environment have been strongly affected by urbanization and urban development. Considering an increasing urban population, the result of urban expansion is to obtain retrievals in the form of environmental effects such as climatic change, water pollution, noise pollution, thermal pollution, and changes in the water cycle system due to waste and other impacts,5-8 the loss of environs, agricultural lands, and orchards,9,10 increasing socioeconomic inequality,11 endanger the people health and their food and water security,12 and so on.

It has been seen by diverse studies that, environmental degradation is caused by a couple of components including fast urbanization due to overpopulation, accelerated industrialization, impromptu and uncoordinated physical improvement due to poor urban administration and ineffectual control policies.14-15

Sketch have shown that urbanization induces changes in rainfall pattern and amounts due to low gentle wind wet, the urban heat island intensiveness, atmospheric instability, and the presence of cloud condensation nuclei.16-17 The urban heat island impact changes the convection of air masses and increments the greatness and recurrence of late spring high-intensity storm.18-19
During the procedure of urbanization, the reflectivity of the land surface is savagely changed when a lot of natural or agricultural lands are converted to built-up surfaces. These progressions emphatically influence the environment/land surface energy exchange.\textsuperscript{20} In addition, nearby climate, and atmosphere regimes.\textsuperscript{21-22} With respect to the hydrological cycle, the greater part of the procedures amongst land and atmosphere, surface, and subsurface\textsuperscript{23-24} are totally impacted by the procedure of urbanization. For instance, a study carried out in Nepal country by the Kathmandu Valley Town Development Committee in 2001 revealed that, between 1984 and 2000, agricultural land has been declining on an average at 2.04 percent per annum.\textsuperscript{25} In 1981, three-fourths of the residents were involved in agriculture which in 1991 slumped to one third.\textsuperscript{26} Similar actions are seen in China, Indonesia, and Nigeria.\textsuperscript{27-29}

This paper endeavors to cause a superior comprehension of the Urbanization and Its Effects on Water and Food Security in Iran: A Case Study of the City of Tehran by gathering, figuring, and computing at measurements information from distinct contexts.

**MATERIAL AND METHODS:**

Tehran and Its Population Growth: The Tehran’s growth has undergone an incredible acceleration both in physical and population aspects from the 1920s. The procedure of extension of Tehran over various timeframes has showed that, over the most recent twenty years, this city meets inverse procedures of expansion and disintegration. In 1956, when the first official census was taken, it showed a population of 1,510,000 and a city area of 100 km\textsuperscript{2}.\textsuperscript{30,34}

From this time, more than 120 villages, along with two other cities, were combined by Tehran and owing to this extremely prolific city growth, in 1980, the Tehran municipality had to expand the scope of its services like, for example, to change the legal expansions from 225 to 520 km\textsuperscript{2}, and to increase the number of municipal districts from 12 to 20.\textsuperscript{31, 32 & 35}

The latest official national census in 2006 showed that Tehran registered a population of 7,700,000 and a city area of 800 km\textsuperscript{2}. This fast city growth has been repeated time after time till now. Finally, it was recognized that the population density of the city during all these periods has appearance a descending trend from 291 to 96 persons per hectare from 1921 to 2006, as can be seen in Table 1. To sum up, we can say that in the last 85 years, Tehran’s population has multiplied by 37 and, what is more, its city area has multiplied by hundred. Despite this, under this rapid physical growth, the city’s expansion was unplanned, and destultry, as can be seen in Figure 1.

![Figure 1: The physical development of Tehran.\textsuperscript{31, 32, 36 & 37}](image)

**Land Use Changes in the Tehran Plain:** In Figure 4 extent of land cover in three floors of green, open, and built in years 1989 and 2003 and 2011 according to satellite photos of Tehran city is shown. As shown in Table 1, the population of Tehran grew about 5-fold during the period of 1956–2006, while the urban occupied land grew 8-fold during the same period. In addition, the urban land size of Tehran in 1956 and 2006 were 10000 and 80000 ha, respectively.\textsuperscript{39}

**Table 1: Changes in population, area, density and numbers of private cars in Tehran for different years.\textsuperscript{31, 36 & 38}**

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<tr>
<td>Population(million)</td>
<td>0.21</td>
<td>0.3</td>
<td>0.69</td>
<td>1.51</td>
<td>2.71</td>
<td>4.5</td>
<td>6.04</td>
<td>6.7</td>
<td>7.02</td>
<td>7.711</td>
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<tr>
<td>Area(hectare)</td>
<td>720</td>
<td>2420</td>
<td>4500</td>
<td>10000</td>
<td>19000</td>
<td>32000</td>
<td>62000</td>
<td>73950</td>
<td>78900</td>
<td>80000</td>
</tr>
<tr>
<td>Density(p/ha)</td>
<td>291.6</td>
<td>124</td>
<td>154</td>
<td>151</td>
<td>143</td>
<td>141</td>
<td>97.4</td>
<td>91</td>
<td>88.9</td>
<td>96.3</td>
</tr>
<tr>
<td>Private car (number for 1000 people)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>25</td>
<td>31</td>
<td>61</td>
<td>74</td>
<td>83</td>
<td>90</td>
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Figure 2: Changes in the population for different years and its linear approximation.

According to Figure 4, the area of green lands and open lands decreased gradually and there is a huge increase in built area.

It is obvious in 1989 only 37 percent of the present situation of Tehran was built while in 2011 the built area rises to 58 percent of total area. Moreover, increasing urban population and concentrating different activities in cities need the change in land and natural areas to constructed areas. Land areas with vegetation cover in Tehran city in the period between 1989 and 2011 declined to about 4052 hectares. Also, the number of open areas and arid in this period decreased about 1057 hectares. In basin areas of Tehran city amount of vegetation cover dropped from 23 percent of total area in 1989 to 17 percent in 2011.

Urbanization and Its Effect on Water consumption and Water Resources: Tehran total water consumption in 1999 was 886 million cubic meters which with an average annual growth rate of 23.1 percent it is reached to more than 990 million cubic meters in 2008. Tehran daily water consumption from 99 liters per person per day in 1967 is reached to 350 liters in 2014. This is while Tehran's population of two million and seven hundred thousand persons in this period have already grown to more than eight million people.

Based on the figures published by Tehran's Water and Sewage Company, the measure of water supplied in Tehran area is more than 703 million cubic meters which 71.7% is the surface water and the rest is subsurface water.

Underground waters are one of the most important resources of Tehran city which in dry seasons until
50% of Tehran drinking water was from underground waters. In conclusion, quality of Tehran underground water is very important.

Figure 6: The trend of whole water consumption of Tehran.

Study results on hydrograph underground water of Tehran and Karaj with attention to their area about 1069 and 587 km² respectively show that the level of underground water surface from years 2008-2009 to 2010-2011 is slumped for Tehran basin about 5.65 cm and for Karaj, it decreased 7.18 cm. It means only in Tehran desert basin the underground water volume has declined about 20.1 million cubic meters for each year and in Karaj desert basin the underground water volume has decreased about 33.1 million cubic meters during the years 2008-2011 totally with an average yearly reduction about 10.1 million cubic meters.

Picture 7 shows the surface level of the underground water in different parts of Tehran city during the years 2010-2011.

Urbanization and Its Effect on Food Security: During the 1956 to 2007 years, Agricultural land and the garden area declined to 22 percent and reach to 3500 ha in 2007. This means a significant reduction in the size of gardens and agricultural land in the city which is an outstanding threat to the food security of Tehran city. Figure 6 shows that the volume of water used annually in the city for varied purposes escalated to 16.6 percent in the period of 1999–2011. This was a distinctive reduction in agricultural water and may impact on agricultural production and food security in general.

Alterations in land use in the Tehran Plain, because of rapid urbanization, were very high and have seriously reduced agricultural and horticultural production and created a significant problem for the individuals in the city. vegetation cover land in Tehran in the period between 1989 and 2011 decreased about 4052 hectares. In basin areas of Tehran city, the amount of vegetation cover dropped from 23 percent in 1989 to 17 percent in 2011.

The jungles area included woodlands around Tehran from 28,174 ha declined to 24,168 ha during 2009 to 2015 respectively.

Iranian Diet and its relationship with water consumption case study Tehran people: In Iran Most people's diet is based on rice - meat and bread, which bread is the leading factor in people's daily diet.

The Persian eating habits (in terms of meal sizes and timing) would be generally quiet the Mediterranean-A standard, simple breakfast, a large lunch, and a light Dinner-Tehran also follow the same principle and bread there is in a variety of meals.

Bread is a major part of Iran and Tehran people diet and in continue, wheat is a vital crop for its production as is shown in figures 8 and 9, a wide range of total agricultural area (about 60 %) in Iran is under wheat cultivation. Wheat and barley are the main crops cultivated in the country. Wheat is the dominant cereal crop, accounting for almost 70 percent of the aggregate cereal production.

Wheat production and its Irrigation water requirements using CROPWAT model in Tehran in 2011: With attention to previous part, Iran after China, India, Russia, America, and Pakistan is the sixth major consumer of wheat in the world.

During 2010-2011 approximately from 12 million hectares harvest crops, about 8.76 million hectares equivalent to 73.9 percent of the total harvest is associated with grain harvest.
According to Figure 8, about 53.8 percent of grain harvest area is related to wheat production; also the major crop which is imported to the country is this crop, which reflects the importance of this product.\(^{43}\)

![Figure 8: The cultivation Area of annual crops in Iran Iranian.](image)

In addition, by comparison of wheat requirement water and the key ingredient of wheat in bread preparation and its key role in daily dietary of Tehran people the more sustainable methods in irrigation and production of this crop is necessary. Based on a consumption survey performed in Iran since 2001-2003 Average consumptions of bread is 286 g per day per person.\(^{49-50}\) In addition, Average consumption of wheat flour in Iran is 416 g per day per person.

**Assumptions:**

- **Tehran inhabitants:** 8,800,000
- **Average diet – IRAN – 2011:** 3235 kcal/cap/day.\(^{44}\)
- **Soil type:** black clay
- **Agricultural Area in Tehran under wheat cultivation:** 61008 ha.\(^{43}\)
- **The yield of wheat in 2011:** 13608 Hg/ha.\(^{44}\)
- **Wheat Calories Content:** 334 kcal/100g.\(^{44}\)
- From CROPWAT Model:
  - **Blue Water:** 384.8 mm
  - **Green Water:** 88.5 mm
- For a given month, the crop water balance can be expressed as follows\(^{52}\):
  
  \[ IWR = K_\varepsilon \cdot E_{to} - P \]

  Where;

  - IWR is the net irrigation water requirement needed to satisfy crop water demand.
  - \(K_\varepsilon\) is a coefficient varying with crop type and growth stage.
  - \(E_{to}\) is the reference potential evapotranspiration, depending on climatic factors.
  - \(P\) is the precipitation.

  Actual irrigation Water requirement in a year = 421.7 mm \(\approx\) 422 mm

**Estimation of Tehran requirement wheat and it’s Irrigation water requirement:** Following CROPWAT results the necessary water for wheat production in Tehran is approximated:

\[ 422 \text{ mm} \times 61008 \text{ ha} = 2.574 \times 10^{11} \text{ Liter, which is equal} \]

\[ \text{to} \ 257,453 \text{ million cubic meters or 25\% of the Total} \]

\[ \text{Water Consumption of Tehran city in 2011. (about} \ 1030 \text{ million cubic meters according to Figure 6)} \]

Additionally, Tehran Wheat Production can be assumed:

\[ 61008 \text{ ha} \times 13608 \text{ hg/ha} = 830196864 \text{ hg} \]

For this reason, in this research During 2010- 2011 the wheat requirement water is calculated by CROPWAT software and as is clear from the results although a distinguishing amount of water produced in Tehran in agriculture and solely for wheat production is spent. (about 288.567 million cubic meters (MCM) per year).

It should be noted that in this study based on CROPWAT model and simplification we only consider the Green and Bluewater in the water footprint (WF) of Tehran wheat production. In other words, the gray and whitewater are not computed in our calculation.\(^{48}\)
And with attention to FAO database Wheat produced Calories in Tehran is computed:

\[ 830196864\text{g} \times 334\text{kcal}/100\text{g} = 2.77286 \times 10^{11} \text{kcal/year} \]

Moreover, Average Diet of Tehran in 2011 can be attained thanks to FAO database by interpolating between years 2000 and 2014 equal to 3235 kcal (cap/day). It is clear Total Requirement Calories of Tehran city would be 1.0391 \times 10^{13} \text{kcal per year because:} 

\[ 3235 \times 365 \times 8800000 = 1.0391 \times 10^{13} \text{kcal/year} \]

The total requirement calories of Tehran’s inhabitances supported by wheat for each year will be equal 4.4628 \times 10^{12} \text{kcal/year} should we assume average consumption of wheat flour in Tehran is 416 g per day per person (equivalent to 1389.44 kcal/day).  

\[ 1389.4\text{kcal/day} \times 8800000 \times 365 = 4.4628 \times 10^{12} \text{kcal/year} \]

On the other hand, according to previous calculations, the Total Calories Produced in Tehran by Wheat is only 2.77286 \times 10^{11} \text{kcal/year}.

Since the Total Calories endorsement by wheat in Tehran is less than the vital Equivalent Calories Consequently, due to compensating it is necessary to government import the rest of the needed wheat. In fact, the Tehran city must import the amount of 1170128 tons of wheat per year.

\[ 4.4628 \times 10^{12} \text{kcal/year} - 2.77286 \times 10^{11} \text{kcal/year} = 3.9082 \times 10^{11} \text{kcal/year} = 1170128.14 \text{ton/year} \]

RESULTS AND DISCUSSION: In other words, the domestic production of wheat in Tehran city just covers 6% of Tehran’s population wheat requirement while it consumes 25% of water consumption in Tehran city.

CONCLUSION: The preliminary analysis in this study, through the case study of Tehran, shows that unplanned and rapid Urbanization of cities in Iran in the past has threatened not only water and food security but also created dramatic predicaments for the individuals who live in cities.

In this paper for the first time by using CROPWAT model a very precious estimation of wheat and it requires irrigation water for Tehran city is done. According to the results, the water and food security and food availability base on the local wheat production is not reliable and is not supported, because the wheat production endorses only 546758 inhabitants or it covers only 6.2 % of the total requirement calories of Tehran’s inhabitances for each year. With comparing the results of Figure 10 and Figure 6 it is obvious that more than 25 percent of total water usage in Tehran during 2010-2011 is just related to the production of the Wheat crop and it shows the Tehran water management and consumption are not in a sustainable way. It should be noted that this Water usage is measured only in terms of water volumes consumed and the volume of polluted water is not considered.

Finally, to carry out good environmental sustainability in Iran urban centres like Tehran, the study has prof ered the following recommendations:
Promoting sustainable, fair, and efficient water use through the development of shared standards on water footprint accounting and guidelines for the reduction and offsetting of impacts of water footprints.

To attain sustainable growth requires that all stakeholders must be actively mobilized towards ensuring that the following strategies; some of which have been outlined in the UN Millennium Project are realizable.55

The high-ranking authorities should ensure that adequate funds are disposed of for educating and raising people’s awareness to convert in their patterns of water and energy resource consumption, alteration in their diet and lifestyle especially for the vulnerable group of the urban population.

Existing rules and regulations relating to housing and urban development should be reviewed. Regional planning laws of the country should also be reviewed to allow for effective poor neighborhood upgrading and urban renewal.

The high-ranking officials on its own part should take a holistic approach by embracing and incorporating the development of rural communities into the sustainable plan agenda to reduce the rate of rural-urban migration as well as the poverty and inequality bedeviling the nations socially, culturally, and economically.

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