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Potential of Rainwater Harvesting for Utilizing in Urban Agriculture (Case study: Mashhad City)

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Abstract

Water scarcity and water issues can be identified as an important challenge to food security, ending hunger and reducing poverty in the 21st century. Therefore, new and effective management mechanisms, along with investment in water technologies and infrastructure, will be needed to reduce the impact of growing water scarcity to mitigate the effects of depleting water resources to ensure that water is allocated for efficient use. One of the new water resources are unconventional resources which received much attention in recent years due to emerging of urban agriculture. One of unconventional resources is rainwater harvesting. Cities, as areas with large levels of impenetrable or low-infiltration lands with different uses, have the potential to harvest significant rainfall. With the rise of urban agriculture and its role in food security, rainwater harvesting seems more necessary than ever. In Iran, a large part of rainwater runoff is wasted, which by collecting and using it, while reducing the risk of flooding, a significant part of this water can be used. Using the information of Khorasan Razavi Meteorological Organization data from 1979 to 2019 (rainfall recorded in the past 30 years in Mashhad synoptic station) and Mashhad Municipality (for occupation area of the buildings) and the model of rainwater harvesting provided by FAO, rainwater harvesting for Mashhad has been mesured. According to residential, commercial and organizations building rooftop area, and based on runoff coefficient of 0.8, rainwater harvesting and storage capacity of 13,535,514,981 liters per year for the city of Mashhad is expected. Based on specific proposed agricultur products and their cultivation requirements, the city of Mashhad can annually produce 73,164,946 kg of tomatoes, 63,250,070 kg of peppers or 63,250,070 kg vegetables, 56,397,979 kg of cucumbers or 56,397,979 kg squash or 67677574/91 kg of lettuce or 67677574/91 kale or 47,493,035 kg of broccoli by utilizing rainwater harvesting.

Resumen

La escasez de agua y los problemas relacionados con el agua pueden identificarse como un desafío importante para la seguridad alimentaria, la erradicación del hambre y la reducción de la pobreza en el siglo XXI. Por lo tanto, se necesitarán mecanismos de gestión nuevos y efectivos, junto con la inversión en tecnologías e infraestructura del agua, para reducir el impacto de la creciente escasez de agua para mitigar los efectos del agotamiento de los recursos hídricos y garantizar que el agua se asigne para un uso eficiente. Uno de los nuevos recursos hídricos son los recursos no convencionales que recibieron mucha atención en los últimos años debido al surgimiento de la agricultura urbana. Uno de los recursos no convencionales es la captación de agua de lluvia. Las ciudades, como áreas con grandes niveles de tierras impenetrables o de baja infiltración con diferentes usos, tienen el potencial de cosechar lluvias significativas. Con el auge de la agricultura urbana y su papel en la seguridad alimentaria, la recolección de agua de lluvia parece más necesaria que nunca. En Irán, se desperdicia una gran parte de la escorrentía de agua de lluvia que al recolectarla y usarla al mismo tiempo que se reduce el riesgo de inundaciones, se puede aprovechar una parte importante de esta agua.

Usando la información de los datos de la Organización Meteorológica de Khorasan Razavi de 1979 a 2019 (lluvia registrada en los últimos 30 años en la estación sinóptica de Mashhad) y el municipio de Mashhad (para el área de ocupación de los edificios) y el modelo de recolección de agua de lluvia proporcionado por la FAO, la recolección de agua de lluvia para Mashhad ha sido medido. De acuerdo con el área de la azotea de edificios residenciales, comerciales y de organizaciones, y con base en un coeficiente de escorrentía de 0,8, se espera una capacidad de almacenamiento y recolección de agua de lluvia de 13.535.514.981 litros por año para la ciudad de Mashhad. Según los productos agrícolas específicos propuestos y sus requisitos de cultivo, la ciudad de Mashhad puede producir anualmente 73 164 946 kg de tomates, 63 250 070 kg de pimientos o 63 250 070 kg de hortalizas, 56 397 979 kg de pepinos o 56 397 979 kg de calabaza o 67677574/91 kg de lechuga o 74/6775 91 col rizada o 47.493.035 kg de brócoli mediante la utilización de la recolección de agua de lluvia.

Keywords: Rainwater harvesting, urban agriculture, Runoff, urban agriculture.

1. Introduction

Water is among the goals of sustainable development and sustainable development depends on it (Tariqul Islam et al., 2017). But water and wastewater are facing crisis, and this is one of the most important issues for the international community. Water scarcity can cost some regions up to 6% of their GDP, stimulate migration and, in the most extreme cases, lead to internal conflicts. To this end, the World Bank has focused its strategic action plan for water on three main issues: sustainable water resources, providing service and resilience. Sustainability is ensuring that today existing resources can continue to benefit future generations. Creating resilience to the weather requires the development of structurs and approaches that can help save lives and livelihoods. If water-related services are flexible, they are better able to cope with shocks and tensions and continue to provide basic services to the public (World Bank,2019). Strong economies need healthy, skilled and educated people. Lack of safe water not only damages the economic potential, but also damages the dignity, safety, health and educational achievements of the people (World Bank, 2019). But smart investments in clean water and waste water prevent irrational mortality and change lives: healthier children become healthier adults who can realize their potential and cotribute more in the economy (World Bank, 2019). It is predicted that in the future water resources will be distributed very unevenly, while many countries have abundant water, other countries are managing severe shortages.

In addition, even though water may seem abundant, much of it is not available or is too expensive for development, or not close to lands that can be used for agriculture (FAO, 2017). Therefore, new and effective management mechanisms, along with investment in water technologies and infrastructure, will be needed to reduce the impact of growing water scarcity to mitigate the effects of depleting water resources to ensure that water is allocated for efficient use, protection of natural resources and to ensure access to water for domestic use and agricultural production (FAO, 2017).

One of the new mechanisms is the use of unconventional water sources. The use of unconventional water resources as a substitute for fresh water, although is currently a minor resource, is riseing in some regions and countries. One of the unconventional sources is rainwater harvesting. With the rise of urban agriculture and its role in food security, which has received much attention in recent years, rainwater harvesting seems more necessary than ever (FAO, 2017). Cities, as areas with large levels of impenetrable lands with different uses, have the potential to harvest significant rainfall. In Iran, a large part of rainwater runoff is wasted, which by harvesting, while reducing the risk of flooding, a significant part of this water can be used.The use of impermeable urban surfaces, especially the roof-top surfaces of buildings, makes it possible to collect rainwater from rainfall, to meet part of the non-drinking needs of residents of buildings and reduced water supply costs, For washing, garden and green space irrigation and other non-drinking uses (Rashidi Mehrabadi et al., 2012). Rainwater harvesting systems are used worldwide to capture, store, and optimally use to improve the social, economic, and environmental well-being of families, communities, or regions, and are an economical, safe, and potentially successful resource (FAO, 2014). According to the FAO (FAO, 2014), some of the benefits of rainwater harvesting are:

1) Cost-effective and safe method for water supply.
2) Providing clean water for domestic and agricultural use and reducing the burden and reliance on groundwater and surface water resources.
3) An important source of water for isolated rural communities that is not covered by the urban water and sewage system.
4) Providing water for gardens and house green space.
5) Rainwater harvesting systems can supplement the school's water supply.
6) Water supply for crops and livestock in areas that have little or no water supply.
7) Promote food security potentially.
8) Reducing the effect of drought on crops and horticulture (FAO, 2014).

Examining the research background and documents, it can be seen that the researches related to rainwater collection in Iran are very limited. Therefore, there is still related studies in this field. Therefore, the present study aims to investigate the potential of rainwater harvesting for various uses, especially urban agriculture in the city of Mashhad in Iran.

2. The importance of the subject

By 2025, Iran should be able to add 112 percent to its extractable water resources (Ehsani and Khaledi, 2003). Researchers in water resources believe that due to climatic conditions and excessive consumption in most metropolitan areas, the problem of water shortage can be reduced to some extent by rainwater harvesting (Rashidi Mehrabadi et al., 2012). Also, according to the World Water Council (WWC) and Food and Agriculture organization (FAO), the outlook for water and food security in 2050 indicates that many areas will face significant water shortages. Water shortages will lead to increased competition, which in turn limits agricultural production and affects the incomes and livelihood opportunities of many rural and urban residents. Excessive use and destruction of water resources in important production areas threatens the sustainability of water-dependent livelihoods and agriculture (FAO & WWC, 2015). The problem is that with increasing competition and pressure on land and water resources, some of the countries experiencing the fastest population growth are those with the least land and water resources. By 2050, much of the net growth in the global population will occur in developing countries’ cities, thus increasing urban demand for water and food will occur.

However, the distribution of land and water resources is not in favor of countries that need to produce more in the future. Therefore, many areas in crisis will need water management innovations, that some of this crisis is due to increased competition for supply of limited resources of water (FAO, 2017).

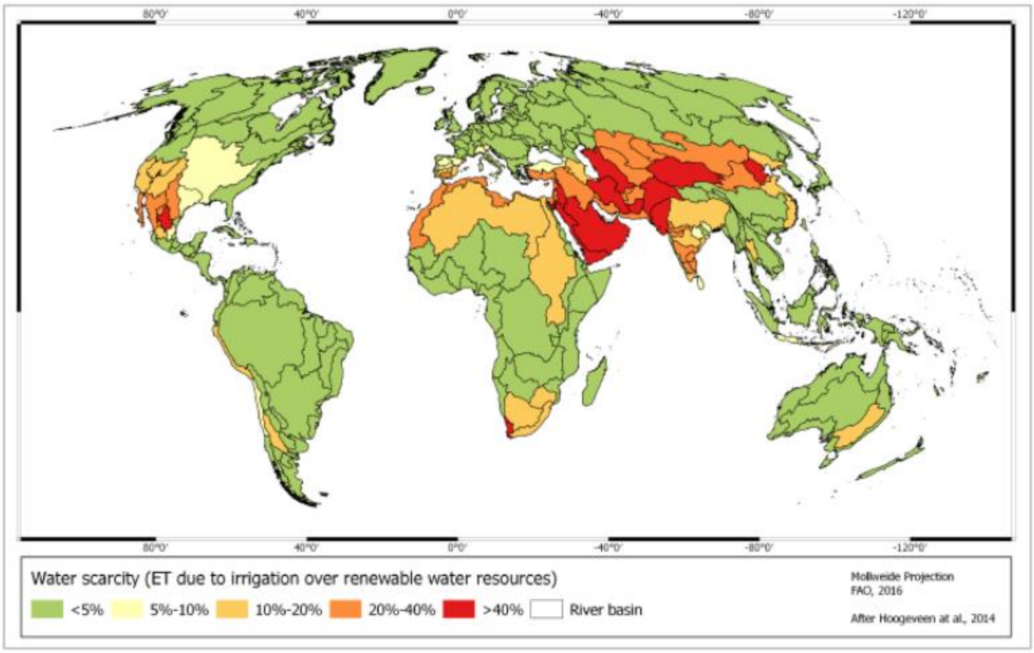


Figure 1 - Water crisis in the world (FAO, 2017)

3. Literature and background

In this section, it seems necessary to describe the concepts of this topic and the operational and research background in the field. Rainwater harvesting is the act of directing, collecting and storing rainwater runoff and can be done in urban areas (roofs, ground level, and and non-urban catchments) and stored in physical structures or soil profiles (FAO, 2014; Liaw & Chiang, 2014; Mahmoud et al., 2014). Rainwater harvesting for agriculture is the collection, transfer, storage, deliver and use rainwater runoff for food production. In practice, rainwater harvesting means deliver and operation at the collection point on the farm (FAO, 2014). Runoff is the water that flowing on the ground that occurs when it rains (FAO, 2014). Rainwater harvesting basin is an area that collects rainwater runoff for a specific farm. Basin surfaces usually include roofs of farmhouses or greenhouses, plastic floor coverings (greenhouses), paved surfaces of sidewalk and airports, and natural slopes. Harvesting basin in rainwater collection efficiency varies according to the type of surface, surface area, surface roughness and the amount and length of slope (FAO, 2014).

Rainwater collection systems date back to thousands of years ago, and ancient civilizations used this water for drinking, irrigation, and washing (Liaw & Chiang, 2014; Prinz, 1996). Rainwater harvesting is one of the most significant management technology to deal with water scarcity, which is developing rapidly in arid areas. Today, because of development of societies and the increasing expansion of cities and their borders, the impenetrable level is increasing (Melo dos Santos & de Farias, 2017). According to studies, harvesting rainwater from rooftops is not limited to specific parts of the world and has long been used in many countries. In countries such as China, India, Thailand, Malaysia, Singapore, Guam, the United Kingdom, Germany, Taiwan, Fuji, etc. Collecting rainwater from rooftops in Iran, has been mainly for drinking water and domestic use (Sepehri et al., 2018). Numerous reports through global organizations such as the FAO and the World Water Forum and the World Bank (FAO 2014 & 2017, FAO & WWC, 2015) have highlighted the importance of this issue.

On the other hand, various studies at the international level have examined this potential in different countries:

Christian Amos et al. (2018) in a study based on the three United Nations Sustainable Development Goals (i.e. clean and sustainable cities; health and well-being without hunger) highlight the lack of initiative in the use of rainwater harvested in urban agriculture, discover barriers and pave the way for new research in the model of sustainable urban development. The results show that there is significant potential for urban agricultural water supply by designing a custom roof-top rainwater harvesting system. For example, one study reports that up to 41% of urban gardening sites in Rome can be covered by pumping water from local roof-tops. Irrigating a small garden (20 square meters) with harvested rainwater can increase its yield by about 20% and provide the calories needed by a typical family. Further research on the integration of rooftop rainwater harvesting and urban agriculture is needed to maximize its contribution to food production and sustainability. Sepehri et al. (2018) carried out a study for the city of Hamadan, Iran. To evaluate the effect of rainwater harvesting on runoff volume and types of household consumption, first the flood rate with different return periods was calculated using SCS method in HEC-HMS model as a popular and effective method in flood risk studies. In the next step, to evaluate the effect of rainwater harvesting system on the volume of flood, assuming that all residential buildings in the city of Hamedan use rainwater harvesting system, a deviant factor with a constant flow whose amount is equal to rainwater harvesting from the roofs was deducted. The results showed that the effect of reducing rainwater harvesting system on runoff volume varies from 145.95 to 333.06 with 24 hours of rainfall for a period of 2 to 100 years. On the other hand, this reduction effect can increase the household consumption requirement from 202.50% to 462.11% and its economic aspect can be from 10.008.98 to 22.840.65 US dollars. Dos Santos (2017) showed that by utilizing rainwater harvesting, the potential for saving drinking water for multi-city urban areas in the semi-arid region of Pernambuco, northeastern Brazil, could reach 25%. The results also show that reducing the pressure on the public water supply system is possible only by combining rainwater harvesting in standard methods by local residents. Tariq al-Islam et al. (2017) by using water efficiency and cost-benefit ratio analysis shows that vegetables and rice can be produced by irrigation with rainwater has a more profitable harvest. Also, the product intensity increases from 155% to 300%.

4. Methodology

The basis of this method is to allocate a surface of land to collect rainwater and then store it for use at the required time. By collecting regional information and implementing water extraction systems, rainfall can be harvest and stored directly and then consumed in various ways. For this purpose, first comprehensive information about the amount of available roof surfaces in the city of Mashhad is obtained and then using rainwater harvesting equation presented by FAO (2014), the amount of water harvested in cubic meters is measured and finally the amount of production of selected produce that will be irrigated by stored rainwater is calculated.

5. The area specifications

The city of Mashhad has a variable temperate climate and is somewhat prone to cold and dry, with hot and dry summers and cold and humid winters. The maximum temperature in summer is 43 celcius degrees and the minimum in winter is 23 degrees below zero. According to the general population and housing census of 2016, Mashhad, with a population of 3,001,184 people, is the second most populous city in Iran. Due to the presence of the shrine of Imam Reza (peace be upon him), this city annually receives more than 27 million pilgrims from inside and two million pilgrims from abroad. For this reason, the city of Mashhad has a very high demand for water, and when receiving pilgrims in the summer, it sometimes encounters water shortages. In recent years, due to climate change, reduced rainfall and increasing population, the uncontrolled extraction of groundwater and surface water resources has increased significantly (Tabatabaee et al., 2016). In addition to creating a water crisis, these factors have also reduced the quality of surface and groundwater.

6. Results

6-1. Average rainfall harvesting

Mashhad has 13 urban areas in which all areas of Mashhad were selected as the study area. Figure 3 and Table 2 show the available roof area of each area by grain size. Using monthly rainfall data in Mashhad between 1979 and 2017, the minimum and maximum rainfall per square meter for each month during these 30 years (Figure 2) and also the average rainfall per square meter per month (Figure 3) was calculated. According to FAO (2014), the potential for rainwater collection from the roofs of buildings is calculated using the following equation:

$$P = A * R * C \qquad (1)$$

Where P is the water harvested in cubic meters, A is the harvested area of the building in square meters, R is the average rainfall in meters and C is the runoff coefficient, which is considered to be 0.8 due to roof-top materials in Mashhad. The coefficient is based on FAO (2014) and materials used for rooftops in Mashhad which are asphalt and bituminous waterproofing.

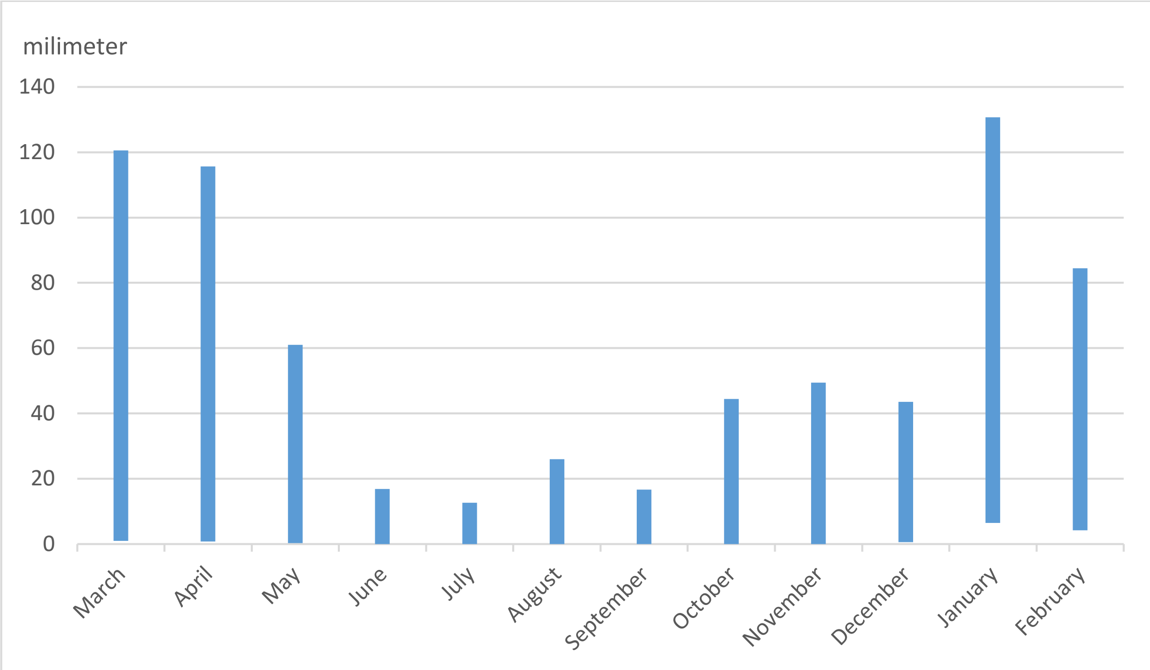


Figure 2- Rainfall recorded in the past 30 years in Mashhad synoptic station (1989-2019)

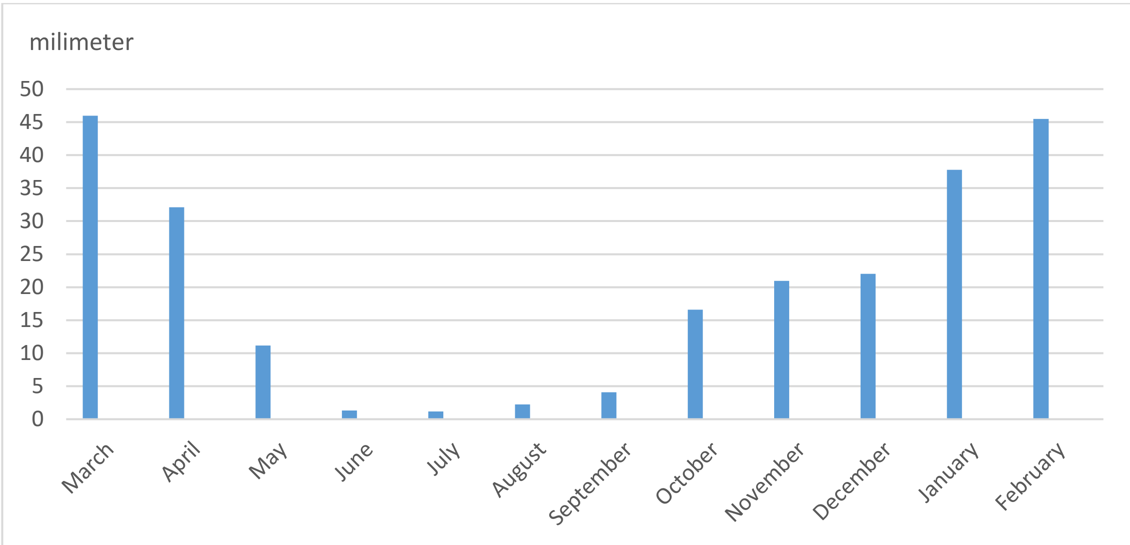


Figure 3- Average rainfall for each month (mm/m^2) (1989-2019)

6-2. Rainwater storage

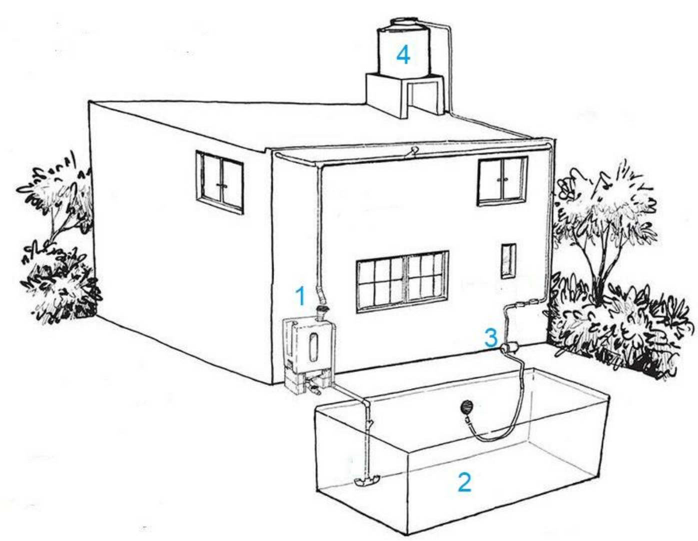
If the house has a basement or yard, the tank will be installed in these locations or will be built in a cylinder with a height from the roof to the yard level, and if these spaces are not available, it will be circular or rectangular installed on the roof-top (Figure 2). The construction of each of these solutions must be done according to the expert's opinion so that its meet technical standard for building capacity.

The general plan of how to build and design a rainwater storage system can be shown in the following figure, in which number one indicates a sand filter (to prevent foliage and mud particles from entering the tank), tank number 2, number three pump No. 4 is a 60 liter drip irrigation tank. Water supply system and related costs are listed in Table 1.

Table 1- Costs related to the construction for rainwater storage

Item		Price(IRR)
1000 litter tanker	Beton or cement	50,000,000
	Polyethylene	25,350,000
Pomp		500,000
Sand filter		-
pipe		2,000,000

Figure 2 - Overview of rainwater harvesting and storage system



6-3. Available space in the City

In order to consider the granulation in the city of Mashhad for the existing urban areas of the roof-top to harvest rainwater, the following division has been determined. These classifications include: education, transportation services, religious, government and public offices, housing, higher education, education (local scale), warehouses, gardens and farms, urban facilities, commercial, urban equipment, workshop production, sanctuaries (Underground networks), sanctuaries (natural features), medical, permanent residence, temporary residence, religious sciences, leisure and recreation, cultural (district), green space (except parks), judicial and disciplinary (city and suburban), judicial And disciplinary (region), sports (city), sports (neighborhood), sports (region), sports (district). Mashhad has

13 urban areas in which all areas of Mashhad were selected as the study area. Figure 3 and Table 2 show the available area by granulation.

Table 2 – Occupied area of buildings in Mashhad by granulation (m^2)

Granulation	Quantity	Share of total area	Average	Total area(m^2)
Less than 70	155,386	28%	43	6,661,498
70-120	148,625	26%	100	14,880,841
120-200	122,917	22%	158	19,419,055
200-500	114,673	20%	286	32,824,394
500-800	8,568	2%	605	5,181,924
More than 800	11,662	2%	13,494	157,372,062
Total	**561,831**	**100%**	**14686**	**236,339,774**

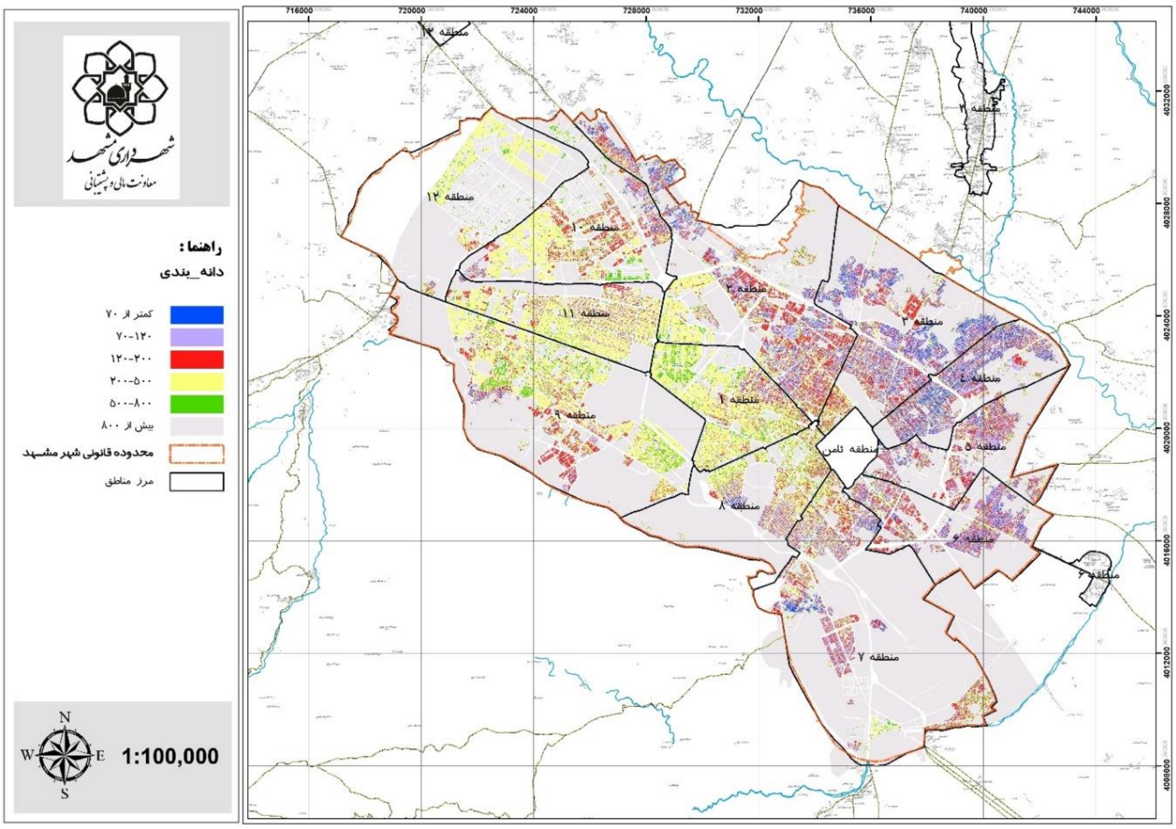


Figure 3- Grain image of buildings in Mashhad city

Table 3- Fesable occupied area

Land use	Number of patch	Average area of each patch (m^2)	Total area (m^2)	Occupied rate	Available area (m^2)
Permanent residence	321,489	207	66,691,204	70	46683842
Unclassifiable[1]	27,865	1,676	46,712,484	0	0
Gardens and Agriculture	997	27,797	27,713,569	0	0
Organization	702	18,744	13,158,477	30	3947543
transportation	318	34,275	10,899,437	10	1089943
Park	1,327	8,196	10,875,568	4	435022
Research and Technology	180	48,072	8,653,006	30	2595901
Natural zone	37	215,107	7,958,977	0	0
Commercial	19,216	332	6,385,846	90	5747261
Warehouse	2,274	1,725	3,922,187	50	1961093
Industrial	3,252	1,181	3,841,507	50	1920753
Right-of-way	449	7,960	3,573,975	0	0
Educational	1,268	2,810	3,563,539	30	1069061
Sport	266	6,459	1,717,993	30	515397
Urban facility	279	5,924	1,652,911	20	330582
Residential center	1,285	1,155	1,484,417	90	1335974
Healthcare center	362	3,973	1,438,380	50	719189
Urban equipment	159	6,601	1,049,541	0	0
Residential enclosure	6	137,556	825,339	50	412669
Art and cultural	124	6,353	787,805	80	630244

[1] In this Item, the area is not determined by municipality of Mashhad for any utilization sofar

Religious	1,187	484	574,316	80	459452
Entertainment and tourist	48	8,655	415,437	30	124631
Land marks	51	4,357	222,229	0	0
Temporal residential	434	393	170,362	80	136289
Non-profit enterprise	264	502	132,491	90	119241
Total	383,839	-	224,420,994	-	70234096

According to the data obtained from Mashhad Municipality, the total area of different land uses in Mashhad is 235,532,352 square meters, of which the available occupancy level will be 70,234,096 square meters, which is shown separately table 3. Therefore, considering the available roof area for rainwater harvesting and the information in Figure 4, using Equation (1), an average of 13,535,514,981 liters of rainwater per year can be obtained from the roof-tops in the city of Mashhad.

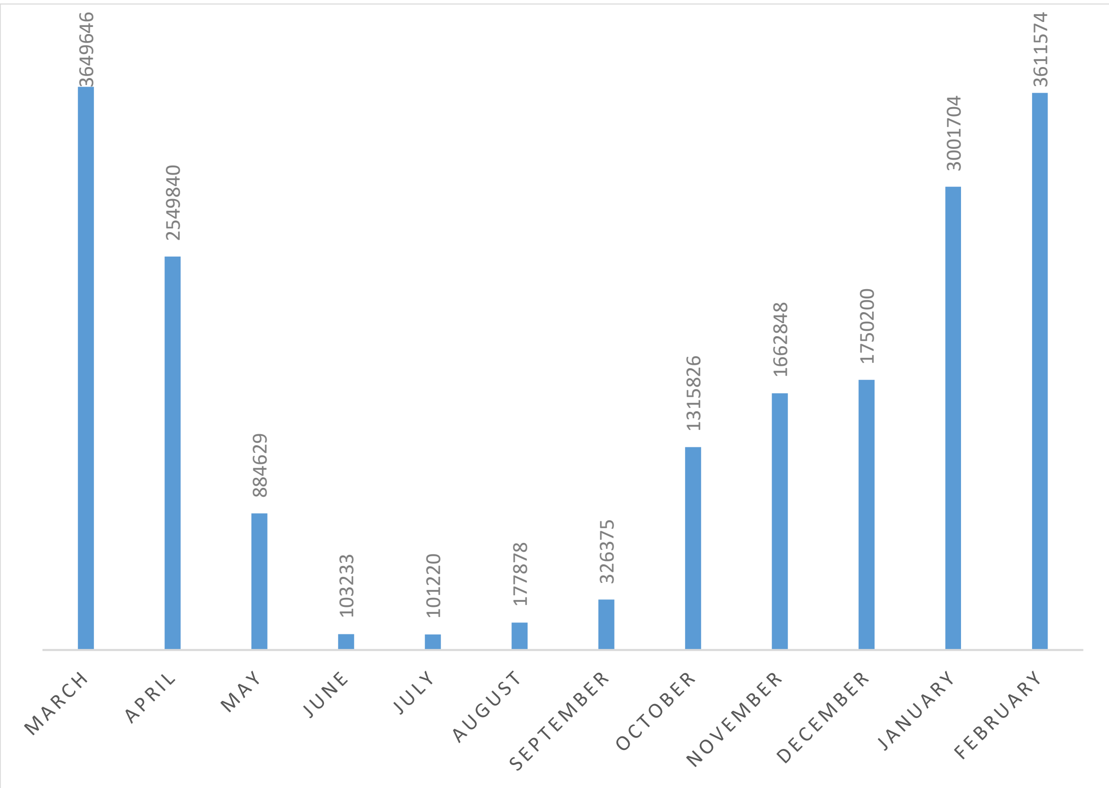


Figure 4- Average rainwater storage in different months of the year in Mashhad city (liter)

7. **Potential agricultural production**

Using the information obtained from Mashhad Municipality, the amount of available area for agricultural production is shown in Table 3. According to the water requirements of selected products suitable for the weather conditions of Mashhad, which is based on literature and a survey of plant production experts of the Agricultural Organization of Khorasan Razavi, the potential production of each item calculated according to equation (2) And the results are shown in table 4.

$$I_i = WC_i * P \qquad (2)$$

Where, I_i is annual production of item *i*, WC_i is water consumption for each item cultivation and *P* is annual rainwater harvesting.

Table 4- Expected production of selected agricultural products harvested by rainwater

Item	Water consumption (L/Kg)	Annual rainwater harvesting (Liter)	Potential production (Kg)
Tomato	185	13,535,514,981	73,164,946
Peper	214	13,535,514,981	63,250,070
Cucumber	214	13,535,514,981	56,397,979
zucchini	240	13,535,514,981	56,397,979
Letus	240	13,535,514,981	56,397,979
Broccli	200	13,535,514,981	67,677,574
Leafy vegetables	214	13,535,514,981	63,250,070

8. **Conclusion**

Adequate access to food and water is essential for life and economic and social development. Water scarcity and water issues can be identified as an important challenge to food security, ending hunger and reducing poverty in the 21st century. In other words, food supply needs water resources and since water shortage is the most important factor limiting the development of the country, any investment in the supply and proper use of this vital resource is necessary and required. Therefore, due to the limited water resources in Iran, it seems that the optimal use of existing water resources, technical use of unconventional water resources and surface water harvesting are among the most practical methods to reduce the problem of water crisis. Rainwater harvesting is a method that can provide part of the water needed by society, especially for micro consumption. Rainwater harvesting methods, while simple and easy to implement, have lower operating costs than other water supply methods.

Among the benefits of rainwater harvesting systems are the full or partial supply of required water, saving existing water resources, reducing runoff and the problem of flooding, as well as reducing the cost of wastewater treatment. According to the avalable level of roof-top area, with a runoff coefficient of 0.8, the average potential to harvest and store rainwater is 13,535,514,981 liters per year for the city of Mashhad. Based on the proposed produces and their cultivation requirements, the city of Mashhad can annually produce 73,164,946 kg of tomatoes or 63,250,070 kg of peppers or vegetables or 56,397,979 kg of cucumbers or squash or 67,677,574 kg of lettuce or cabbage or 47,493,035 kg of broccoli. Therefore, it is recommended that in addition to the many positive effects and consequences of urban agriculture, supporting packages, encouragement and sufficient cultural preparation be provided for the public acceptance of this project so that people can enjoy its benefits. In this regard, it is suggested that policymakers and municipality authorities provide adequate structural and financial supports to encourage people for utilizing urban rainwater harvesting and urban agriculture.

Reference

1) Christian Amos, C., Rahman, A., Karim, F., Mwangi Gathenya, J. 2018. A Scoping Review of Roof Harvested Rainwater Usage in Urban Agriculture Australia and Kenya in focus. *Cleaner Production*, 202: 174-190.
2) Dos Santos, S. 2017. Potential for rainwater harvesting in a dry climate Assessments in a semiarid region in northeast Brazil. *Cleaner Production*, 164: 1007-1015.
3) Ehsani, M., Khaledi, H. 2003. Recognition and Promotion of Agricultural Water Productivity in order to Ensure Water and Food Security of the Country. *11th Conference of the National Committee for Irrigation and Drainage of Iran*, 2003, Tehran, Iran.
4) FAO. 2014. Compendium on Rainwater Harvesting f or Agriculture in the Caribbean Sub-region.
5) FAO. 2017. Water for Sustainable Food and Agriculture, A Report Produced for the G20 Presidency of Germany. Rome.
6) FAO & WWC. 2015. Towards a Water and Food Secure Future: Critical Perspectives for Policy-makers, Food and Agriculture Organization of the United Nations, Rome, 2015. World Water Council, Marseille.
7) Liaw, C.H., Chiang, Y.C. 2014. Dimensionless Analysis for Designing Domestic Rainwater Harvesting Systems at the Regional Level in Northern Taiwan. *Water*, 6(12): 3913-3933.
8) Mahmoud, W.H., Elagib, N.A., Gaese, H., Heinrich, J. 2014. Rainfall Conditions and Rainwater Harvesting Potential in the Urban Area of Khartoum. *Resources, Conservation and Recycling*. 91: 89-99.
9) Melo dos Santos, S., de Farias, M. M. M. W. E. C. 2017. Potential for Rainwater Harvesting in a Dry Climate assessments in a Semiarid Region in Northeast Brazil. *Cleaner Production*, 164: 1007-1015.
10) Okhravi, S.S., Salmian, S.S., Malekian M.M., Mousavi S.S. 2013. Investigation of Locating Areas Prone to Rainwater Harvesting Using GIS and MDSS Analysis. 2nd National Conference on Rainwater Harvesting Systems, 2013, Mashhad, Iran.
11) Prinz, D. 1996. Water Harvesting-past and Future, in Sustainability of irrigated agriculture, *Springer*: 137-168.
12) Rashidi Mehrabadi, M ., Saghafian, B., Shamsaii, A . 2012. Evaluation of Rainwater Harvesting Performance in Residential Areas to Meet Water Needs (Case study: Qazvin city), *1st National Conference on Rainwater Catchment Systems*, Mashhad, Iran.
13) Sepehri, M., Malekinezhad, H., RezaIlderomi, A., Talebi, A., Hosseini, S.Z. 2018. Studying the Effect of Rain Water Harvesting from Roof Surfaces on Runoff and Household Consumption Reduction. *Sustainable Cities and Society*. 43: 317-324.
14) Shoaei, D., Qudusi, J., Taluri, A.R. 2013. Rainwater Catchment System Systems for Sustainable Development of Environmental Resources. Council for Scientific Research, Registration Number 822.

15) Tabatabaee, S.A., et al. 2016. Mashhad Wise Water Forum: a path to sustainable water resources management in a semi-arid region of Iran. In EGU General Assembly Conference Abstracts.
16) Tariqul Islam, Md., Mohabbat Ullah, Md., Mostofa Amin, M. G., Hossain, S. 2017. Rainwater Harvesting Potential for Farming System Development in a Hilly Watershed of Bangladesh. *Applied Water Science*, 7: 2523–2532.
17) World Bank Group. 2019. Working Together for a Water-Secure World.