# Predicting the Impact of Internet of Things on the Value Added for the Agriculture Sector in Iran Using Mathematical Methods

Hanieh FaghihKhorasani, Abbas FaghihKhorasani

Faculty of Social Sciences, University of Tehran, Iran

## Abstract

In terms of water resources, Iran has less fresh water than its population demands. Also, due to climate change, inefficient management and excessive consumption of this vital resource, the water shortage situation is becoming more critical day by day. Searching for a solution for sustainable use of water sources, this study proposes utilizing the Internet of things technology in order to implement smart irrigation in agricultural lands in Iran. Investigating the economic impact of the Internet of Things in Iran's agriculture sector is the purpose of this article. The most important advantages of using smart irrigation are decreasing water consumption and increasing the productivity of agricultural yields (e.g., fruits, vegetables, etc.). This research attempts to predict Iran's economic growth in the event of smart irrigation implementation in agricultural fields and farms. The effect of investment in smart irrigation on water consumption and agricultural production is estimated by regression with cross-sectional data. In the end, by using the information obtained through the mathematical method, Iran's economic growth through GDP growth is estimated in the case if the Internet of things technology is fully implemented and the full benefits of using this technology are gained.

## Keywords

Internet of Things, technology, smart irrigation, economic growth, gross domestic product, Iran.

FaghihKhorasani, H. and FaghihKhorasani, A. (2022) "Predicting the Impact of Internet of Things on the Value Added for the Agriculture Sector in Iran Using Mathematical Methods", *AGRIS on-line Papers in Economics and Informatics*, Vol. 14, No. 3, pp. 17-25. ISSN 1804-1930. DOI 10.7160/aol.2022.140302.

## Introduction

Iran is one of the member countries of the Middle East and North Africa[1] region. All the countries in MENA top the list of the countries enjoying least water resources (in terms of freshwater) in the world. Due to the climate change, these countries are going through frequent, severe, and prolonged droughts that have left them in high water stress. Thus, these countries will be the first victims of the water shortage crisis in the world (Perry and Steduto, 2017).

Iran, with approximately 1.22 percent of the world's landmass and 1.16 percent of the world's population, accounts for only 0.25 percent of the world's freshwater resources (Vallée and Margat, 2003); Iran's rank in terms of its share of freshwater in the total existing in the world is 54th from the end (Perry and Steduto, 2017). Moreover, about 72.6% of the total renewable freshwater resources are being used in Iran (World Trade Report ,2013) which 92.2% of it is used in agriculture. Despite the limited water resources of the country and the irregular use of this irreplaceable source, the use of water in the agricultural sector is not optimal and its efficiency is very low. In other words, not only is water used much more than other countries with similar climates, but the amount of Iranian agricultural products is very low compared to them.

A beneficial factor which can help reduce water consumption and increase productivity is the use of new technologies. In this day and age, Internet of Things (IOT) technology and its applications in various fields have attracted a lot of attention and are of great importance for the economy and society (Li, 2011). Governments, corporations, and consumers utilize the Internet of Things to introduce new business models, improve service delivery, enhance productivity and increase their overall quality (Garrity et al., 2015). The Internet of Things is used in various fields and sectors of the economy; one of which is in agriculture (Manyika et al., 2015). IoT technology has been introduced in smart irrigation, control and maintenance of agricultural machinery

[1] MENA

and tracking the status of livestock and poultry in a farm (Kim et al., 2008). Although the Internet of Things is a fairly new concept in Iran and it has a long way to be fully implemented in the agriculture sector, some first steps have been taken toward this goal.

The remainder of the article is organized as follows. The Materials and methods chapter is consist of three sections; the presentation of Iran's economic sectors and its current status is the objective of Section 1. In Section 2, we introduce the Internet of Things technology and its application in various areas. Finally, section 3 endeavors to explain the way the article was conducted. The result of the survey will be discussed in details in Results and discussion chapter. The last chapter is the conclusion of this study.

## Materials and methods

### Agriculture in Iran

Iran is a country in Southwest Asia and in the Middle East region with an area of 1,648,195 square kilometers. It is the 17th largest country in the world. Iran's gross domestic product (GDP) in 2018 is estimated to be 18619 thousand billion Rials[2]. Iran has four economic sectors as follows: "Agriculture", "Oil", "Industries and Mines" and "Services". The share of these groups in GDP is equal to 10, 12.3, 22.7 and 57.1 %, respectively (Central Bank of Iran[3]).

In terms of population, it is the second most populous country in the MENA region after Egypt, with a population of about 83.99 million (Central Bank of Iran). Iran is faced with impending water crisis as the climate changes. Iran has only 0.25% of the world's freshwater resources and, abysmally, 92.2 % of Iran's water consumption is used in the agriculture sector. The average use of water per capita in Iran's agricultural sector was 1,420 $m^3$ in 2011. Agricultural water consumption in Iran has an ascending trend such that the water usage had have increased from 63 BCM (billion cubic meters) in 2008 to 81 BCM in 2011(Hamdi et al., 2018).

The total area under cultivation in 31 provinces of Iran was 12,192,846 hectares in 2020; additionally, the total amount of agricultural products comprising 48 different fruits and vegetables was 91,793,888 ton (Deputy of Strategic Planning and Supervision of the Agriculture Ministry in Iran, 2020). The productivity, how much yields were harvested per hectare of land, of agricultural products in Iran was approximately 7528 kilogram per hectare; Iran's agricultural productivity is notably low compared to countries with similar climates.

[2] Iran's currency
[3] This is the latest report available

Repercussions of the climate change are inevitable; they should be addressed in water resources management (Heydari and Morid, 2020). Iran's economy will suffer severely in case of prolonged and consecutive droughts if the country does not prepare to face such phenomenon. Salami (2009) reports that in 1999-2000 drought, it was considered to be the worst one in Iran's history, the amount of money which was lost directly from agriculture sector was 1,605 million dollars and the overall GDP dropped 4.4 precents in that year (Salami et al., 2009). Enhanced water management and long-term resiliency to disasters and climate change are achievable by the use of digital technologies (Sarni et al., 2019). What we believe is that the Internet of Things is the technology which can not only help us to reach sustainable water use but it also will bring us economic prosperity.

### The Internet of Things

The Internet of Things, sometimes referred to as machine-to-machine communication technology, comprises of a set of smart devices equipped with sensors and microchips that are connected through a network, usually the Internet (Atzori et al., 2010; Li et al., 2014; Saidu et al., 2015). More than 9 billion devices worldwide are currently connected to the Internet, including computers and smartphones. This number is expected to increase dramatically in the next decade; the McKinsey Institute estimates it could reach 1 trillion devices (Manyika et al., 2015).

There are five necessary technologies in order to make IoT technology widely used: Radio Frequency Identification (RFID), Wireless Sensor Networks (WSN), Middleware, Cloud Computing and IoT application software (Atzori et al., 2010). In the ensuing paragraphs these technologies are defined.

**Radio Frequency Identification:** This technology which allows microchips to be designed for wireless data communications, has led to major advances in embedded communication devices. They help to automatically identify everything to which an electronic barcode is attached (Gubbi et al., 2013).

**Wireless Sensor Networks (WSN):** These networks include devices equipped with independent distributed sensors and are capable of monitoring physical and environmental conditions; WSN can work with radio frequency detection systems to monitor the status of factors such as location, temperature and motion (Atzori et al., 2010).

**Middleware:** it is a software layer that sits between software applications making it easier for software developers to communicate between input and output. The middleware hides details of various technologies that are irrelevant to IoT developers (Gubbi et al., 2013).

**Cloud Computing:** One of the most important results of IoT is the creation of an unprecedented amount of data (Gubbi et al., 2013). Many IoT applications require massive data storage, high processing speeds for real-time decision making, high-bandwidth networks, and high-speed data streams, either audio or video. Cloud computing provides an ideal solution for managing the data flow and processing it for countless IoT devices and humans in real time (Lee and Lee, 2015).

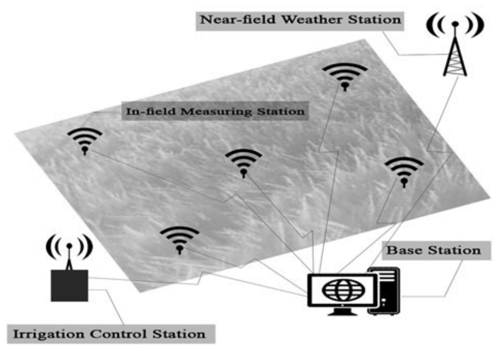
**IoT application software:** While devices and networks provide physical connectivity, IoT software provides reliable and robust device-to-device and human-to-device communication. IoT applications on devices must ensure that data and messages are received in a timely manner and they function properly (Lee and Lee, 2015).

Diverse areas can become the subject of IoT utilization; however, the specific area which this article is interested in is how the Internet of Things is implemented in agriculture.

In developing countries, irrigation is one of the main problems in agriculture (Nandurkar et al., 2014). In Iran, irrigation is done manually through traditional ways; so that the farmer irrigates at regular intervals, which sometimes leads to excessive use of water or in some cases the farmer neglects to irrigate diligently. Lack of water would slow the plant's growth, results in dehydration or small fruit and eventually leads to wilting the plant. Conversely, if there is more water than the plant's need, the nutrients in the soil would wash away culminating in plants' withering.

Smart irrigation helps farmers to prevent water wastage, minimize runoffs, improve the quality of their lands and crops by irrigation at the right time, accurately determine the soil's moisture level, eliminate human error (e.g. forgetting to turn off the valve after irrigating the land) and helps to save valuable energy, time and resources. Installation and configuration of intelligent irrigation systems are generally relatively simple. Estimating the water need, though, is somewhat difficult. There are different variables which must be taken into consideration; variables such as crop size, soil quality, irrigation process, precipitation, soil ability to retain moisture, temperature, and so forth can play a role in how much water a specific plant needs in a particular day.

The main technology used for smart irrigation is Wireless Sensor Networks; it enables irrigation systems to be very efficient and consume little water. An image of the distribution system of Wireless Sensor Networks in farmland is shown in Figure 1. This system consists of some measuring stations distributed throughout the land, an irrigation control station and one base station. In-field measuring stations are responsible for monitoring the soil's moisture, the soil's temperature and the air temperature. Nonetheless, a near-field weather station monitors meteorological information in the area such as: air temperature, relative humidity, precipitation, wind speed, wind direction and solar radiation. All data received from measuring stations is transmitted wirelessly to the base station. The base station processes the data through the decision programs and sends control commands including irrigation's time, the amount of water which is needed, direction the water should be sprayed and irrigation's speed to the irrigation control station; the irrigation control station becomes updated accordingly. Each existing sprinkler under the command of the control station would specifically irrigate the amount of water which is needed for each location on the ground (Kim et al., 2008).




Source: FaghihKhorasani and FaghihKhorasani (2022)

Figure 1: System layout of wireless sensor network for site-specific irrigation.

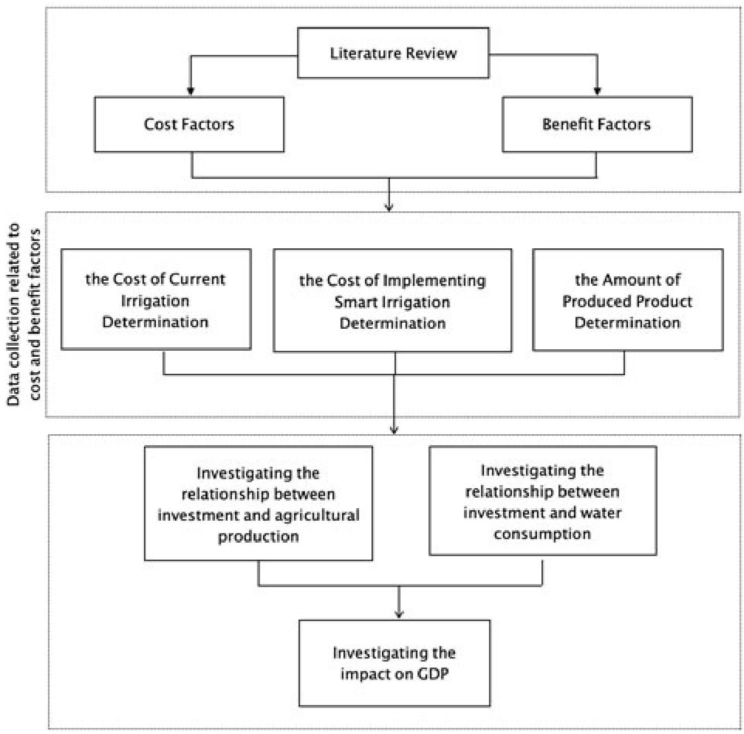
Using IoT in agriculture, the land is divided into smaller sectors where each sector receives customized treatments based on their location, soil type, and historical records (how much irrigation, fertilizers, seeds, and other farm inputs that specific sector used to receive by traditional farming). The Internet of Things' goal is to transform yields production and farm productivity dramatically by implementing better management (Raj et al., 2021). Thus, the first and the most important advantage of using IoT technology in smart irrigation is reducing water consumption between 20 to 40 %. The next major benefit resulting from irrigating plants just as much as they need is yield efficiency increase. If smart irrigation were implemented, agricultural yields would increase up to 20 % (Manyika et al., 2015).

## Methodology

The first step taken to accomplish this study was literature review (Figure 2). To determine the economic impact of IoT, benefit-cost analysis was used in this paper. Therefore, throughout the literature review, it was tried to find the answer to two questions. What are the cost factors of implementing smart irrigation technology in agricultural lands in Iran? What are the benefits of implementing smart irrigation technology in agricultural lands? It was elucidated in section 3 that the advantages which are the boons of IoT implementation are decrease in water consumption and increase in agricultural yields. These factors should be converted into commensurable units in order to calculate the economic impact. The cost factors for employing smart irrigation are: sensors, solenoid valves, servers, IoT software, central control board and so forth; the cost factors were extracted from several pilot smart irrigation projects in Iran.

Furthermore, for attaining the cost of irrigation in Iran, the amount of water consumption for each 48 agricultural yields was extracted from the report "number 47" provided by UNESCO in 2010[4] (Mekonnen and Hoekstra, 2010). By knowing the cost of water in Iran, the total cost of irrigation using traditional approaches was calculated. Total 69,630.97 million cubic meters of water is consumed in Iran for the purpose of irrigating 48 kinds of agricultural products. The price for each cubic meter of water is 600 Rials for agricultural consumption. The amount of each fruit and vegetable cultivated in Iran was gathered from the report of the Deputy of Strategic Planning and Supervision

[4] This report is the newest source available on water consumption for Iran.




Source: FaghihKhorasani and FaghihKhorasani (2022)

Figure 2: Schematic of article's methodology.

of the Ministry of Iran's Agriculture (2020). The products' price per kilogram are also procured in this report. The total Iran's revenue from agricultural yields was determined using these data. The first fifteen crops which comprise the most cultivated area in Iran are mentioned in Table 1[5].

## Results and discussion

In order to compute the evaluating relationship between the smart irrigation investments and either water consumption or agricultural production the ensuing steps have been taken. The cost of smart irrigation implementation was gained through further investigation in those pilot projects. Based on assembled information, the present cost of employing IoT was considered 1.05 billion Rials per hectare for further calculation. Annual costs of investing in smart irrigation was calculated from the following equation (McKinney and Savitsky, 2006).

Equation 1:

$$F = P(1 + i)^n \qquad (1)$$

- $F$: the future value of investing in smart irrigation technology.
- $P$: the present value of investing in smart irrigation technology.
- $i$: Interest rate (it is considered 15 %; it is equal to one-year bank's interest in Iran).
- $n$: number of operation years (in calculations, it is considered 10 years).

To obtain the relationship between the impact of investment and value-added resulted from each benefit (decrease in water consumption and increase in agricultural yields) of implementing smart irrigation, the following relationship is considered Equation 2:

$$Y = c + f(x) + \varepsilon \qquad (1)$$

- $Y$: value-added resulted from each benefit that is a dependent variable and a function of the amount of investment.
- $c$: width of origin.
- $f(x)$: the amount of investment in smart irrigation that is an independent variable which affects the value added of each mentioned benefit.
- $\varepsilon$ : a small amount that is considered for error.

In this study, using EViews 10, the impact of investment in smart irrigation on the value added resulted from water consumption saving and also the impact of investment in smart irrigation on value added resulted from increase in agricultural production is obtained by regression and cross-sectional data. The critical t is assumed to be equal to 2. The allowable error rate in this regression is 5 %. The F test is used for the significance test

5 Due to high volume of data, the first fifteen crops with the most cultivated area are mentioned in Table 1. Further information is available through online sources.

| Crop | Cultivated Area (Ha) | Yield (Ton) | Price (Rial / kg) | Water Consumption ($Mm^3/yr$) |
|---|---|---|---|---|
| **Wheat** | 1,960,295 | 8,303,502 | 75,000 | 10,939.58 |
| **Rice, paddy** | 854,874 | 4,560,693 | 82,500 | 4,526.29 |
| **Barley** | 691,136 | 2,618,560 | 34,000 | 225.76 |
| **Pistachios** | 424,358 | 386,905 | 2,450,000 | 3,129.42 |
| **Apples** | 222,253 | 4,217,172 | 63,458 | 1,710.51 |
| **Grapes** | 218,263 | 3,141,837 | 140,000 | 0.09 |
| **Dates** | 210,333 | 1,301,642 | 92,000 | 2,064.74 |
| **Potato** | 152,802 | 5,636,507 | 12,015 | 963.83 |
| **Rapeseed** | 147,099 | 261,012 | 150,000 | 0.00 |
| **Walnuts** | 133,138 | 258,412 | 1,100,000 | 655.75 |
| **Maize** | 132,572 | 1,089,410 | 35,250 | 805.04 |
| **Tomatoes** | 131,663 | 6,359,703 | 10,000 | 1,014.51 |
| **Oranges** | 124,784 | 2,700,531 | 40,343 | 958.65 |
| **Sugar Beet** | 108,433 | 5,606,851 | 14,733 | 1,714.48 |
| **Beans, dry** | 104,619 | 249,001 | 79,791 | 272.1 |

Source: Deputy of Strategic Planning and Supervision of the Ministry of Iran's Agriculture report, 2020; Mekonnen and Hoekstra, 2010

*Table 1: Crops and their related information in Iran.*

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| Investments | 0.007828 | 0.000644 | 12.14954 | 0.0000 |
| c | 16368.61 | 24425.27 | 0.670151 | 0.5061 |

Source: FaghihKhorasani and FaghihKhorasani (2022)

Table 2a: The relationship between the impact of investment and value-added resulted from savings in water consumption.

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| Investments | 0.108973 | 0.012958 | 8.409537 | 0.0000 |
| c | 1726427.0 | 491243.8 | 3.514399 | 0.0010 |

Source: FaghihKhorasani and FaghihKhorasani (2022)

Table 2b: The relationship between the impact of investment and value added resulted from increasing of agricultural .

of the whole regression, in which the maximum allowable error is equal to 5 %. The result for each test is shown in Table 2.

The relationship between the impact of investment and value-added resulted from savings in water consumption is achieved from investments and *c* coefficients shown in Table 2a. It should be noticed that the Prob value for the investment, independent variable, is zero. This value is less than 0.05. Which means that the null hypothesis of the test is rejected. In the null hypothesis of the test, it is assumed that the coefficient of the independent investment variable is equal to zero. By rejecting it, it can be concluded that the coefficient of the independent variable of investment is a number other than zero and is equal to 0.007828 and is statistically significant. The value of Prob for *c* is 0.5061. This value is greater than 0.05. Which means that the null hypothesis of the test is accepted. In the null hypothesis of the test, it is assumed that the coefficient c is equal to zero, and if it is accepted, it can be concluded that the coefficient of the variable c is equal to zero.

$Y_1 = 0.007828 * x$

Similarly, the relationship between the impact of investment and value added resulted from increasing of agricultural production is gained from investments coefficient shown in Table 2b. It can be seen that the Prob value for the investment, the independent variable, is zero. This value is less than 0.05. Therefore, it can be concluded that the coefficient of independent investment variable is a number other than zero and is equal to 0.108973. The value of Prob for c is equal to 0.001. This value is also less than 0.05; hence, it can be concluded that the variable c is equal to 1726427.

$Y_2 = 1726427 + (0.108973 * x)$

It was elucidated through regression that the value added from each benefit has a meaningful correlation with the amount of investment; ergo, Iran's GDP was predicted for the hypothetical situation in which smart irrigation were implemented in all agricultural lands and all the promised benefits were acquired. The predicted GDP was computed using the following equation.

Equation 3:

$$GDP_{predicted} = GDP + \sum_{k} \sum_{g} x_g^k {Y_1}_g^k {Y_2}_g^k \quad (3)$$

- $x_g^k$: the amount of investment for product $k$[6] in area $g$[7].
- ${Y_1}_g^k$: value added resulted from savings in water consumption from product *k* in area *g*.
- ${Y_2}_g^k$: value added resulted from increase in production of product *k* in area *g*.

According to Central Bank of Iran[8], the value of gross domestic product in relation to prices in 2018 was equal to 18619 thousand billion Rials, which is obtained from the aggregation of value added of four sub-sectors of Iran's economy, including: agriculture, oil, industry, and mines and services. The share of the agricultural sector in GDP in relation to prices was equal to 1901 thousand billion Rials, which encompassed 10.2 % of GDP.

If smart irrigation is implemented in agricultural lands, it will save water and increase crop production. These factors will create added value in the amount of 1254.45 thousand billion Rials compared to prices in 2018. If we add this amount

[6] 48 different crops published in the report of the Deputy of Strategic Planning and Supervision of the Ministry of Iran's Agriculture

[7] 31 provinces mentioned in the report of the Deputy of Strategic Planning and Supervision of the Ministry of Iran's Agriculture

[8] The 2018 economy report from Central Bank of Iran is the latest report available online.

to the country's GDP in 2018, the value of GDP will increase to 19873.45 thousand billion Rials. Iran's GDP would grow 6.7 % accordingly.

## Conclusion

The water crisis in Iran's agricultural sector continues in an increasingly complex manner. In a recent attempt, the water authority company tried to stop the excessive extraction of water by equipping the agricultural wells with smart meter technology. This was done while there was no plan for how agricultural water consumers should cope. This approach has fueled water tensions across the country. Our paper has tried to show the benefits of a way to reduce water consumption and increase efficiency in the agricultural sector. In a study process, we calculated the costs of implementing smart irrigation in existing farmlands. Then we showed that there is a meaningful correlation between the investment in this technology and water consumption as well as increased efficiency in the agricultural sector. Using a formula, we predicted that Iran's GDP rate will increase to 6.7 % if this technology is used.

It is important to keep in mind that in developing countries, there are also problems along the same path of making water distribution smart with all its advantages and necessity. The first issue is awareness of the benefits of the Internet of Things, which are not well known in these countries, especially among farmers. The infrastructure is still not complete, the Internet has limited availability and low quality and the access to related sensors and telecommunication devices are still marginal. The necessary standards for the implementation of irrigation intelligence have not been developed, the necessary training for the use of the Internet of Things in the farm has not been given, and farmers are reluctant to change.

The rate of water for agricultural use is next to nothing in Iran, as well as electricity used by water pumps. This results in low incentives for farmers to change the irrigation model or the type of cultivation. Government investment is an important factor in the transformation of traditional to smart irrigation. For this reason, the integrity of water governance is important in accepting the importance of making irrigation smart. Different governmental organizations with different and sometimes conflicting interests have reduced the coordinated implementation of policies in favor of reducing water consumption. The rate of change in our water governance is much slower than the rate of climate change. We weighed the economic and productivity benefits of water smartness to pave the way for accelerating this fundamental shift in water conservation.

Future studies can investigate the social issues of irrigation method transformation in developing countries.

*Corresponding authors*
*Abbas FaghihKhorasani, Ph.D. candidate*
*Faculty of Social Sciences, University of Tehran, Jalal-e-Al-e-Ahmad Hwy, Tehran, Iran*
*Phone: (+98) 9121328942, E-mail: abbas.faghih@ut.ac.ir*

## References

[1] Atzori, L., Iera, A. and Morabito, G. (2010) "The internet of things: A survey", *Computer Networks*, Vol. 54, No. 15, pp. 2787-2805. ISSN 1389-1286. DOI 10.1016/j.comnet.2010.05.010.

[2] Central Bank of Iran's report (n. d.) "*Summary of economic developments in the country*". [Online]. Available: https://www.cbi.ir/SimpleList/AnnualReview_fa.aspx [Accessed: Oct. 10, 2021]. (In Persian).

[3] Deputy of Strategic Planning and Supervision of the Agriculture Ministry of Iran (2020) "*Crop Statistics Report*". [Online]. Available: https://amar.maj.ir/Dorsapax/userfiles/file/omure-eghtsadi/gharardadha/89/amarzeraei-j1-gozaresh-98-99.pdf. https://amar.maj.ir/Dorsapax/userfiles/Sub65/baghbani-gozaresh-1399.pdf. [Accessed: Oct. 10, 2021]. (In Persian).

[4] Garrity, J., Biggs, P., LaSalle, C. and Polomska, A. (2015) "Harnessing the internet of things for global development", *SSRN Electronic Journal*, 61 p. E-ISSN 1556-5068. DOI 10.2139/ssrn.2588129.

[5] Gubbi, J., Buyya, R., Marusic, S. and Palaniswami, M. (2013) "Internet of things (IOT): A Vision, architectural elements, and Future Directions", *Future Generation Computer Systems*, Vol. 29, No. 7, pp. 1645-1660. ISSN 0167-739X. DOI 10.1016/j.future.2013.01.010.

[6] Hamdi, A. Y., Liaghat, A., Rasoulzadeh, A. and Ghaderpour, R. (2018) "Investigation of in the Capita Water Consumption Variation in Iran Based on the Past Two-Deca Diet", *Journal of Water and Soil Researches of Iran*, Vol. 1, No. 50, pp. 77-87. ISSN 2008-479X. DOI 10.22059/IJSWR.2018.246084.667795. (In Persian).

[7] Heydari, N. and Morid, S. (2020) "Water and agricultural policies in Iranian macro-level documents from the perspective of adaptation to climate change", *Irrigation and Drainage*, Vol. 69, No. 5, pp. 1012-1021. ISSN 1531-0353. DOI 10.1002/ird.2498.

[8] Kim, Y., Evans, R. G. and Iversen, W. M. (2008) "Remote Sensing and control of an irrigation system using a distributed wireless sensor network", *IEEE Transactions on Instrumentation and Measurement*, Vol. 57, No. 7, pp. 1379-1387. ISSN 1557-9662. DOI 10.1109/tim.2008.917198.

[9] Lee, I. and Lee, K. (2015) "The internet of things (IOT): Applications, investments, and challenges for enterprises", *Business Horizons*, Vol. 58, No. 4, pp. 431-440. ISSN 0007-6813. DOI 10.1016/j.bushor.2015.03.008.

[10] Li, L. (2011) "Application of the internet of thing in Green Agricultural Products Supply Chain Management", 2011 *4th International Conference on Intelligent Computation Technology and Automation*, pp. 1022-1025. DOI 10.1109/icicta.2011.256.

[11] Li, S., Xu, L. D. and Zhao, S. (2014) "The internet of things: A survey", *Information Systems Frontiers*, Vol. 17, No. 2, pp. 243-259. E-ISSN 1572-9419, ISSN 1387-3326. DOI 10.1007/s10796-014-9492-7.

[12] Manyika, J., Chui, M., Bisson, P., Woetzel, J., Dobbs, R., Bughin, J. and Aharon, D. (2015) "*The Internet of Things: Mapping the Value Beyond the Hype*", San Francisco; McKinsey & Company. [Online]. Available: https://www.mckinsey.com/~/media/mckinsey/industries/technology%20media%20and%20telecommunications/high%20tech/our%20insights/the%20internet%20of%20things%20the%20value%20of%20digitizing%20the%20physical%20world/the-internet-of-things-mapping-the-value-beyond-the-hype.pdf. [Accessed: Oct.10, 2021].

[13] McKinney, D. C. and Savitsky, A. G. (2006) "*Basic Optimization Models for Water and Energy Management*", The University of Texas at Austin, Thechnical Report. [Online]. Available: https://www.caee.utexas.edu/prof/mckinney/ce385d/Lectures/McKinney_and_Savitsky.pdf. [Accessed: Oct. 10, 2021].

[14] Mekonnen, M. M. and Hoekstra, A. Y. (2010) "*The Green, Blue And Grey Water Footprint of Crops and Derived Crop Products*", The Netherlands; UNESCO-IHE Institute for Water Education. [Online]. Available: https://waterfootprint.org/media/downloads/Report47-WaterFootprintCrops-Vol2_1.pdf. [Accessed: 10 Oct., 2021].

[15] Nandurkar, S. R., Thool, V. R. and Thool, R. C. (2014) "Design and development of Precision Agriculture System Using Wireless Sensor Network", *2014 1st International Conference on Automation, Control, Energy and Systems (ACES)*. pp. 1-6. DOI 10.1109/aces.2014.6808017.

[16] Perry, C. J. and Steduto, P. (2017) "Does Improved Irrigation Technology Save Water? A review of the evidence". DOI 10.13140/RG.2.2.35540.81280.

[17] Raj, M., Gupta, S., Chamola, V., Elhence, A., Garg, T., Atiquzzaman, M. and Niyato, D. (2021) "A survey on the role of internet of things for adopting and promoting agriculture 4.0", *Journal of Network and Computer Applications*, Vol. 187. ISSN 1084-8045. DOI 10.1016/j.jnca.2021.103107.

[18] Saidu, C., Usman, A. and Ogedebe, P. (2015) "Internet of things: Impact on economy", *British Journal of Mathematics & Computer Science*, Vol. 7, No. 4, pp. 241-251. ISSN 2456-9968. DOI 10.9734/bjmcs/2015/14742.

[19] Salami, H., Shahnooshi, N. and Thomson, K. J. (2009) "The economic impacts of drought on the economy of Iran: An integration of linear programming and macroeconometric modelling approaches", *Ecological Economics*, Vol. 68, No. 4, pp. 1032-1039. ISSN 0921-8009. DOI 10.1016/j.ecolecon.2008.12.003.

[20] Sarni, W., White, C., Webb, R., Cross, K. and Glotzbach, R. (2019) "*Digital Water: Industry leaders chart the transformation journey*", International Water Association and Xylem Inc. [Online]. Available: https://iwa-network.org/wp-content/uploads/2019/06/IWA_2019_Digital_Water_Report.pdf. [Accessed: Oct. 10, 2021].

[21] Vallée, D. and Margat, J. (2003) "*Review of World Water Resources by Country. Rome; Food and Agriculture Organization of the United Nations*". [Online]. Available: https://www.fao.org/3/Y4473E/y4473e.pdf. [Accessed: Oct. 10, 2021].

[22] World Trade Report (2013) "*Fundamental economic factors affecting international trade*", International Trade. [Online]. Available: https://www.wto-ilibrary.org/content/books/9789287042224s004-c005/read. [Accessed: Oct. 10, 2021].