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Distribution of Water Shortage and Soil Moisture Consumption (Case Study: Guilan Province)

Jalal Behzadi[a*]

[a]Assistant Professor, Department of Agriculture, Islamic Azad University of Lahijan, Lahijan, Iran.

[*]Corresponding Author, E-mail address: drbehzadijalal@yahoo.com

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Abstract

Water shortage is considered a serious problem in many countries in the world. Even in other countries where there is a better climatic condition thanks to a higher precipitation rate, water shortage still exists in the months and seasons with high water needs. Iran is a country located on the dry belt of the earth, and water shortage can be sensed in it. Guilan Province is different from other provinces due to its special geographical and climatic condition, and especially its high precipitation rate, which is five times higher than the whole country's average. But the time and positional distribution of precipitation is not uniform, and it severely decreases in April by the movement of precipitation systems, and this trend continues until late August. Due to the variety of climates in Guilan, the precipitation rate, temperature and also evaporation rate which is a function of temperature have a great impact on water balance. On the other hand, soil is another essential source of life. The mutual effects of climatic elements especially rain and temperature, and the moisture capacity of the soil, are some of the topics related to water balance, water shortage and soil moisture consumption. In the present study, the statistical data related to precipitation and temperature obtained from six climatic stations including Anzali, Lahijan, Astara, Qale Rudkhan and Manjil that were picked out of thirteen stations were analyzed, and the annual water shortage average was calculated. Then the distribution of water shortage among the stations was determined using the GIS software and was presented in a map. The problems in agriculture, industries, urban and rural sections caused by water shortage can be found and solved more easily using a water shortage map.

Keywords: Guillan, Moisture, Soil, Water shortage.

1. Introduction

Some countries that produce food products in large scales, such as India, Australia, China, Spain and the United States, have already reached the water shortage red line. Clouds fertilization technique is an innovative method of reducing the impacts of hydrological drought and increasing the available water (FAO).

Hadadin et al. (2010) conducted a research entitled "Water shortage in Jordan-Sustainable solutions". In this study, they have presented specific recommendations addressing water resource shortage in the kingdom and highlighted the importance of conservation of water and discussed the basics of sustainable solution.

In a research entitled "Water transfer as a solution to water shortage: A fix that can Backfire", Gohari et al. (2013) concluded that supplying more water to the basin without considering the dynamics of the interrelated problems, will eventually lead to an increase in water demand. In a research entitled "Evaluation of water shortage crisis in the Middle East and possible remedies", Bozorg-Haddad et al. (2020) described the condition in the 2017 dry season and examined possible solutions to the chronic water shortage such as use of ground water, desalination of sea water and recycling waste water.

In a study entitled “Effects of Urban Development Patterns on Municipal Water Shortage”, Heidari et al. (2020) concluded that characterizing impacts of urban development patterns on future water shortage conditions is required for sustainable water management and smart urban growth and can help urban planners and water managers to develop an adaptive path to meet future water demands and decrease the vulnerability of municipal water supply systems to shortage. Chen et al. (2020), this study is of great theoretical significance and applicable value in promoting the effectiveness and sustainability of urban water systems. and concluded that The analysis of the Land-Water-Food Nexus indicates how shifts in cultivated crops can potentially solve the overuse of water resources without adverse effects on food supply. It also provides meaningful information to support policy decisions about regional cropping strategies. Ali Akbar Abbasi et al. (2015) evaluated the impact of short structures on runoff and soil moisture storage (case study of Kardeh Dam area) and concluded that small amounts of rainfall in such areas, along with its poor distribution, causes droughts and water shortages. Ahmadloo et al. (2021) planned the cultivation and development of wood cultivation for the present and future of the Tehran province using Sentinel-2 satellite data and terrestrial for surveying and preparing a distribution map of poplar plantations in October 2021. Biniaz and Bazrafshan (2016) located rainfall storage and rangeland improvement with six various methods.

The results show that among the four key factors affecting the location of project implementation, three factors (rainfall, soil condition, vegetation status) were unchanged and had a uniform status, so the final map affected by the slope factor was obtained. And it is only possible to implement Faro projecting and meter projects. Ghorbani Moghaddam et al. (2016) studied the effect of rainwater extraction methods on the initial establishment of rangeland plants in rangelands in September 2021.

Nourzadeh Haddad et al. (2013), compared the efficiency of some geostatistical methods to investigate the spatial distribution of micronutrients in agricultural lands of Hamedan, and found that in the northern parts of the province, the lack of micronutrients is very evident. Abed Golkarami and Kaviani (2017) studied the effect of limited water resources on hydropolitical stresses with emphasis on Zayandehrood catchment. The study showed that population growth and urbanization, industrial growth, climate change and its instabilities, improper abstraction of groundwater and conventional agriculture are the most important factors of limiting water resources, and have subsequently caused tensions in the basin.

Sajedi et al. (2009) evaluated the effect of water shortage stress and nutrient application on crop yield and the effect of selenium on yield. They concluded that yield components were not significant, but with the application of selenium, the yield and yield components increased. Yousefi et al. (2018) concluded in their research that by improving irrigation efficiency, less fallow is needed, and by applying this fallow, the system can satisfactorily meet its downstream needs, thus the water managers need to consider improving irrigation efficiency. Ebrahimipak et al. (2019) studied the economic optimization of water distribution in Qazvin irrigation network in water conditions, and it was found that reducing irrigation water is suggested. In case of water shortage, the use of integrated wells downstream of this network is recommended. Kafi and Jami Al-Ahmadi (2019) examined the challenges of agricultural sector in the face of drought and water shortages and possible solutions. He found that since almost the entire country is facing drought, it is vital to understand the effects and impacts of this phenomenon on the agricultural sector and to adopt a rational approach to water use management.

Six selected stations were selected out of other meteorological stations both in terms of data length, which is more than thirty years, and through the cluster method. The data of six selected stations were used through water balance method, and surplus, water shortage, and soil moisture consumption were estimated, and a graph was illustrated. The magnitude of water shortage was determined based on millimeters per cubic meter, and the water shortage map was drawn. This map is the basis for studies for projects related to agriculture and natural resources, and meets the basic needs of many projects.

2. Materials and Methods

Temperature and rainfall data of six different stations were used uniformly in thirty-five years. Using precipitation and temperature data in Torrent White method, modified and unmodified transpiration evaporation and residual water in the soil, lack of essential water and transpiration, soil moisture consumption, and excess water were obtained.

2.1. Climatic Classification

Climatic classification was done through coupons. In this classification, six stations were identified. The stations located in plain areas are of rain forest and highly humid climate types, but Manjil is of a semi-arid and steppe climate. This region is located in the central moderate area of Guilan. The other stations are located in humid areas.

2.2. Water Balance

Six stations of Guilan province which were picked out based on precipitation index in clustering method, including Manjil, Shanderman, Lahijan, Anzali, Rudkhan Castle, and Astara. Manjil which possesses a different climate from other parts of Guilan, is of arid climate with a soil capacity of about 200 millimeters. Keep in mind that Torrent White measured soil moisture capacity as 300 and drought as 200 millimeters in New Jersey which is a humid region, and this indicates a low water capacity in the studied soils (Guilan). In the plain areas, the lowest precipitation is recorded in Shanderman, and the highest amount was in Anzali. It should also be pointed out that in the presented tables PE= balanced evaporation and transpiration, UP= unbalanced evaporation and transpiration, P-PE = remaining water from precipitation after evaporation, ΔSt= monthly variations, S= water surplus, RO= runoff, TC= temperature, ACC= highest water requirement, D = water shortage, P= total monthly precipitation, ST = water remaining in soil. Also, in every figure, the water balance regarding that station has been illustrated.

The steps and steps are based on the method and instructions of Trent White, which should be done in order, the most important of which are to draw a diagram of water balance, water shortage, soil moisture consumption, and excess water. Water shortage of six stations was determined based on water storage capacity in the soil, which is low in Guilan province, and was monitored in the province. Also, in every figure, the water balance regarding that station has been illustrated.

2.3. The Geography of Guilan Province and the Measuring Stations

Guilan is located in the north of country in the longitude of 50.35 to 48.32 and in the latitude of 38.27 to 33.36. It neighbors the Caspian Sea on the north, Mazandaran province on the east, Qazvin province on the south, and Azerbaijan and Ardabil provinces on the west. The area of the province equals 13790.5 square kilometers and it is made up of three geographical areas: plains, foothills and mountainous areas. 29% of the land is agricultural, 41% forestial, and 16% for pastures. The plain area includes the two areas of Talesh and Shafa Rud plain to the east of Kelachay. Talesh, Tarom-Khalkhal, and Deylaman mountains are the three mountain ranges surrounding the province.

The stations used that have good overlap with the adjacent stations, and through the cluster, the best stations were selected in terms of long data, which include Astara, Anzali, Qaleh Rudkhaneh, Lahijan, Shanderman, Manjil (Fig. 1).

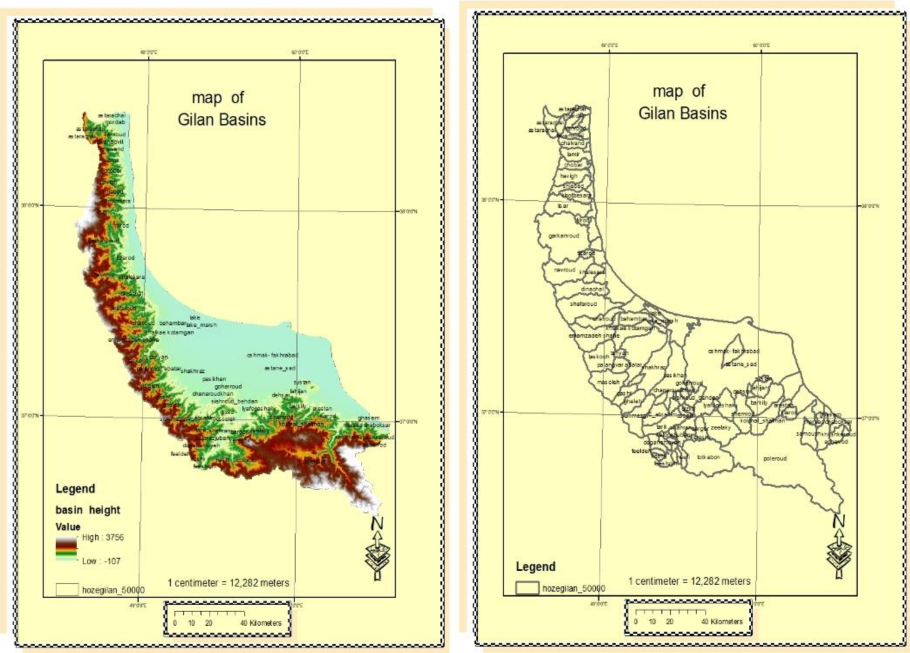

Fig. 1. The geographical location of the stations in Guilan province

3. Results and Discussion

3.1. Water Balance at Shanderman Station

Shanderman Station Balance Sheet was used as an example in the study. The graphs were completed based on the tables for the same station according to the White Torrent instruction for calculating the wording. The highest AE (actual transpiration and evaporation) of 114.33 was recorded in August and the lowest of 17.88 millimeters was seen in January. The highest D (water shortage) of 66.84 was in July and the lowest of zero was in wet months until April. The highest RO (runoff) was 63.4 and the lowest was 1.1 millimeter in August (Table 1). It is clear that July and August face a water crisis, especially in dry years. But from February to April, the water resources are in their best condition (Fig. 2).

Table 1. Water Balance in Shanderman Station

	October	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**
TC	18.60	14.3	10.22	8	6.9	8.3	12.7	16.6	21.25	23.95	24.93	22.9
I	4.86	2.94	2.04	1.63	2.39	2.15	4.10	6.15	8.97	10.68	11.37	10.0
UP	2.5	1.7	0.9	0.6	0.5	0.5	1.4	2.1	3.1	3.9	3.8	3.6
PE	72.75	43.35	22.048	15.48	12.9	15.45	47.32	110.36	110.43	146.25	133.38	111.24
P	216.4	203	181.7	112.19	129.02	109.8	85.49	74.77	46	69.7	35.46	159.4
P-PE	144.3	159.65	159.65	96.7	116.1	94.3	38.17	-35.7	-64.43	-76.55	-97.92	48.16
ACC								-35.7	-100.13	-176.68	-274.6	
st	200	200	200	200	200	200	200	168	120	82	50	98.16
Δst	0	0	0	0	0	0	0	-32	-47	-38	-32	4.16
AE	72.75	43.35	22.04	15.48	12.9	15.4	47.3	106.77	94	107.7	67.46	111.24
D	0	0	0	0	0	0	0	3.83	16.43	38.6	65.92	0
S	144.3	159.65	159.65	96.7	116.1	94.3	38.17	0	0	0	0	44
RO	82.7	121.2	140.41	118.16	234.7	164.5	101.3	50.7	25	12	6	3

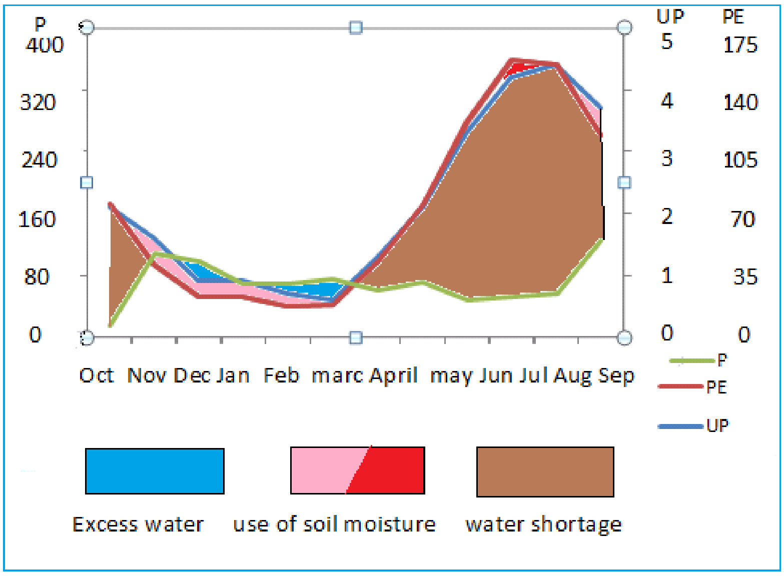

Fig. 2. Water balance (soil moisture consumption) diagram of Shanderman station

3.2. Water Balance at Lahijan Station

The highest P-PE of 159.6 was recorded in November and the lowest of 35.7 millimeters was in April. The highest water shortage of -274.6 was in July and the lowest of zero was in March. The highest RO (runoff) was 234.7 in January and the lowest was 3 millimeters in August. It is clear that July and August face a water crisis, especially in dry years (Fig. 3).

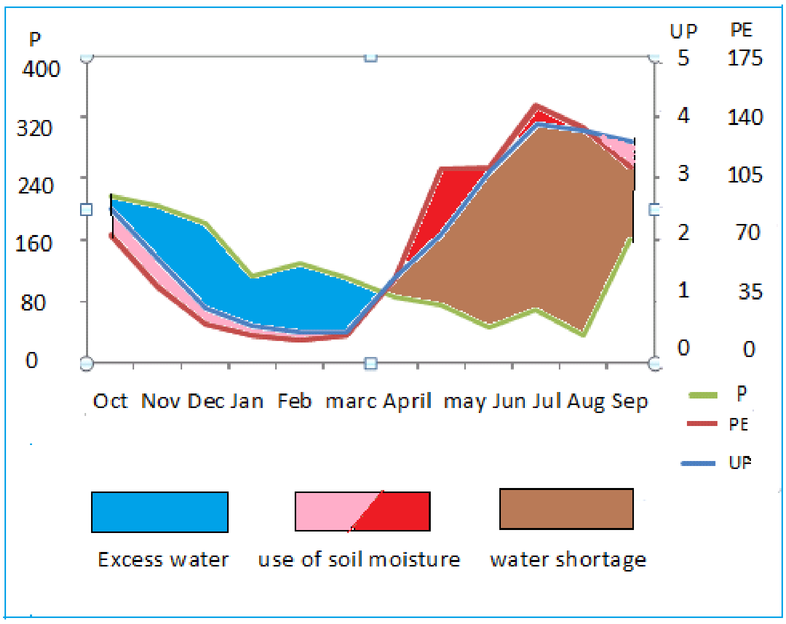

Fig. 3. Water balance (soil moisture consumption) diagram of a station

3.3. Water Balance at Astara Station

The highest water requirement was in June with -98.98 millimeters, and the lowest was in March. The highest changes occur in June with -37 mm and the lowest is in April. The highest actual evaporation and transpiration is in June with 142 and the lowest is in January with 14 mm. the highest water shortage is in July with 55.26 mm and the least shortage is recorded in October, November and other wet months. The most severe water crisis is in June and July, and the least is in November to April (Fig. 4).

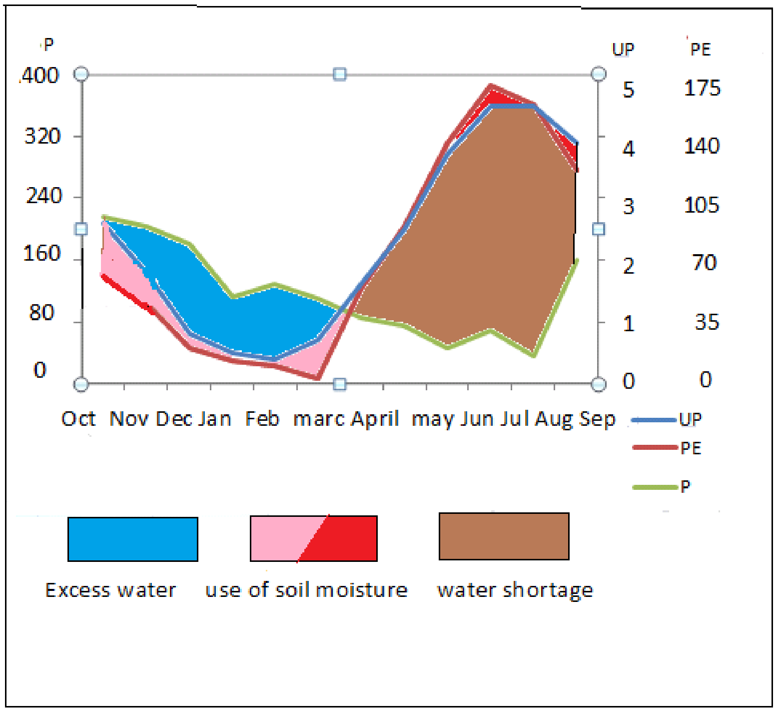

Fig. 4. Water balance (soil moisture consumption) diagram of Astara station

3.4. Water Balance at Anzali Station

The highest water requirement of -101.4 is in June, and the lowest is in March. The most variation of 42 mm occurs in June and the least is observed in April. The highest actual evaporation and transpiration of 146 mm is in June and the least of 14 mm is in January. The highest water shortage of 42.29 mm is in July and the lowest is in December and other wet months through April. The most severe water crisis is in June and July and the least is in November through April (Fig 5).

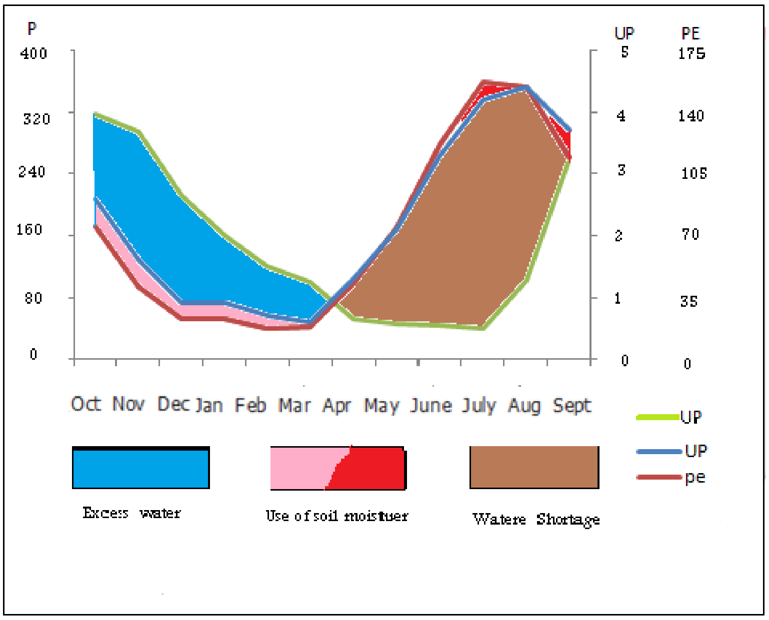

Fig. 5. Water balance (soil moisture consumption) diagram of Anzali station

3.5. Water Balance at Rudkhan Castle Station

The highest water shortage of 11.69 is in May and the lowest is recorded in wet month through April. However, this station has a lower water shortage compared to the others, but in July and August water crisis reaches its peak. From January to April the lowest water crisis of almost zero is recorded. The highest water requirement of -93.89 is in July and the lowest is in March and April. The highest ΔSt of -33 is in June and the lowest amount is recorded in wet months until April. The highest AE of 135.3 is in June and the lowest of 10.32 mm is in January. The highest water shortage of 11.69 occurs in May and the lowest is in wet months until April (Fig. 6).

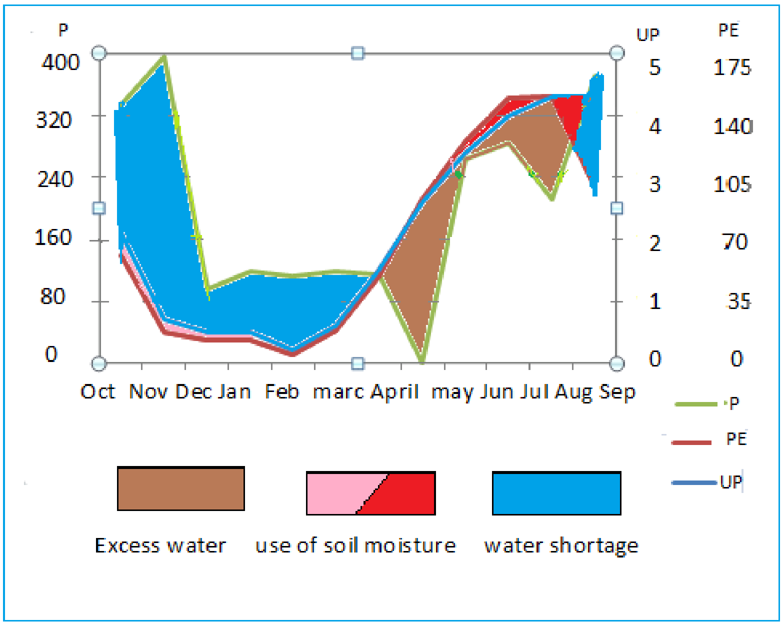

Fig. 6. Water balance (soil moisture consumption) diagram of Rudkhan Castle station

3.6. Water Balance at Manjil Station

The highest P-PE of 44mm is in February and the lowest of -155.75 occurs in July. The highest water requirement of -898.77mm is in July and the lowest of zero occurs in January. The highest actual evaporation and transpiration of 33.15 is in June and the lowest of 10.32 occurs in January. The highest water shortage of 149.7mm occurs in July and the lowest is recorded in February and other wet months. The highest runoff is 15.7 and the lowest of 0.3 occurs in August. It is clear that TC, I, UP, AE and DE are higher than other stations. This region possesses the highest water shortage and the lowest water surplus and soil moisture. The most severe water crisis occurs in June and July, and the least severe is recorded in January and February. It should also be pointed out that in evaluating the water balance of the six stations, the highest variation in water balance parameters is recorded in Manjil (Fig. 7).

Based on the obtained diagrams, Manjil possesses the first rank of water shortage among all the stations. The second through the sixth rank are dedicated to Shanderman, Lahijan, Astara, Anzali and Rudkhan Castle respectively. The highest water shortage is recorded in Shanderman, and the lowest is seen in Rudkhan Castle. The highest soil moisture consumption occurs in Manjil and Shanderman, and the lowest is in Rudkhan Castle. It should be pointed out that water crisis exists in all the stations during June and July, and there is a better water balance from February to April. It is clear that these stations have pretty various water potentials, and the highest variation is recorded in Manjil station, which not only has a high variation compared to the other stations, but also it can be seen from the diagram of Manjil that this station has the lowest water potential among all the others. It can also be witnessed from field observations that there is a very weak water potential with scattered vegetation in this region. This is another reason to separate Manjil station from the other plain stations of Guilan. The average water shortage of the stations is as following: Manjil: 637mm, Shanderman: 129mm, Lahijan: 125mm, Astara: 95mm, Anzali: 36mm, and Rasht: 28mm. The field figures and results are close (Fig. 8).

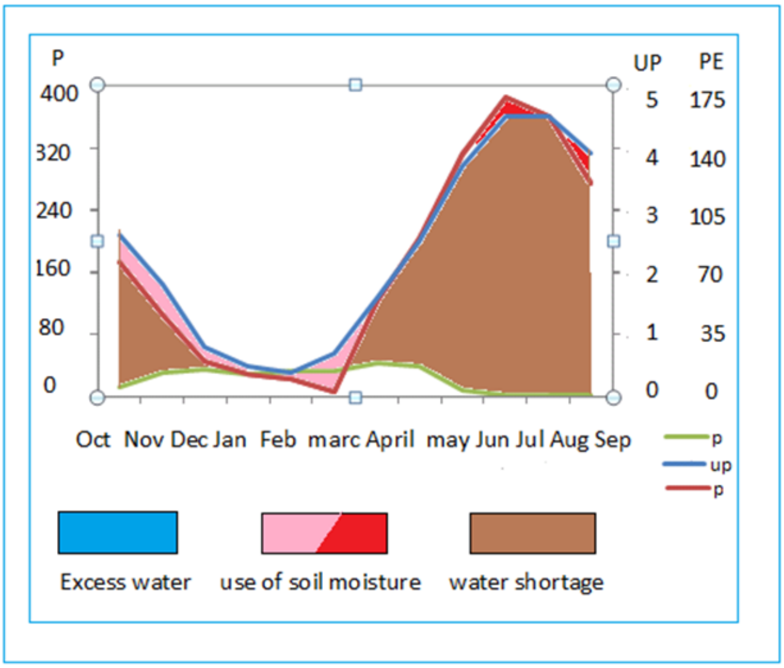

Fig. 7. Water balance (soil moisture consumption) diagram of Manjil station

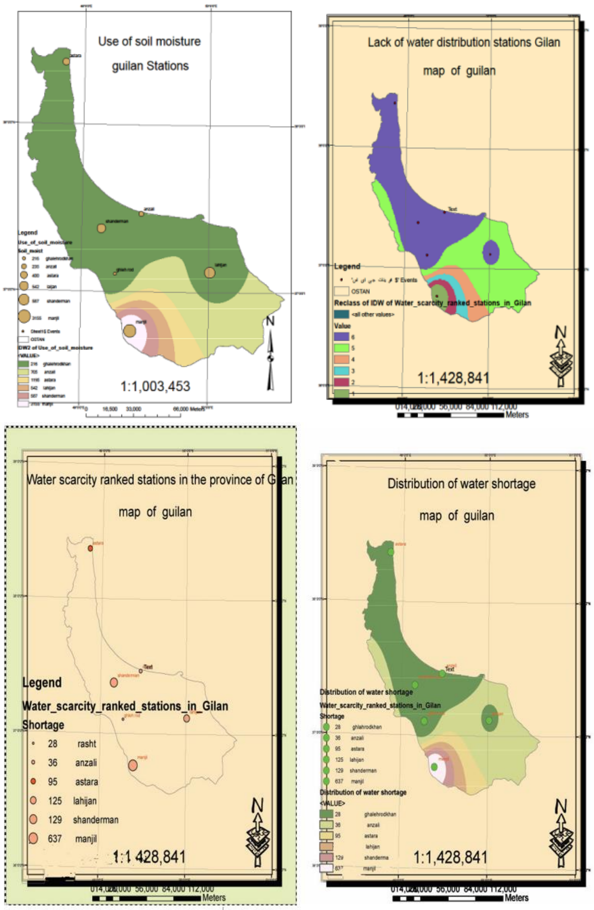

Fig. 8. Soil moisture consumption of Guilan stations

4. Conclusion

Water balance which is influenced by climatic conditions and meteorological elements especially precipitation and temperature, is effective on all the environmental subjects such as agriculture, etc. The variation of water balance in wet and dry years is of high importance and can have a great impact on environment, sustainable development, water resources management, better environmental, economic and agricultural planning, etc. Based on the operations performed at selected stations, a comparison was made between field research numbers and Torrent White water balance research. The numbers obtained were close to the field data. In the present study, the focus has been on including average long-term behavior (variations) and oscillations (variability) of monthly elements such as precipitation, and balanced and unbalanced evaporation, and eventually obtaining the water remaining in soil, water shortage, water surplus and runoff. There are various factor affecting water resources in Guilan, such as high, but irregular annual precipitation, vast farming, high expectation of urban and rural communities in water consumption, development of new industries and technologies, etc. Therefore, the current water resources are not adequate for these needs, especially in hot seasons. This lack of balance in Guilan considering the high climate and water balance variety has made planning in different sectors extremely difficult, especially in agriculture, urban and rural tourism, and the environment.

In order to focus the studies and obtaining proper results, clustering method has been used, and six stations naming Anzali, Rudkhan Castle, Lahijan, Shanderman, and Manjil were picked out of thirteen stations. Based on the obtained diagrams, Manjil possesses the first rank of Water potential among all the stations. The second through the sixth rank are dedicated to Shanderman, Lahijan, Astara, Anzali and Rudkhan Castle respectively. The average water shortage of the stations is as following: Manjil: 637mm, Shanderman: 129mm, Lahijan: 125mm, Astara: 95mm, Anzali: 36mm, and Rasht: 28mm. The highest water shortage is recorded in Shanderman, and the lowest is seen in Rudkhan Castle. The highest soil moisture consumption occurs in Manjil and Shanderman, and the lowest is in Rudkhan Castle. It should be pointed out that water crisis exists in all the stations during June and July, and there is a better water balance from February to April. It is clear that these stations have pretty various water potentials, and the highest variation is recorded in Manjil station.

Considering the increase of water requirements in industrial, agricultural, urban, rural, and domestic sectors, water shortage has increased dramatically, especially in dry years and periods and hot seasons. In some areas such as Rudbar, Tarom and Manjil, the shortage is so severe that it sometimes leads to expansion of deserts.

Low soil capacity especially in plain areas leads to an intense water volume increase after every heavy precipitation, which can in turn lead to water shortage in dry years. Soil humus and water holding materials in soil are being continuously eroded due to land use change, destruction of forests, building farms and destroying them again, building cities and towns, etc. and this leads to the weakening of minerals and more acidification in soil. This is why deciduous species at first and then evergreen trees should be planted in order to maintain and save the water and soil of the region. Also using drainage in order to guide the water, urban and domestic water storages for storing rain water and building small dams, different kinds of fish producing pools and meeting the water requirements in agriculture and so on should be practiced in the province to make the best use out of rainfalls and prevent the water from going into the sea. It is essential to save every tree in the province considering the high climatic diversity and the great impact of the forests in maintaining the moisture and climate.

5. Conflicts of Interest

No potential conflict of interest was reported by the authors.

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