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Impact of Climate Changes on Water Resources Availability in the Orontes River Watershed: Case of Homs Governorate in Syria

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ABSTRACT

Homs governorate watershed is considered as the agricultural production hub and a strategic water reservoir of Syria. However, land fertility and the increase of population, as well as climatic changes, urged the farmers in this region to intensify the agricultural development. This has resulted in increasing pressure on available water resources of upper Orontes River Basin. Therefore, it is necessary to develop a prediction model that helps to estimate future availability of water resources. This paper analyzes how some strategies can help the government in achieving sustainable development. Consequently, their water security in the wake of climate changes till 2050. Four scenarios were studied depending on the actual situation (RF) with improving the irrigation efficiency: (1) Reuse of reclaimed agricultural water return, (2) Optimum exploitation of Zeita reservoir, (3) The reducing of the per capita share of drinking water and minimizing evaporation from the surface of Kattenieh Lake, and (4) Separation between Homs-Hama networks and raising their water conveyance efficiency by exchanging them with pressured pipe networks. The aforementioned scenarios were through three cases of climate changes (normal, dry and very dry years). The results are visualized as graphs, maps and tables, and showed that by application of the first three scenarios, the critical point (water deficiency) will disappear with obtaining surplus about 38% comparing with (RF), to achieve water needs of Homs-Hama networks (third priority) in case of normal years and high irrigation efficiencies in 2050. Also, water deficiency will decrease about 93% and 65% in case of dry and very dry years, respectively. While by application of the fourth scenario with closed circuits of industrial plants, we can avoid water deficiency and reduction of pollution rate in case of dry years in 2050, and decrease its rate to 77% comparing with (RF) in case of very dry years. This will necessitate water withdrawal (about 200 MCM) from other nearby basin such as Coast basin to minimize the gap between supply and demand.

Keywords: Watershed, Strategies, Critical point (water deficiency), Scenario, Closed circuits, Supply and demand.

INTRODUCTION

In many basins around the world increasing water demand is leading to the overexploitation of limited water resources and more frequent and more pronounced periods of extreme water scarcity (Falkenmark and Molden, 2008). Despite broad acceptance of the principles of Integrated Water Resources Management (IWRM), (Global Water Partnership (GWP), 2000), which calls for a multifaceted approach to resolving water management issues, responses often still focus narrowly on supply side management, or the "hydraulic mission" (Alan, 2001), which includes large-scale infrastructure projects, such as dams, reservoirs and water transfers. The Orontes River basin has been no exception to this. Water resources management in the

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Orontes River Basin is further complicated by the trans-boundary nature of most surface and ground water resources as well as the trans-boundary and contested allocations and uses of water resources (UNDP, 2004). The Orontes River originates in Lebanon, flows through Syria and ends in the Mediterranean Sea in Turkey. This river crosses in particular Homs governorate in Syria known as the Upper and Middle Orontes River basins between latitudes 33^{o} 40′ and 35^{o} 25′ North and longitudes 36^{o} 18′ and 37^{o} 28′ East, about 50-55 kilometers east ofthe Mediterranean Sea coast and 150 km north the capital city of Syria (ESCWA-BGR, 2012). Whereas, the length of Orontes River is about 86 km in this part and covers about 8788 km^{2}area which was calculated by GIS software, has five sub-basins, each and every one has its own geological, meteorological, hydrological and demographical characteristics, (Figure 1). Rainfall occurs from September to March, it decreases from 800 mm at the Al-Houlah plain sub-basin to 100 mm in the eastern parts of Wadi Al-Haroon sub-basin. By analyses of available water resources of the study area at the probabilities (50%, average years or normal; 75%, dry years and 95%, very dry years) for 35 previous year, the gross average renewable conventional water resources (surface and rainfall, runoff and groundwater) were 486.73 MCM, and decreased to 404.44 MCM and 290. 85 MCM in the dry and very dry years, respectively (Table 1). Also the moving average every 11year for these resources showed dwindling gradually as a result of climate change in the region (Figure 2). The quick overpopulation leaded to overpressure on the natural resources especially water resources and the change in its quality and quantity. Consequently, to misbalance between population needs and available water resources, this agreed with results of (Droubi, 2006). Whereas Figure 3 showed a decrease in the growth rate in Homs and Hama during the period 1970-2010 although overpopulation in them (CBS-SYR, 2011a).The amount of produced water (pumped water in networks) for domestic use increased from 40.32 MCM in 1998 to 58.1 MCM in 2010 because of increase in amount of consumed water from 25.494 MCM to 39.76 MCM in that period. Consequently, the water loss was about 31.57% in Homs city and the same thing for the other sites (Table 2). It can consider that the drinking water sector and domestic use as second consumer of water resources after agricultural use. Drinking water systems networks have low efficiency (less than 67%). Therefore, it is very important to improve its efficiency to save water and protect it from pollution. Previous discharge of industrial effluents from plants existing before Kattenieh dam such as General Fertilizer Company (GFC), Thermal Power Station (TPS) and a Military Establishment and after the dam, which withdraw its water directly from Kattenieh reservoir caused contamination, in agreement with data reported by (UNDP, 2004). Till now the rate of polluted water return is very high comparing with withdrawal water that operates these industrial plants which is estimated about 14.08 MCM before the dam and 29.8 MCM after dam in 2010. Homs governorate watershed represents the agricultural production hub and a strategic water reservoir of Syria. To analyze the causes and the effects of this overexploitation of water resources, we have to look at the factors influencing this high need in water such as: the population growth and its activities, and the effect of climate changes.

The main objective of this study thus was to analyze how some strategies could help the country in achieving sustainable agricultural development and consequently water security in the wake of climate changes.

METHODOLOGY

Available water resources and water demands for each sub-basin were estimated using all publically available dataset from the Ministry of Irrigation (MoI), Central Bureau of Statistics in Syria (CBS), Ministry of Housing and Construction (MOHC), and the Ministry of Agriculture and Agrarian Reform (MAAR) for 35 previous year, similar data were reported by UNDP (2002a). The time series data was analyzed by the Box-Jenkins method, which considers moving average and probability distributions such as normal (Ghos), Kritski-Menkel and Pearson Type3 that are appropriate for available data through 35 previous year, similar data were reported by UNDP (2002b). Whereas: Ghos's equations by using Excel software is: NORMINV (0.50, mean, St_{Dev}) at probability of 50%, NORMINV (0.25, mean, St_{Dev}) at probability of 75% and NORMINV (0.05, mean, St_{Dev}) at probability of 95%. While Kritski-Menkel's equation: Pm=100*m/ (n+.1), whereas: m= the tested year and n= number of tested years. However, Pearson Type 3 depends on coefficient of skewness tables and some mathematical equations (Harter, 1998). The prediction in future water flows is according to Pearson Type 3 distribution. The average precipitation over the basin was calculated by Thiessen's mean (or Representative area method, Mowafy and El-Sayed (1999)) and by equal precipitation lines method by using geographic information system (GIS). Other climate factors such as temperature, wind, radiation and evaporation were generated by using NewLoc-Clim 1.10 software which prepared by FAO. Also, the following points were studied and analyzed since 1998-2010 to incorporate into the estimation process.

- Expansion of irrigated areas, water use efficiency of upper Orontes irrigation networks and Homs-Hama irrigation networks, FAO soil classification using GIS, actual crop water requirement by using AquaCrop, statistical group data, GCSAR's data, 2011, population (CBS-SYR, 2011a) and development of water quota per capita from cultivated area and agricultural water.
- Development of annual water quota per Capita from domestic use as produced and consumed water and efficiency of domestic water networks.
- Development of unconventional water.
- The water balance for both conventional and unconventional water in the year 2010 was according to Molden et al (2001) mathematical equations:

$$\mathbf{Q_{in} + R + \Delta S = Q_{out} + E}$$

Where: $\mathbf{Q_{in}}$ = surface plus subsurface inflows, $\mathbf{Q_{out}}$ = surface plus subsurface outflows, **R** = precipitation, **E** = evaporation and transpiration, **ΔS** = change in storage within the domain consisting of changes in groundwater, surface water, or storage changes within the unsaturated zones. A positive sign indicates a removal from storage. The synthetic water balance is expressed as a difference between the available water resources (WR) and the demands of water users (D) within the considered water balance unit (river basin): **WR – D = ± B**

The positive water balance (+B) will permit to increase the supply and meet the raising water demands in the future, or the surplus of water is released downstream available for other users. The negative water balance (-B) implies that some or all of the users will not receive the demanded water quantities. The returned water from the irrigation depends on the irrigated areas and on the efficiency of irrigation. The returned water from the industrial plants was about 90% of withdrawal waters. The water demands consist of the supplies for the water users, those include: (1) Minimum ecological flow in the river, (2) Domestic water supply of Homs and Hama cities, (3) Irrigation water demands between the state border and Kattenieh dam (15,424 ha) including: Five canals irrigation system (6,849 ha), irrigation from the river (448 ha) and irrigation with groundwater from wells (8,127 ha), (4) Homs irrigation network (13,195 ha), (Table 3), (5) Industrial water consumption, and (6) Irrevocable water losses from kattenieh reservoir. The required minimum ecological flow in the river has been set to 1.0 m^3/sec. The losses from Kattenieh reservoir depends on the available storage in the reservoir. The assumed losses are approximate average values as determined in the assessment of water balance of Kattenieh dam, (Table 4). Also, the study identified water needs of the various sectors, and priorities secured drinking water for the cities of Homs and Hama, environmental flow requirements (EFRs) and obligations of industrial plants on the river as the first priority. The second priority included in addition to the first priority irrigation networks of Upper Orontes needs with alternative network for wells within the campus of Ain Altanour spring, while the third priority included needs of Homs irrigation network, evaporation losses and leakage of Kattenieh Lake. The situation was divided according to population growth rate of Homs city (2.35%), Homs countryside R1 (2.77%), Homs countryside R2 (5.15%), Hama city (2.30%) and Hama countryside R3 (3.42%). The water balances were calculated for probabilities of water imports and deduction of water demands till 2050 according to overpopulation in the future. Consequently, recognizing the time that water scarcity occurrence and how we can move the critical point farthest by suggesting some solutions as construction of new dams in the Lake of Kattenieh (Figure 4), to minimize high evaporation from its large surface and raise the proportion of the insurance needs that belongs to the third priority.

According to the precedence, the following proposed assumptions were used in the future predictions:

- Due to climate changes, an annual reduction in surface and groundwater resources will be about 0.25% and annual increase in the evaporation rate will be about 0.25% (Breisinger et al., 2011; Mourad and Berndtsson, 2011).
- Due to water shortage, urban development, keeping the cultivated land almost constant, the implementation of modern irrigation practices will annually save about 41% of the consumed water and raise water productivity (Khozam, 2010; Mourad and Berndtsson, 2012).
- Due to industrial development in Syria and especially in Homs governorate, the annual industrial demand is assumed to increase by 2 %, (CBS-SYR, 2011b).
- According to Figure 3, the population growth rate of both Homs and Hama will decrease annually by about 0.03 % (CBS-SYR, 2011a).
- Due to improvements in water infrastructure, the waste term from the domestic networks will be 25%, and according to recommendations of the World Health Organization, 2006 which suggested that 100 Liter/Capita/day (Lpcd) as water consumption for domestic purposes considers sufficient. Consequently, we suggest that domestic water demand will decrease to reach 110 Liter/Capita/day (Lpcd) in the city and 85 Lpcd in the countryside in 2050.

Calibration process:

Rainfall: The average rainfall was about 2700 Million m^3 (MCM) calculated using Thiessen's mean method and 2736 MCM by equal precipitation lines method as shown in Figure 5, (ESCWA-BGR, 2012). This difference was because of lack meteorological stations in the governorate, similar data were reported by GCSAR (2011).

Gross water resources: Because of this accuracy analysis, there was similarity between the values obtaining from the three distributions, as shown in the Table 5, similar data were reported by Khozam (2010).

Water balance in the Upper Orontes basin (section A) in 2010: This year is considered as the base year, comparing renewable conventional water resources and unconventional resources with the demand for water as in the Table 6. We found that the year was dryer than year 2004 in terms of surface water inflow, available groundwater and rainfall where it covered all obligations of first priority in section A, while the coverage of second priority obligations partially according to the required needs and irrigation efficiencies which changed from 35% to 85%. Through calculation of water inflow entering to Kattenieh dam, we found that it equals 160.03 MCM and it equals the total monthly outflow from Jauadieh station to the Kattenieh dam. This confirms the accuracy of calculation and measurement of hydrological stations in the site. Thus, about 88.06 MCM can be withdrawn from the dam to cover the needs of agriculture and industry in section B of the basin (Table 7). In comparison, we found that there isn't fully coverage of all water requirements in terms of agriculture and this is led to the depletion of groundwater by drilling many unlicensed wells and through the river directly by random pumping to cover the existing deficit, this agreed with the results of Scheumann et al (2011); Droubi et al (2008). Also, we noticed that monthly inflows entering to Rastan dam reached 55.2 MCM, and by comparing with 2004, noticed that the volume of these inflows was 220.03 MCM, and this confirms that year 2010 was dry. By studying the possibility of water harvesting and applying it, according to the contour lines and the possibility of rainfall ensuring, we found, it is confined in the eastern and southern parts of the site with low rates (Figure 6).

RESULTS AND DISCUSSION

Agricultural water supply and demand.

There is a disharmony between the agricultural plan prepared by the Ministry of Agric. and Agra. Reform (MAAR-SY, 2010), and the area actually cultivated, this is mainly due to the obvious defect in the distribution of agricultural water on other sectors in addition to that farmers are looking for rapid profit without following a policy of low water requirements alternative crops, also to environmental deterioration and existing water scarcity. There was a clear increase in arable land about 8% in the section A during the period 1998-2010 as a result of rocky land reclamation and this is accompanying with increase of irrigated area up to 3.53%, while rainfed areas decreased from 11,090 ha to 8,172 ha (Figure 7). Thus, water requirements have increased in spite of the decrease in the annual available water. This reflected immediately on agriculture in section B, especially irrigated area from surface water (Homs-Hama irrigation network). However, the reservoir does not satisfy demand, it is supplemented by groundwater wells which were often unlicensed to reach about 11,951 well in 2010 (ESCWA-BGR, 2012), and as a result, there was a clear decrease in water table and drought many of them, this agreed with the results of Hamade and Tabet (2013) in the Ghab region. This increase in the area accompanied with declining per capita share of the total irrigated area from18.0×10^{-3} ha in 1998 to 12.6×10^{-3} ha in 2010 as a result of overpopulation and reducing irrigated area by groundwater sources. Also amount of water allocated to agriculture was decreased from 261.7 m^3 to 198.2 m^3 per capita in the section A. Therefore it was a large and noticeable turnout by the peasants in application of modern irrigation techniques, whereas irrigated area of modern irrigation systems formed 72% of the total irrigated area (15,424 ha) in section A, and 47% in section B, and this is led to improving the efficiency from 35% to 85% in some places, similar data were reported by (Somi, 2004). When we evaluated the efficiency of conveyance for the five canals (Jussie, Rable, Maiessra, Zeita and Nahrieh), we found that lined part ranged between 76.7 and 91.1%, while the unlined part about 39.1%. Consequently, irrigation efficiency didn't exceed 43% if we could give the net water consumption of crop. Thus the hectare demanded about

18,762 m^3 at the efficiency of 35% and 15,089 m^3 at 43%, while the amount of water withdrawal didn't exceed 12,400 m^3/ha in 2010. It fell down to 7,684 m^3/ha at irrigation efficiency of 75% by using groundwater resource. And it was accompanied with mismanagement in water distribution on the monthly level according to irrigated crops needs in that area where we noticed that the passing discharge in July was 4.299 m^3/s, while the actual need reached 8.251 m^3/s at irrigation efficiency of 50% in the same month. Thus the deficit was 47.89%, while there was a water surplus from October to March, as shown in Figures 8 and 9. The same thing for Homs irrigation network that needs about 88 MCM/year at irrigation efficiency of 52%, according to a study of Iranian Sonieer Yecom Company. Based on the above and characterization of the main problems in sections (A and B) in the period 1998 to 2010, it was led to drafting and drawing digital data concerning the land use and its coverage in the studied site in 2010 using geographic information system GIS software, this agreed with results of Al-Adamat et al (2010); Assaf and Saadeh (2008). We found that the north-eastern, eastern and southern parts of the site (Wadi-Al haroon sub-basin) covered by natural pastures, rocky and bare lands and some buildings while arable land (planted and fallow) and non-arable (buildings, lakes and rivers, rocky and sandy), in addition to meadows and forests, (which constantly decreasing in both sections), covered the two sides of the river (Wadi Rabeia sub-basin, Kattenieh Lake sub-basin and the upper part of the midmost Orontes basin), as shown in Figure 10. Land use balance in section A refers to 51% of the arable land, 32% of non-arable land, 9% for meadows and pastures and 8% of forests. Regarding to the arable land, the ratio of cultivated land was about 8% fallow and 82% (65% irrigated {53% by groundwater sources and 47% by surface water sources} and 35% non-irrigated). Whereas fallow, orchards, rainfed olive and fodder crops have increased in the eastern and northern parts of section B, while irrigated orchards and field crops have decreased in that part. The crops varied in section A between summer and winter crops and fruity trees which was about 48% (The highest rate of 27.8% for almond followed by apples 15.3% and then by irrigated olive 3.4%) and the remain of the crops such as wheat represented 29.7% (the highest ratio among the cropped area) and the intensification was 110.57% for summer crops such as (maize and autumn potatoes and vegetables). In section B, trees covered 24% and the rest was rainfed crops and part of them has been irrigated whereas the wheat has formed the highest percentage to reach 45%. Through the use of evapotranspiration estimation programs of planted crops and that takes into account the properties of the soil, plant, water, climatic conditions and applied efficiency, the crop water requirements (CWR) had been met either by wells or springs water or government networks or direct pumping or gravity from the river, which decreased from 299.4 MCM/year at irrigation efficiency of 35% to 123.3 MCM/year at 85% in section A. Thus most crops had high water needs in both sections. We deduced that surface water contribution was 55.3% and about 44.7% for groundwater of the total water demand in section A. It was found that agriculture was formed about 70% of financial returns in the governorate. This should be taken into account when we make any decision with respect to reallocation and rehabilitation of the water and agricultural sector.

Future water balance:

Reference scenario (Current actual status):

Future water balance have predicted for 2050 by using renewable conventional water inflow only. By analyzing the results, as in the Figure 11, we noticed the effect of improving irrigation efficiency on the critical point, whereas: water inflow at the probabilities of water imports 50% (I), water deficit appeared before 2015, when the irrigation efficiency of 35%, it disappeared at improving the efficiency of irrigation to 50% till 2025, and when we improved the efficiency to 75% and 85%, we noticed its disappearance to 2030. But when the probabilities of water imports was 75% (II), we found that the deficit appeared before 2011, when the irrigation efficiency of 35%, and the critical point shifted to 2015, when the irrigation efficiency was 50%, and to 2025 at irrigation efficiency of 75% and 85%. While the deficit appeared at water inflow probability of 95% (III) before the year 2011 at all irrigation efficiencies and noticed even if we have improved irrigation efficiency to 85%, couldn't avoid the water deficit, this agreed with the results of (Khozam, 2010). To achieve the sustainable use of water resources in the studied basin, several scenarios have been proposed to save resources and to balance between supply and demand under limited water resources due to climate changes and low water conveyance efficiency. These scenarios are:

1- Reuse of unconventional water resources (only agricultural water return after treatment):

Through this scenario, we observed the deficit appeared in the status (I) at irrigation efficiencies (IE) of 35% and 50% before 2030, while it disappeared completely at efficiencies of 75% and 85% till 2035, whereas we noticed, in the previous status, that deficit appeared before 2014. But at the status (II), the critical point have shifted when improvement of irrigation efficiencies by low rates before 2025, then to 2015 in the status (III), (Figure 12). This is in agreement with the results of Haddad and Mizyed (2004) and Mourad and Berndtsson (2012).

2- In the case of possibility of investing Zeita reservoir:

This is enclosed on use of groundwater to irrigate field crops, and the surface water of Zeita dam to meet the first priority needs, and use part of its water for irrigation. We found after improving irrigation efficiency, the deficit is completely disappearing at the status (I) before 2045. Also it reduced comparing with previous scenario at both statuses (II) and (III), (Figure 13). This scenario has been studied as an important option because it noticed through the reference studies, there is a clear pollution in drinking waters of Ain Altanour spring which is primarily relied upon it to meet the drinking needs of Homs city. As can be seen obviously the effect of this scenario on response of environmental flow requirements after Kattenieh dam, especially in dry years.

3- In the case of the reduction of the individual's share of drinking water and minimizing the surface of Kattenieh Lake by creation of alternative dam.

Referring to the recommendations of the World Health Organization, 2006, this scenario has been reduced water per capita to reach 110 L/day in the city and 85 L/day in the countryside in 2050. Accordingly, we noticed reduction of produced water from 365.9 MCM/2050 to 242.15 MCM after improvement of the efficiency of water conveyance in network to 75%, in addition to decrease of Kattenieh Lake surface according to proposed solution in the research methods as in the Figure 4. The results showed that water deficit disappeared completely at the status (I) after the improvement of irrigation efficiencies with a residual surplus about 38% to response the needs of the third priority. In case it dropped about 93% and 65% at both statuses (II) and (III), respectively, comparing with the reference scenario, (Figure 14).

4- Improving Homs network efficiency and undertaking industrial plants by application closed circuits.

In this scenario, we have been improved Homs network and raised its efficiency to 75% instead of 52% though separation between Homs-Hama networks and application of pump station on Rastan dam to meet Hama network needs and exchanging them with pressured pipe networks, the needs will go down from 88 MCM/year to 61 MCM/year. Thus we relatively decrease water losses and pollution, specially also when the industrial plants reuse their waters again after treatment. This is in agreement with the results of Mourad et al (2011) and Petit and Baron (2009). Thus, we will be able to insurance the third priority obligations fully in section B, even at the status (II) in 2050. While water deficiency will decrease to 77% comparing with (RF) in case of very dry years and this will necessitate water withdrawal about 200 MCM from other near basin such as Coast basin, similar data were reported with Mourad (2012). Consequently, the adoption of water demand management method in order to determine the distribution of water in various sectors, rather than supply management and rational use of water leads to the sustainable use of water resources with a surplus that can be utilized in the development future projects.

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Table 1. Renewable available water resources (MCM) in (A) section, as a result of data analyses during the period (1975-2010) by using Pearson type 3.

Probability	50 % (Normal years)	75% (Dry years)	95 % (Very dry years)
Orontes flow at Umeiry (boundary between Lebanon and Syria)	346.08	287.64	200.97
Groundwater in Syria	99.95	89.91	75.71
Direct Rainfall on Kattenieh Lake	20.44	15.61	9.60
Surface Runoff on Kattenieh Lake	20.26	11.28	4.51
Total	486.73	404.44	290.85

Table 2. The demand on domestic water as produced (pumped through domestic networks) and consumed by population in 2010.

Site		Number of beneficiaries in thousand	Growth rate %	Domestic water amount Millions m^3 (MCM)		Loss rate %	Quota L/capita/ day (Lcpd)	
				produced	Consumed		produced	Consumed
Homs	City	822	2.35	58.10	39.76	31.57	193.66	132.53
	R1	127	2.77	6.80	4.39	35.48	147.22	94.99
	R2	174	5.15	8.59	5.46	36.51	135.19	85.84
Hama	City	407	2.30	48.65	33.98	30.15	327.57	228.80
	R3	46	3.42	3.55	2.37	33.24	211.07	140.91
Total		1576	-	125.7	85.96	-		

Table 3. Predicted water demands (MCM) in (A and B) sections during the period (2010-2050).

Year	2010	2020	2030	2040	2050
Sanitary Minimum flow	31.54	31.54	31.54	31.54	31.54
Homs and Hama Domestic	125.70	162.47	211.29	269.27	365.91
Withdrawal from Kattineh	31.54	31.54	31.54	31.54	31.54
5 canals Irrigation 6,849 ha	78.58	78.58	78.58	78.58	78.58
Irrigation from river 448 ha	4.45	4.45	4.45	4.45	4.45
Groundwater Irr. 8,127 ha	62.45	62.45	62.45	62.45	62.45
Homs Irrigation 13,093 ha	117.22	117.22	117.22	117.22	117.22
Total Demands	451.48	488.25	537.07	595.05	691.69

Table 4. Losses from the surface of Kattenieh Lake (MCM) during the period (1975-2010).

Probability	50% (Normal years)	75% (dry years)	95% (very dry years)
Evaporation	60.91	60.91	51.04
Seepage losses	12.62	12.62	12.62
Total Losses	73.53	73.53	63.67

Table5. The statistical hydrological distributions of gross water resources (MCM) in A and B sections during the period (1975-2010).

Probability	Kritski-Menkel	Normal (Ghos)	Pearson type3
50%	508.37	488.51	486.73
75%	382.44	404.5	404.4
95%	293.61	284.56	290.85

Table 6. Water balance in the section A [MCM/2010] (balance in Kattenieh dam).

Available water resources					
Flow of Orontes river from Lebanon entering Syria at Umeiry.	**Ground water resources between the state boundary and Kattineh Dam**	**Return water from the domestic, agricultural and industrial systems.**	**Direct rainfall on the surface of Kattineh Lake**	**Direct surface runoff into Kattineh reservoir.**	**Total**
302.15	78.58	85.11	12.89	8.65	487.38
Water demands					
Domestic water consumption	**Irrigation water consumption**	**Industrial water consumption**	**Irrevocable Water losses from Kattineh Reservoir**	**Minimum ecological flow in the river**	**Total**
125.7	153.83	14.08	69.8	31.5	394.91
The residual water which we can benefit from it in (B) part					92.47

Table 7. Amount of actual withdrawal water from (A) to (B) and the demands.

Demand for water	Actual withdrawal (MCM)	demands (MCM)
Ecological inflow	40.98	42
Industrial water	8.89	29.7
Homs-Hama irrigation networks	37.30	136.9
Tel Shour irrigation canal	0.89	1.57
Total	88.06	210.17

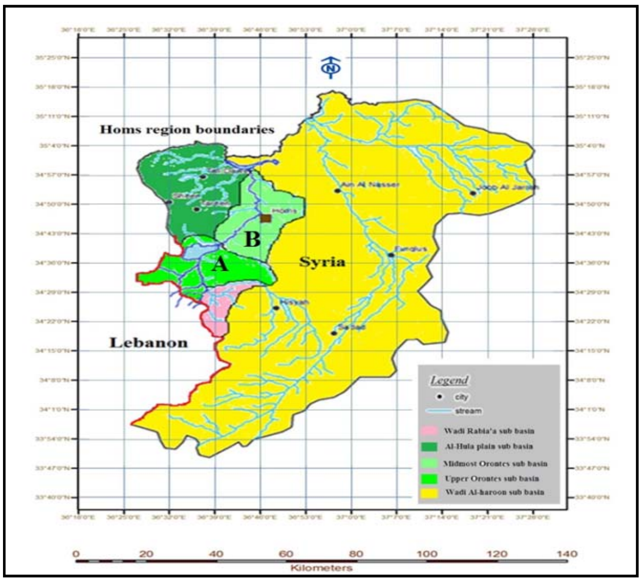

Figure 1: Orontes River Basin, including the upper catchment south of Lake Kattenieh (A) and the lower catchment north of the lake (B). The upper catchment is shared between Lebanon and Syria Map source: ESRI Data and Maps, 2010; Ra'ad, 2013).

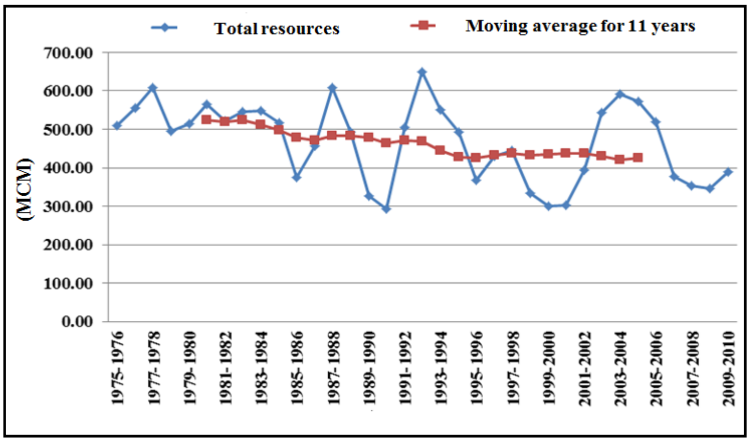

Figure 2: The time series of available water resources in the studied area.

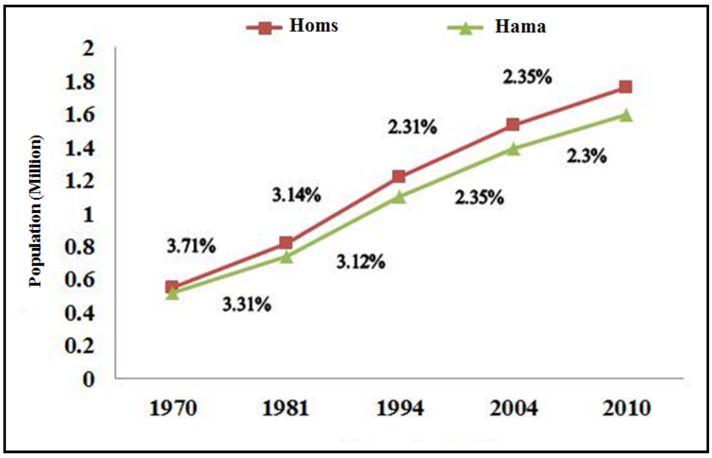

Figure 3: The Overpopulation and growth rate in Homs and Hama governorates which benefit from studied area's water.

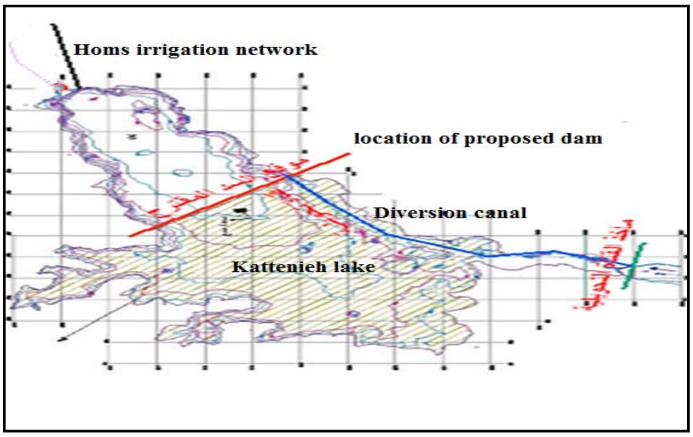

Figure 4: Location of proposed dam, according to (Ra'ad, 2013).

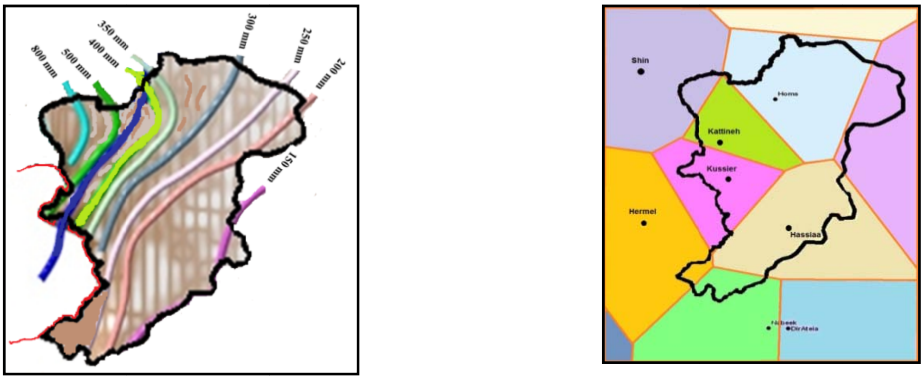

Figure 5: Layouts of precipitation using by equal precipitation lines and Thiessen's mean methods ESRI Data and Maps, 2010; ESCWA-BGR, 2012).

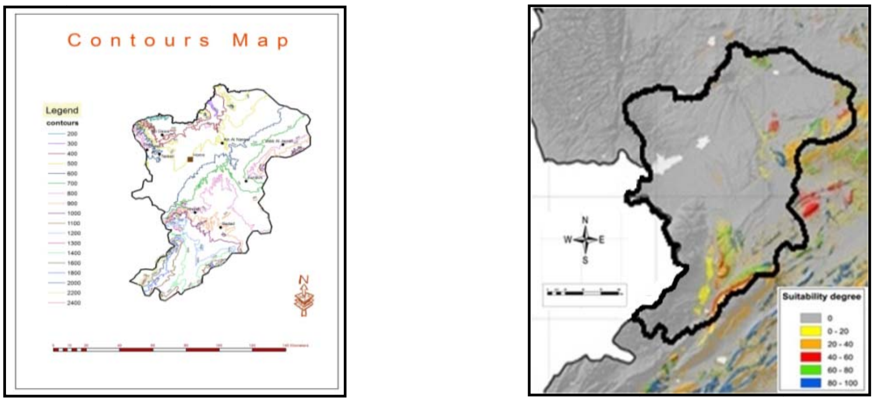

Figure 6: Contour lines and the possibility of water harvesting (ICARDA, 2010; GCSAR, 2011).

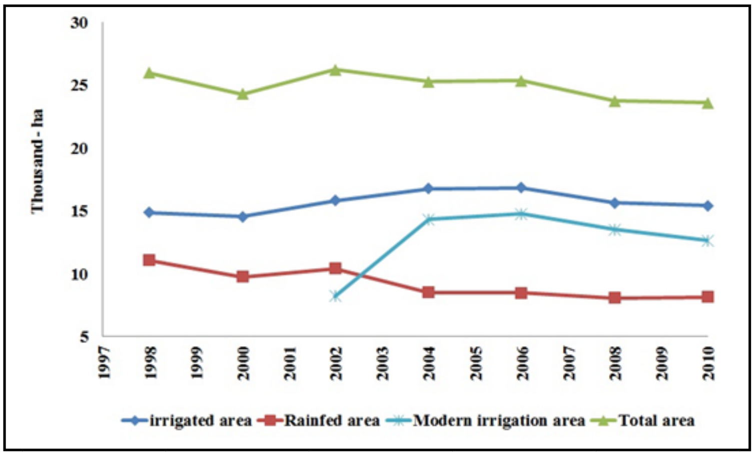

Figure 7: Development of cultivated lands in the section (A) during the period (1998-2010).

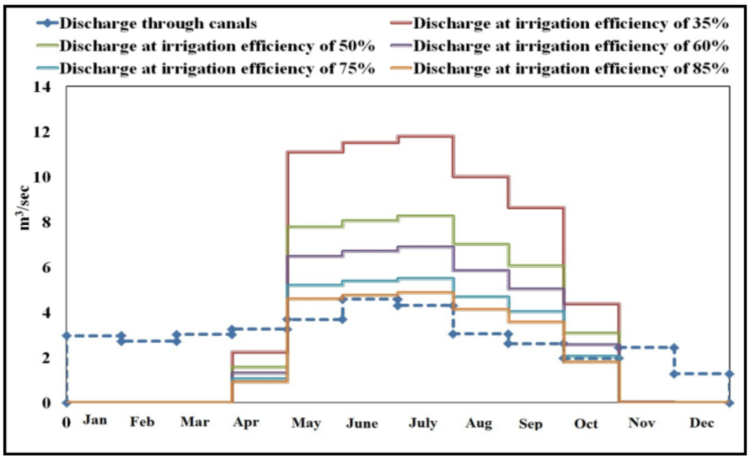

Figure 8: passing and actual discharge to meet irrigated crops in the section A.

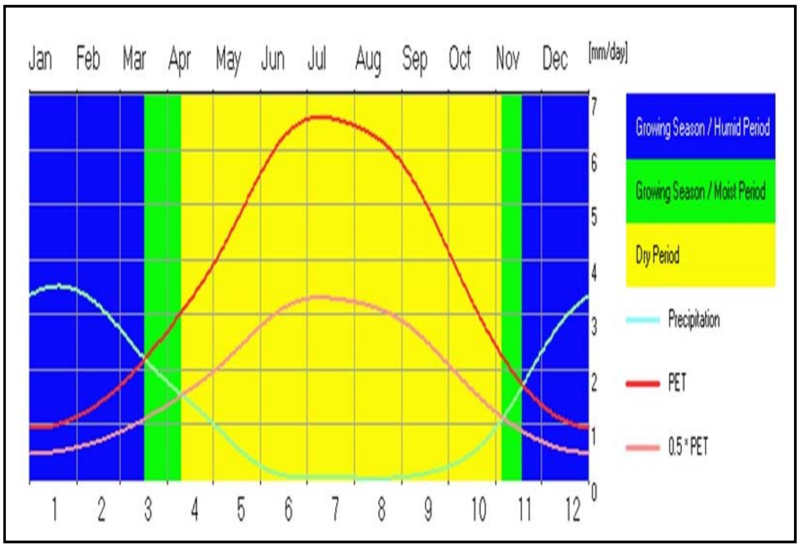

Figure 9: The water gap between precipitation and evapotranspiration of Class A (average of the previous ten years, 2000-2010 in the studied area)

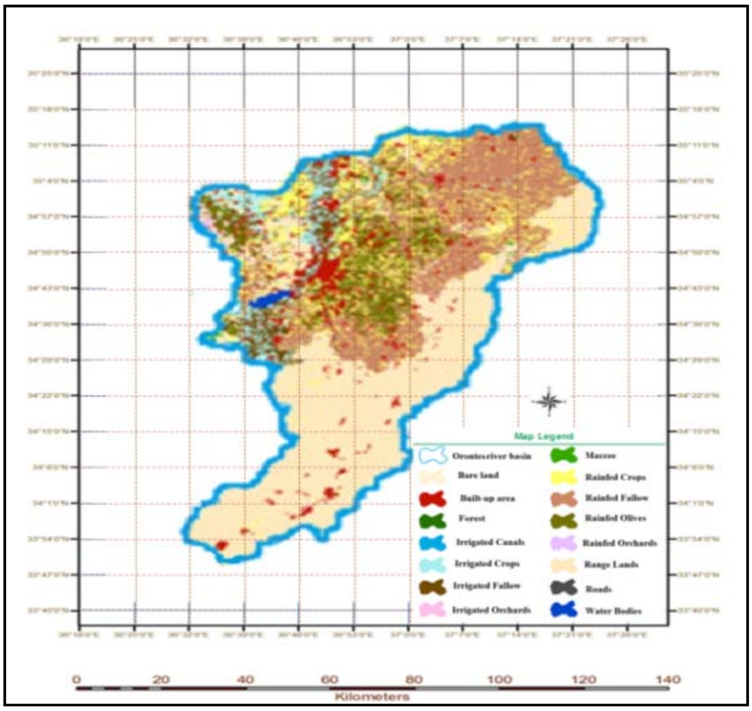

Figure 10: Land cover in Homs governorate (ICARDA, 2010)

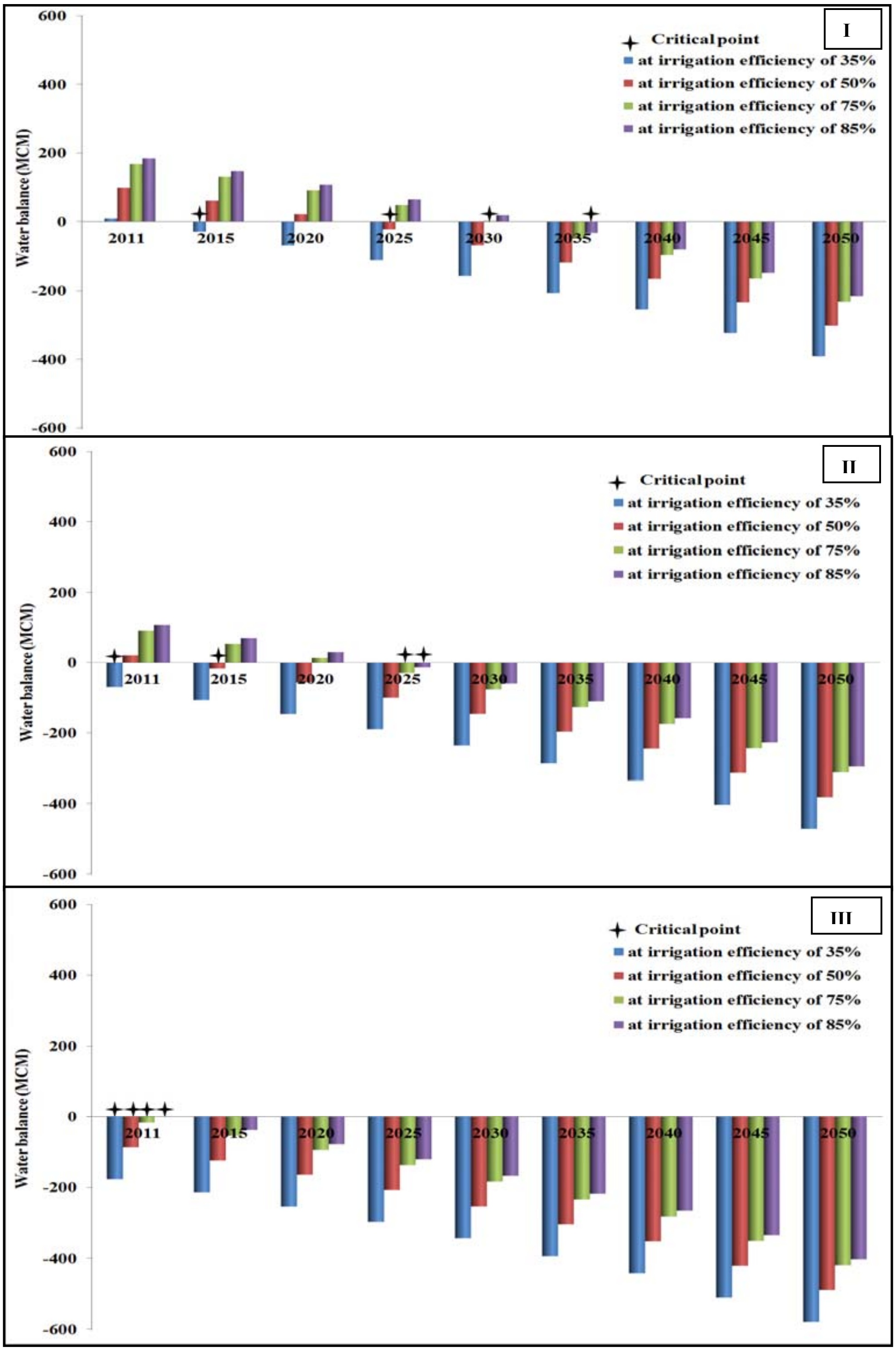

Figure 11: Water balance at the possibility of conventional water inflows at 50% (I), 75% (II) and 95% (III) {RF Scenario}.

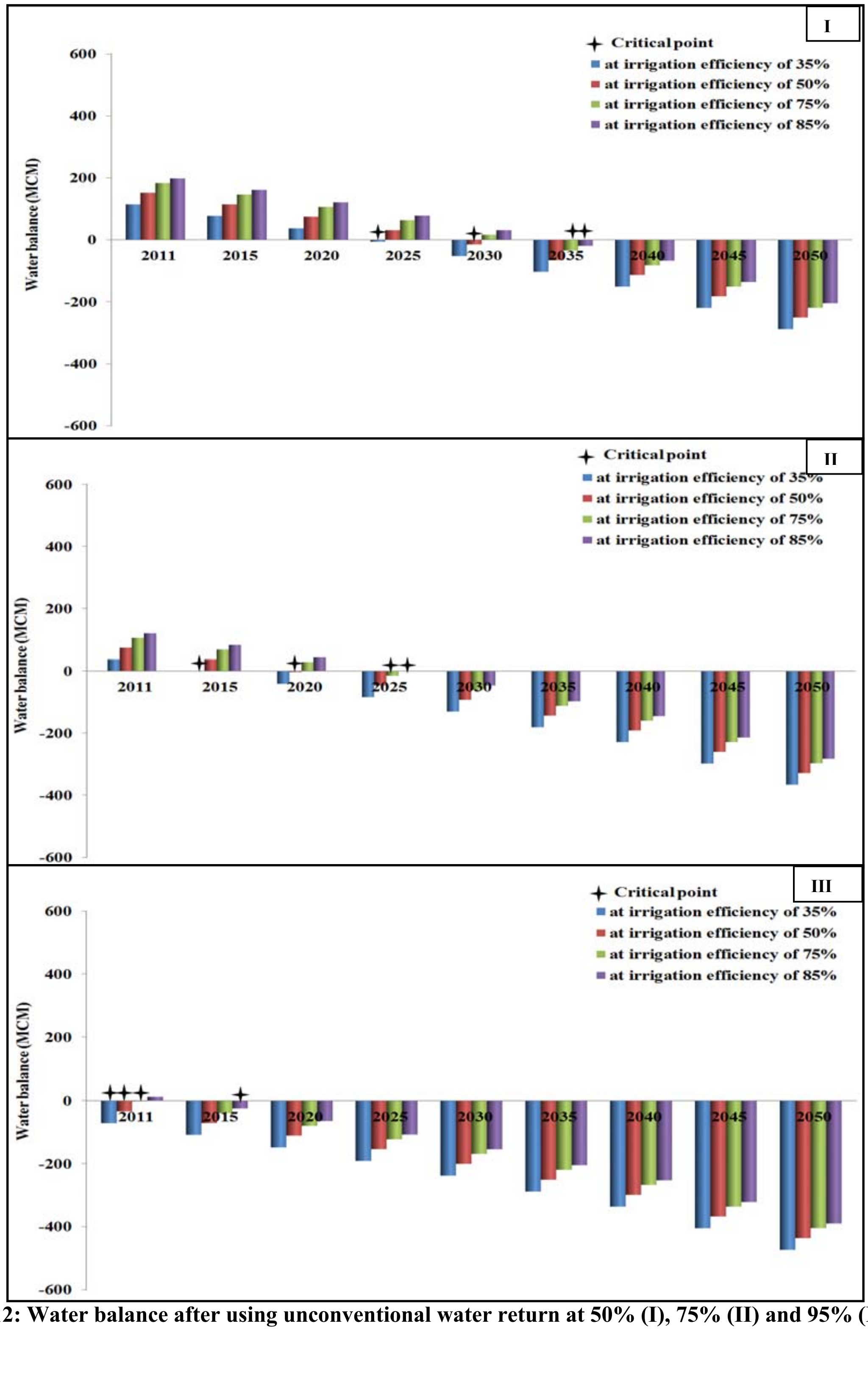

Figure 12: Water balance after using unconventional water return at 50% (I), 75% (II) and 95% (III) {Scenario 1}.

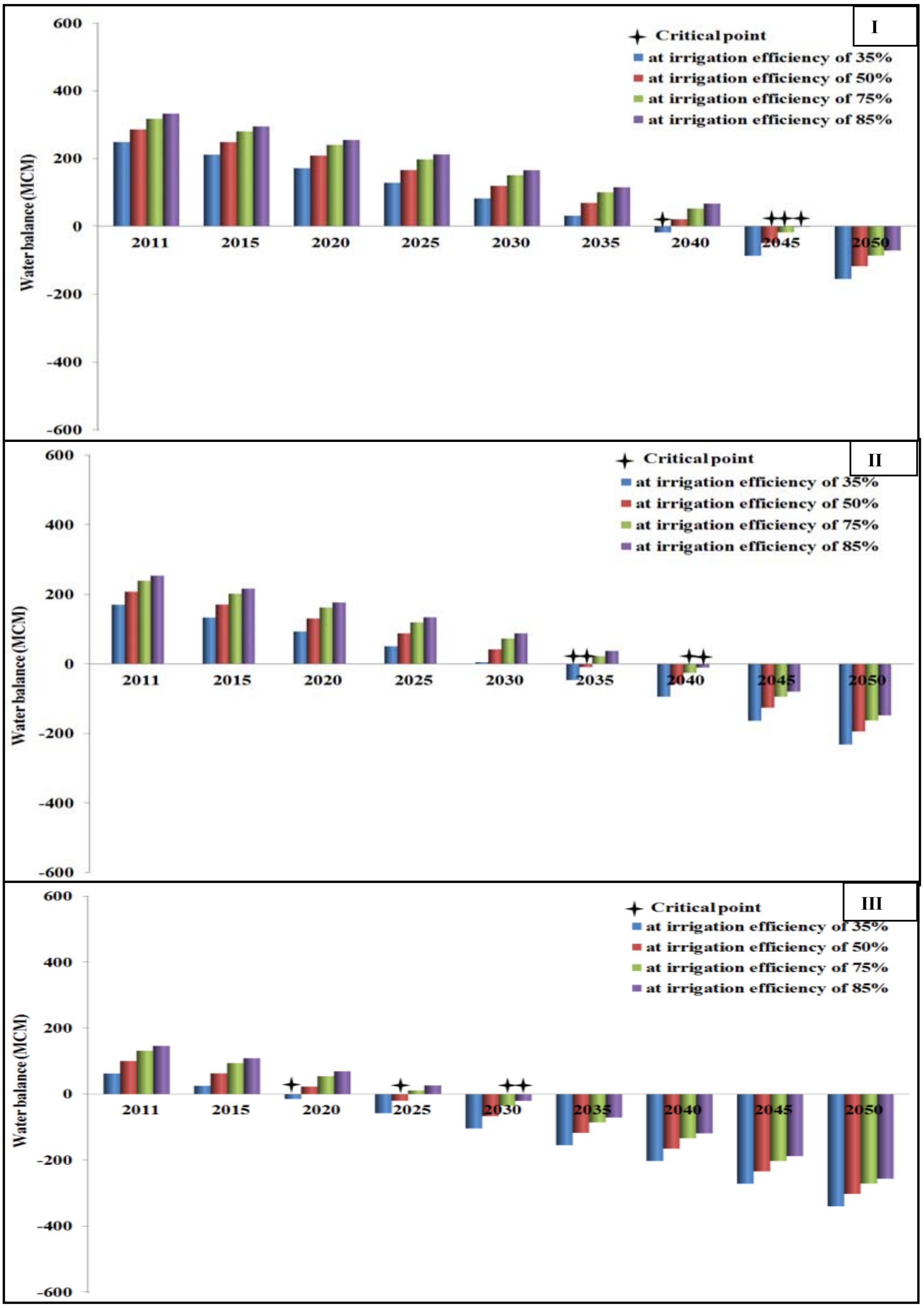

Figure 13: Water balance at the possibility of use of Zeita reservoir at 50% (I), 75% (II) and 95% (III) {Scenario 2}.

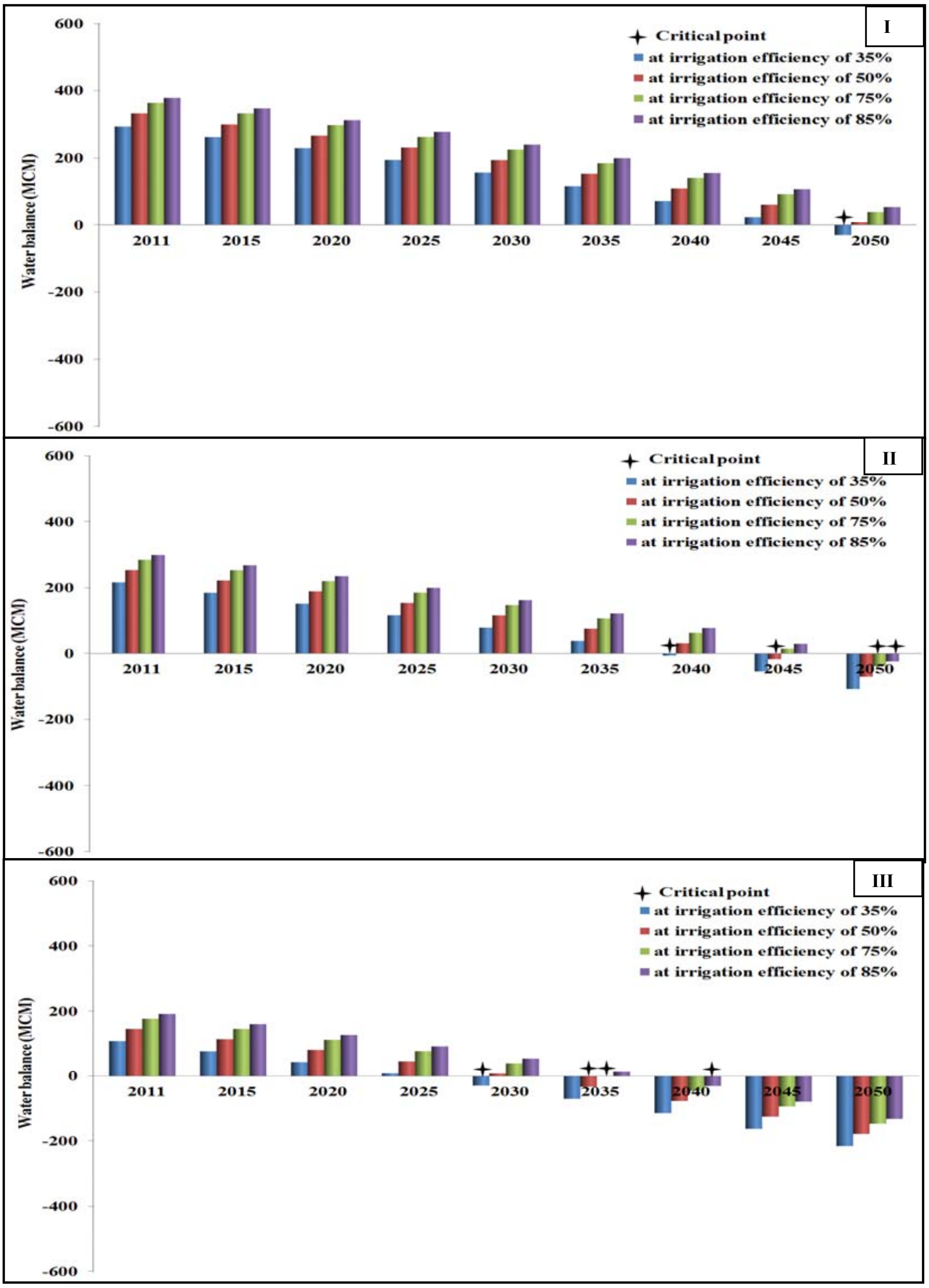

Figure 14: Water balance at reduction of the individual's share of drinking water and minimizing the surface of Kattenieh Lake by creation of alternative dam at (I), (II) and (III) {Scenario 3}.

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تأثير التغير المناخي على إتاحة المصادر المائية في حوض العاصي: حالة محافظة حمص في سورية

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ملخص

تعد المسقط المائي لمحافظة حمص محور الإنتاج الزراعي وخزان مائي استراتيجي في سوريا، غير أنّ خصوبة الأرض وتزايد السكان بالإضافة للتغيرات المناخية استحثت مزارعي المنطقة لتكثيف النمو الزراعي، وهذا أدى لزيادة الضغط على الواردات المائية المتاحة في حوض العاصي الأعلى. لذا كان من الضروري إعداد نموذج تنبؤ يسهم في تقدير إتاحة الواردات المائية المستقبلية للحوض. حيث تحلل هذه الورقة كيف يمكن لبعض الاستراتيجيات أن تساعد الدولة في تحقيق تنمية مستدامة وبالتالي أمنها المائي في أعقاب التغير المناخي حتى عام 2050. فيما يأتي درست أربع سيناريوهات بالاعتماد على الحالة الفعلية الراهنة مع تحسين كفاءة الري (السيناريو المرجعي): (1) سيناريو إعادة استعمال رواجع الماء الزراعي المعالجة، (2) سيناريو الاستخدام الأمثل لخزان سد زيتا، (3) سيناريو خفض حصة الفرد من مياه الشرب والاستخدام المنزلي وتقليل التبخر من سطح بحيرة قطينة، (4) سيناريو الفصل بين شبكتي ري حمص–حماه ورفع فاعلية نقلهما للماء باستبدالهما بالشبكات الأنبوبية المضغوطة. وكان ذلك خلال ثلاث حالات للتغيرات المناخية (السنوات الطبيعية، الجافة، الجافة جداً). صيغت النتائج على شكل مخططات وخرائط وجداول وأظهرت أنّه بتطبيق السيناريوهات الثلاثة الأولى، ستختفي النقطة الحرجة (العجز المائي) مع الحصول على فائض بحدود 38% بالمقارنة مع السيناريو المرجعي يكفي لتلبية متطلبات شبكة ري حمص- حماه (الأولوية الثالثة) عام 2050 في حالة السنوات الطبيعية وكفاءات الري العالية. أيضاً سينخفض العجز بحدود 93% و65% في حالة السنوات الجافة والجافة جداً على التوالي. في حين بتطبيق السيناريو الرابع والدارات المغلقة للمنشآت الصناعية نستطيع تدارك العجز وتخفيض نسبته إلى77% مع تخفيف نسبة التلوث في حالة السنوات الجافة والجافة جداً على التوالي وهذا الأخير سيلزم باستجرار مائي بحدود 200 م.م^3 من حوض قريب آخر كحوض الساحل لتصغير الفجوة بين العرض والطلب.

الكلمات الدالة: المسقط المائي، الاستراتيجيات، النقطة الحرجة (العجز المائي)، سيناريو، الدارات المغلقة، العرض والطلب.

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