Journal of Hydrosciences and Environment
Available online at http://jhe.usb.ac.ir/

ISSN: 2345-5608

Water Resource Simulation in an Arid Watershed Considering an Allocation for Dust Stabilization and Different Scenarios of Water Supply and Demand

S.A. Hashemi Monfared*[1], Y. Zamani[2], M. Azhdary Moghaddam[3]

1. Assistant Professor of Civil Engineering, University of Sistan and Baluchestan, Zahedan, Iran
2. Ph.D student of Civil Engineering, University of Sistan and Baluchestan, Zahedan, Iran
3. Associate Professor of Civil Engineering, University of Sistan and Baluchestan, Zahedan, Iran.

ARTICLE INFO

Article history:

Received: *5 January 2016*
Accepted: *15 December 2016*

Keywords:
Stabilization Dust,
Evaluation,
Sistan Region,
Water Resources Simulation,
Water Supply.

ABSTRACT

Water is the main demand of people settled in the arid areas of large watersheds. This demand is more necessary and critical in the areas with the potential of dust sources and fine sediments entering into the watershed in a long-time period. Sistan watershed to the south-east of Iran is a region with the specific hydrological conditions. The 120-day winds blow continuously in the summer propagating large amounts of dusts directly into the cities and rural areas. In this study, a demand is considered for the dust stabilization in the study area. A field surrounding the watershed that directly affects the amount of dusts is selected. The amount of water demand that is needed for the stabilization and saturation of the soil is measured by the soil sampling and experimental on-site works. A demand for dust stabilization is defined and the water resources systems are simulated. Different scenarios of water supply and demand are considered. Results show the unmet demands of the different scenarios (Sc) in a 15-year period in the region. The highest amount of unmet water demand is calculated for the scenario No.10 that is the combined effects of reducing agricultural land use and increasing the agricultural efficiency and reducing evaporation from Chahnimeh reservoir and flow of discharge in accordance with the agreement between Iran and Afghanistan enforced in 2015. Different scenarios are evaluated in terms of dust stabilization priority and also agriculture using the analytic hierarchy method. This shows the high score of Scenario No.9 that is the combined effect of reducing agricultural land use and the increasing the agricultural efficiency and reducing the evaporation from Chahnimeh.

1. Introduction

Water resources management requires a deep understanding of the special value of the water for human life, interaction of human beings and the social significance of water resources for national economic development (Rosenberg 2008). Planning and management of water aims at meeting the water requirements of all water users although sometimes it is not possible. Frequently, conflicts among water users arise from the fact that water is a scarce and shared resource (Sandoval-Solis *et al*. 2010). Integrated water resources management (IWRM), especially in areas facing the limited water resources has become an essential approach. IWRM was introduced in the 1980s to optimize water uses between different water demand sectors and water resources (Ludwig *et al* 2014). Lévite (2003) studied the effects of agricultural sector on the Steelport River by WEAP software. Results showed that in some parts of the basin in most severe demand management as parts of the requirement are not provided. Demand management do not respond to drought conditions and demand management can allocate enough current for internal needs. Lake Naivasha River Basin located in Kenya will face severe problems in coming years because of rising demand in different parts of the region. Alfarra (2004) used WEAP software to study the river basin system in order to find the causes of the possible future problems. Results showed that the main problem lied in the agricultural sector so that in some parts, water could be provided to meet irrigation requirement while it could not be provided in other areas. Yates *et al*. (2007) performed a modeling study by using WEAP model to evaluate the effects of adding environmental goals. The main scenarios of the study contained priority for water allocation in the past which had two different shapes. Assaf and Saadeh (2008) investigated the indexes of water quality in the catchment area upstream of the Litani in Lebanon using WEAP model and GIS evaluation. Results confirmed that the gravity of this problem is demonstrated the importance of taking immediate action on the scarce of fresh water resource. Mutiga *et al*. (2010) used WEAP software to allocate water as a planning tool studied for minimizing water use conflicts in Kenya. In this study, WEAP on the data available for three sub-

* Corresponding author's email:
hashemi@eng.usb.ac.ir

basins was established with a monthly step. They showed that irrigation improved productivity significantly by the downstream requirements water supply. Li *et al*. (2015) used WEAP analysis to investigate the future water situation in the Binhai area by setting different scenarios of socio-development and urbanization until 2020. The results illustrated that the pressure on the BHNA water resources would increase in the future and several suggestions were advanced to assist decision makers in planning water management to meet future demands in this region. Alemayehu *et al*. (2010) assessed the implications of development planning of water resources in the catchment area of Lake Tana. This study utilized WEAP model to determine the likely impact of a number of possible development scenarios on lake water levels. The simulation results revealed that if all the planned developments occurred, it would lead to an average of 2198 GW hydro-power, but the mean annual water level of the lake would be lowered by 0.44 meters. Mehta *et al*. (2013) studied scenario-based planning of water resources for water and electricity in Lake Victoria and showed that water supply in all three towns was then limited by infrastructure. Safavi *et al*. (2015) planned a model in Zayandeh-rud basin for assessing baseline scenario made with 21-year period of hydrological analysis. Results for the baseline scenario revealed that water demands would be supplied at the cost of depletion of surface and groundwater resource, making this scenario undesirable and unsustainable with the potential of irreversible negative impact on water sources. WEAP is also used in Olifants catchment in South Africa to analyze current and future demands (Arranz and McCartney 2007). In another research, WEAP was applied in Ghana to simulate the impact of small reservoirs in the Volta. The results indicated that the reservoirs had low impact on the flow of the White Volta River. However, the creation of bigger reservoirs on the river could have significant effect on the flow of the White Volta River and reduced its contribution to the Akosombo Lake which was further downstream in the Volta Basin (Hagan 2007). In Perkrra catchment to analyze scenario implementation, a model was performed by WEAP. Results showed very sharp peaks of the flow time series downstream and a high vulnerability at the demand nodes with demand coverage varying between 10% and 100% (Mugatsia 2010). In a study on the Rio Grande trans-boundary basin, Sandoval-Solis and McKinney (2012) described that the environmental flows were not considered as an integral part of the water management. Important natural regions of the Chihuahuan desert are threatened due to the lack of environmental flows. In this study, they estimated the maximum volume of water available for environmental flows without affecting human and international water requirements and without increasing the flood risk in Presidio-Ojinaga. A reservoir reoperation policy for Luis L. Leon reservoir was proposed to supply environmental flows without violating the system constraints. The policy that supplied the maximum water to the environment was two-thirds (66%) of the prior reservoir alteration conditions; it also improved human water supply.

Mulch has been used for dust stabilization in many regions in the similar areas during last decades. The availability of chemical constituents in the composition of mulch will pose a lot of environmental problems after the application such as soil, groundwater and air contamination.

In this study, a region with high potential of dust was selected along the direction of the 120-day summer winds. A water allocation was used to stabilize dust and a water demand was defined for this case. The amount of water for soil saturation was measured with the experimental works in the study area. The water required to stabilize the dust for 24 hours and 5 months of continuous blow of wind was calculated. Different scenarios of water supply and demand was defined for the region and compared with the reference scenario in the watershed. The percent of unmet water demand for each sector was simulated in a 15-year period.

2. Study Area

The Sistan region (3050 N–31280 N and 61150 E–61500 E) is located close to the Iranian border with Pakistan and Afghanistan to the southeastern part of Iran.

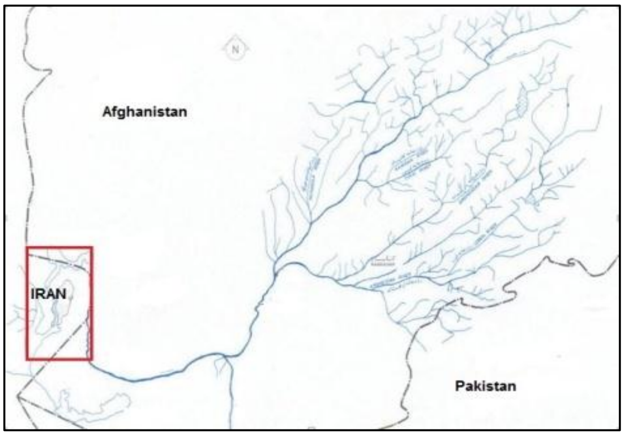

Figure 1. The map of the study area shown in red

This region has a major source of dust in south-west of Asia, often producing intense dust storms that cover the Sistan region in eastern Iran, and southwestern Afghanistan and Pakistan (Goudie and Middleton 2006; Alam *et al*. 2011; Rashki *et al*. 2012). Also five cities and 980 villages with a population of more than 400,000 are located in this area. The climate is arid with an annual average precipitation of 60 mm occurring mainly in winter while annual evaporation exceeds 4000 mm as a result of high temperatures. The Hirmand River and Chahnimeh reservoirs are important water sources in the Sistan region.

Hirmand River basin is shown in figure 1. The study area is highlighted in red.

During summer, the area is under the influence of a low-pressure system attributed to the Indian low thermal that extends further to the west as a consequence of the south Asian monsoon system. These low-pressure conditions are the trigger for the development of the Levar northerly wind, commonly known as the "the 120-day wind" (Hossenzadeh 1997). The direction of the 120-day wind in Sistan is shown in figure 2.

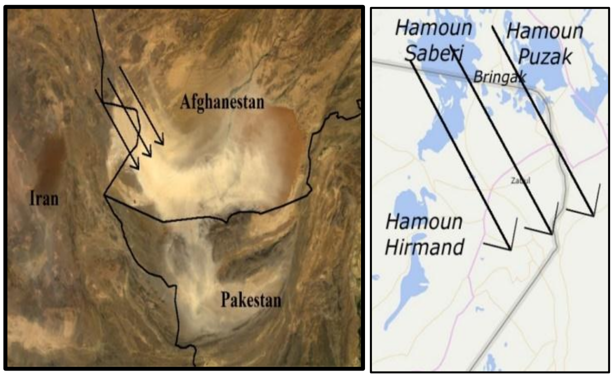

Figure 2. The direction of the 120-day wind in the catchment of the study area

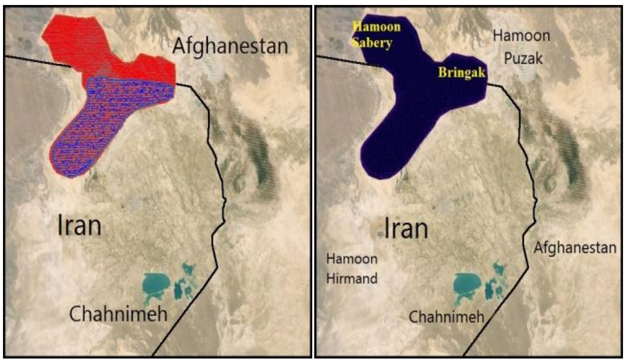

Figure 3. The whole critical area of wind erosion (Red color) and the critical area of wind erosion (Blue color) in the study area

3. Material and Methods

The purpose of transporting water to Hamoon wetland is to saturate the soil to create an adhesion between the components of soil to prevent soil takeoff and scour. Water requirement for the consolidation of dust is equal to sum of the amount of evaporation from the soil surface and the amount of water to saturate the soil.

The amount of daily evaporation from the soil surface is approximately equal to 3.95 mm according to Aydin *et al*. (2005). Therefore, in each month 1185 cubic meters evaporates from one-hectare soil surface in each month.

The amount of evaporation= $3\cdot 95 * 10^{-3} * 30 * 100 * 100 = 1185 \frac{m^3}{ha.month}$

An undisturbed soil sample is selected from dust area and is tested to calculate the amount of porosity. The porosity is about 30 percent. Because the region of dust area is very large, a homogenous soil texture is considered as the critical soil in the study area. The dominant texture of soils in the Sistan region is loam, sandy loam, and clay loam. Physical properties of the soil are shown the table 1.

Table 1. The physical properties of the dominant soil texture in the Hamoon region

Density $(\frac{gr}{cm^3})$	% Clay	% Silt	% Sand	soil texture
1.6	14	18	68	Sandy loam
1.32	19	44	37	Loam
1.18	32	38	30	Clay loam

According to table 1, clay-loam soil is considered as the critical soil because it has low weight and can be propagate as dust. The 120-day winds have the potential to move up to 200 tons per hectare of soil in this area (Ahmadi *et al*. 2005).

Soil transferred from Hamoon wetland= $200 \div 1\cdot 18 = 169\cdot 4 \ \frac{m^3}{ha}$

Soil porosity transferred= $169\cdot 4 * \frac{30}{100} = 50 \ \frac{m^3}{ha}$

The amount of 169.4 m^3 soil with 50 m^3 porosity is transferred. So neglecting evaporation, 50 m^3 ha^{-1} water is required to be transferred for the saturation of soil . Five months from May to September are critical in the region because winds have the power of erosion and dust propagation. The amount of evaporation from the soil surface is 1185 m^3 and the water demand is 5925 m^3 in these five months. Therefore, the total water requirement for soil saturation is 5975 m^3 ha^{-1} in these five months of wind blow in the study area.

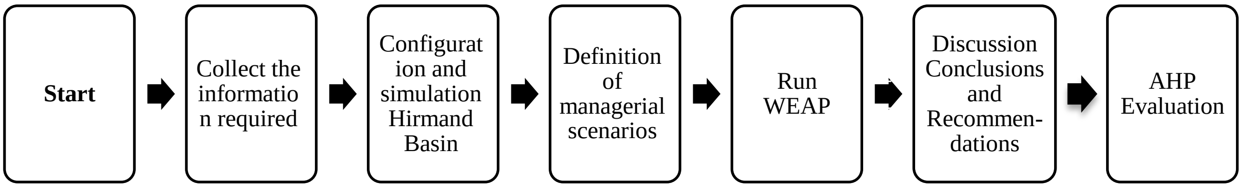

Figure 4. The steps of modeling in Sistan area

4. Model Formulation

In this study, first the amount of water required for dust stabilization in the study is calculated as mentioned before. The data needed for the modeling of the region are collected and a water demand is considered for the dust stabilization. A 15-year period is selected for the water allocation modeling in the watershed by WEAP model and the defined scenarios are evaluated using the collected data and the analytic hierarchy. Steps of performing this type of modeling are presented in figure 4.

FAO crop requirements are computed assuming a demand site with simplified hydrological and agro-hydrological processes such as precipitation, crop growth emphasizing irrigated, evapo-transpiration and rainfall agriculture. Clearly, non-agricultural crops can be included as well (Sieber and Purkey 2011).

5. Scenario Definition

For the study of the supply-demand relations and the effect of considering new demands in the study area, some hydrological and supply-demand scenarios are described for this region. These scenarios have occurred in the last decade or are predicted to be occurring in coming years. The chosen scenarios of water management in this research are as follows:

Scenario 1 (Reference scenario): This scenario represents the current situation with past water resource management and is there by default. Reference scenario is used as the basis for comparison with other scenarios.

Scenario 2: Reducing 30 percent of evaporation in Chahnimeh using the physical and biological coating composition.

Scenario 3: Decreasing 50 percent of total cultivated agricultural land.

Scenario 4: Increasing the agricultural water irrigation efficiency during 5 years up to 65% using sprinkler and pressurized irrigation system (assuming the agricultural water irrigation efficiency at 34%).

Scenario 5: Municipal wastewater treatment domestic water

Scenario 6: Combination of scenarios 2 and 3.

Scenario 7: Combination of scenarios 2 and 4.

Scenario 8: Combination of scenarios 3 and 4.

Scenario 9: Combination of scenarios 2, 3 and 4.

Scenario10: Combining scenario 9 with flow of discharge agreed upon by Iran and Afghanistan (assuming that the agreement between Iran and Afghanistan annually releases 820 million m3 (MCM)). Table 2 shows the sites specs of water demands and supplies in Sistan area.

There are four section of water consumption including 3 subsections in industry, 3 subsections in agricultural, 7 subsections in drinking water (6 urban and 1 rural) and a demand for Hamoon wetlands (dust stabilization) in the Sistan region.

The major rivers and reservoirs, as well as the demand sites in the Sistan area are shown in figure 5 that shows a conceptual schematic of the Hirmand catchment by using WEAP software.

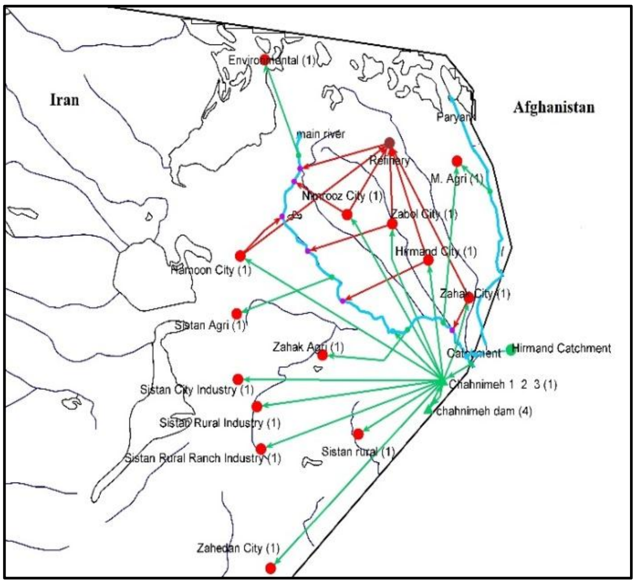

Figure 5. Water resources and demand sites in Sistan area.

Table 2. The sites specs of water demands and supplies in Sistan area.

Reservoir1	This reservoir is triad Chahnimeh1, Chahnimeh2 and Chahnimeh3. Inflow of Sistan river enters to this reservoir. Total storage is 680MCM Dead storage is 320 MCM This reservoir is the main source of water for agriculture, industry, urban water and wetlands demands.	Reservoir2	Excess water of reservoir1 enters to this reservoir (Chahnimeh4 or Chahnimeh dam). Total storage is 820MCM Inactive zone is 200 MCM.
Paryan River	The river is on the border of Iran and Afghanistan. Paryan River provides M Agri[a] section water demand.	Sistan River	This river is the main river Hirmand catchment. Sistan river flows enter to reservoir1 and the Excess water for M Agrid and Zahak Agri and Sistan Agri demands will be Allocated, Finally, This River Enters to Hamoon wetland.
Zahak City	Population of this city is 14,324 people; Annual water use rate is 53.34 m^3/person	Zahedan City	Annual water use is 26 MCM from the Reservoir1
Hirmand City	Population of this city is 6,774 people; Annual water use rate is 55.37 m^3/person	Sistan Rural	Population of this city is 226,343 people; Annual water use rate is 54.75 m^3/person
Zabol City	Population of this city is 141,810 people; Annual water use rate is 58.02 m^3/person	M Agri[a]	Cultivated area is about 54,000 ha; Water use rate[b] is 8450 m^3/ha
Hamoon City	Population of this city is 7,232 people; Annual water use rate is 47.97 m^3/person	Zahak Agri	Cultivated area is about 49,000 ha; Water use rate[b] is 8750 m^3/ha
Nimrooz City	Population of this city is 3,328 people; Annual water use rate is 46.01 m^3/person	Sistan Agri	Cultivated area is about 32,000 ha; Water use rate[b] is 7950 m^3/ha
Sistan City Industry	Water use rate is 3/6 MCM/Year	Environment al	This area is about 60,000 ha, Water use rate[c] is 5975 m^3/ha
Sistan Rural Ranch Industry	Water use rate is 17/8 MCM/Year	Sistan Rural Industry	Water use rate is 8 MCM/Year

a- Miyankanghi agriculture area;
b- This rate is obtained according to the cropping pattern dominant in each area;
c- This rate is obtained in Material and Methods;

6. Result and Discussion

The impact of different scenarios is described and examined on the dust stabilization unmet water demand.

According to results of WEAP, the water demand for stabilization of dust is 358.5 million m3 yr-1. Table 3 shows the unmet demand for dust stabilization under different scenarios from 2014 to 2029. In the reference scenario (Sc 1) the unmet demand for dust stabilization in 2014 is equal to 17.194 MCM and 17.325 MCM in 2029 increasing unmet demand in later years due to the population growth rate (1.05%)show in figure 6. Sc 2 considers the reduction of 30 percent of evaporation in Chahnimeh by physical and biological coating composition. The aim of biological coating is to avoid water quality loss in Chahnimeh2 that is used for drinking. By applying Sc 2, the unmet demand for dust stabilization reaches nearly from 17 MCM to 9.8 MCM, the amount of unmet demand for dust stabilization is reduced by 110.568 MCM as compared to the reference scenario. The population growth rates in the next years will cause an increase in unmet demand from 9.8 MCM to 9.95 MCM in this scenario (Sc 2). The agricultural demand in this area is high and the reduction of agricultural land use will reduce the demand on the agricultural side and the unmet demand for dust stabilization sector will decline. In Sc3 in which agricultural land is reduced to 50 percent, the unmet demand for dust stabilization is reduced from 17 MCM to 1.9 MCM. In the last years due to the increasing population, the unmet demand for dust stabilization sector is increased from 1.9 MCM to 2 MCM. In this scenario (Sc3), the amount of unmet demand for dust stabilization is reduced by 229.332 MCM as compared to the reference scenario. In Sc4, the agricultural efficiency is assumed to be improved up to 65% by sprinkler and pressurized irrigation system in 5 years. In the first year, the efficiency is 34 percent and the unmet demand is 17 MCM. In the second year, the efficiency is considered 40 percent and the unmet demand reaches 11 MCM. In the third year by 50 percent of efficiency, the unmet demand decreases to 7.8 MCM. In Sc5, the municipal wastewater is used for the stabilization of dust. To prevent environmental problems, the municipal sewage from treatment plant is transferred to the region of dust propagation. With this scenario, the unmet demand is decreased from 17 MCM to 16.6 MCM. In this scenario (Sc5), the amount of unmet demand for dust stabilization is reduced by 9.272 MCM as compared to the reference scenario. In Sc6, the effect of reducing evaporation from Chahnimeh and cultivated agricultural land is considered (Sc2 and Sc3). In this scenario (Sc6) after the base year, the unmet demand for dust stabilization is zero; therefore, the demand for water by dust stabilization sector is completely met. Sc7 considers a combination of the effect of reducing Chahnimeh evaporation and increasing the efficiency of agriculture (Sc2 and Sc4). In 2015 the decrease in Chahnimeh evaporation (30 percent) and the increase in agricultural efficiency to 40 percent reduced the amount of unmet demand for dust stabilization to 4.169 MCM and in 2016 reduced it to 0.231 MCM. In 2017 as Chahnimeh evaporation is decreased and agricultural efficiency is increased by 60%, all demand is met and total water demand is supplied for the stabilization dust. In Sc8, the effect of a combination of reducing agricultural land use and increasing the agricultural efficiency is studied (Sc3 and Sc4). In this scenario (Sc8) all water requirement after base year is supplied. Sc9 allows studying the effects of three scenarios (Sc2 and Sc3 and Sc4). According to results, Sc6 will meet the demand of dust stabilization sector for water from 2016 on. Sc10 investigates the effect of reducing agriculture land use, increasing the efficiency of irrigation and reducing Chahnimeh evaporation and discharge yields according to the agreement between Iran and Afghanistan. This scenario is a combination of Sc9 with a discharge of agreement (820 MCM). In this scenario (Sc10) in 2015 assuming a decrease of 50 percent in agricultural land and a reduction of evaporation from Chahnimeh and the efficiency up to 40 percent and also the released discharge according to the agreement, the unmet demand for dust stabilization sector reaches from 17 MCM to 63 MCM. Because the Sistan region water demand is more than 820 MCM (The agreement between Iran and Afghanistan.

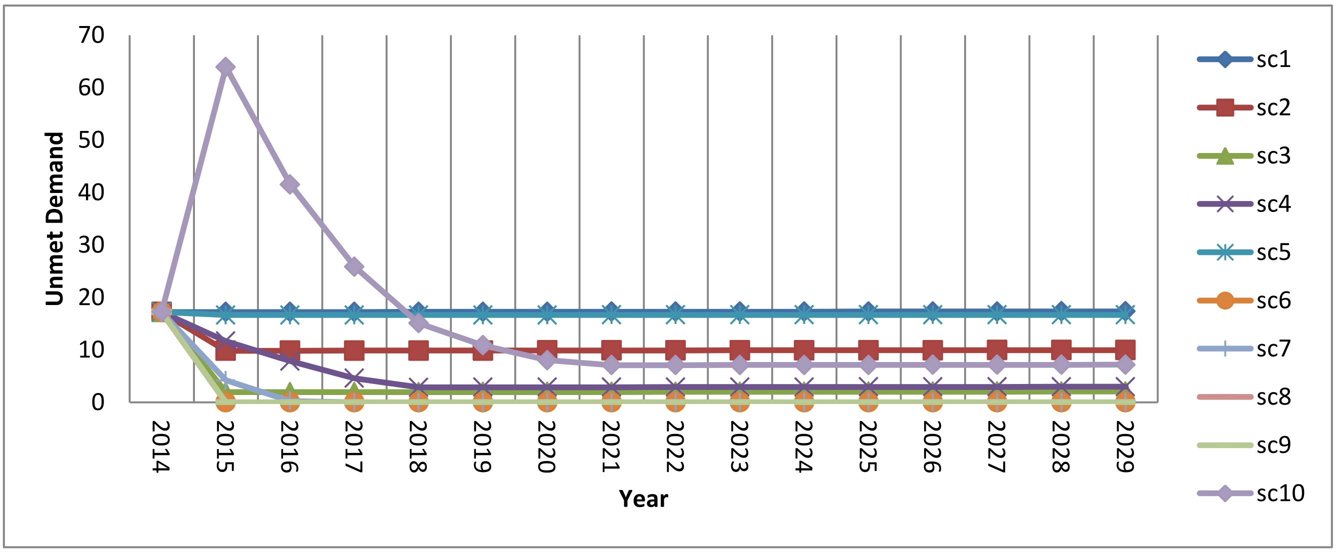

Figure. 6 Comparison of unmet demands for different scenarios

Table 3. The unmet demands for dust stabilization in different scenarios

Year/Scenario	Sc1	Sc2	Sc3	Sc4	Sc5	Sc6	Sc7	Sc8	Sc9	Sc10
2014	17.194	17.194	17.194	17.194	17.194	17.194	17.194	17.194	17.194	17.194
2015	17.202	9.829	1.907	11.647	16.628	0	4.169	0	0	63.907
2016	17.211	9.838	1.916	7.832	16.631	0	0.231	0	0	41.518
2017	17.219	9.846	1.925	4.562	16.633	0	0	0	0	25.851
2018	17.227	9.855	1.934	2.847	16.635	0	0	0	0	15.078
2019	17.236	9.864	1.944	2.857	16.637	0	0	0	0	10.859
2020	17.244	9.872	1.953	2.866	16.639	0	0	0	0	8.037
2021	17.253	9.881	1.963	2.876	16.642	0	0	0	0	7.073
2022	17.262	9.890	1.973	2.885	16.644	0	0	0	0	7.083
2023	17.270	9.900	1.983	2.895	16.646	0	0	0	0	7.094
2024	17.279	9.909	1.992	2.905	16.649	0	0	0	0	7.104
2025	17.288	9.918	2.002	2.915	16.651	0	0	0	0	7.115
2026	17.297	9.928	2.013	2.925	16.654	0	0	0	0	7.126
2027	17.307	9.937	2.023	2.935	16.656	0	0	0	0	7.137
2028	17.316	9.947	2.033	2.946	16.658	0	0	0	0	7.148
2029	17.325	9.956	2.044	2.956	16.661	0	0	0	0	7.159
Sum	276.131	165.563	46.799	76.045	266.859	17.194	21.594	17.194	17.194	246.483

In this scenario (Sc10), the farming lands are reduced by 50%, Chahnimeh evaporation is decreased by 30%, agricultural efficiency is increased by as high as 50%, and the discharge is done in accordance with the agreement between Iran and Afghanistan, resulting in the decrease in unmet demand from 63 MCM to 41 MCM. This reduction of unmet demand (from 63 MCM to 41 MCM) by increasing agriculture efficiency is associated with the dependence of the basin to agriculture and a large percentage of water that is used in agriculture. In this scenario (Sc10) in 2017, assuming a decrease of 50 percent in agricultural land and reduce of Chahnimeh evaporation and agricultural efficiency to 60% and providing discharge as the agreement, the unmet demand for dust stabilization is reduced from 41 MCM to 25 MCM. In this scenario (Sc10) in 2018, unmet demand with an agricultural efficiency of 65 percent is reduced to 15 MCM. It is specified that the unmet demand of dust stabilization part drops as agricultural efficiency is improved.

This indicates that the management of water resources in the basin would allow facing water demand of sectors such as consolidation of dust that are not considered and also, allows facing the effects on the social, economic, diseases, migration problems in this region.

Table 4 presents the percent of water supply for dust stabilization in the critical months (May-September) for the different scenarios. As a result, the percent of water supply is 100% in May and June for all scenarios and August for all scenarios except Sc10. The least amount of water supply is obtained for September in Sc1 and Sc5. According to the results, the region is posed to dust in July and September.

7. Scenario Assessment

In this section, the defined scenarios are evaluated using the analytic hierarchy against four criteria: dust stabilization, agricultural, domestic, and industrial demands. The importance of criteria was studied in two different modes. The first mode is when the dust stabilization is top priority criteria and the second mode is the top priority of agricultural standards.

First mode: Top priority of dust stabilization criteria

A dust stabilization criterion is a greater priority than the other three criteria. The weights of different criteria are determined according to figure 7a in that the weight of criterion of dust stabilization is greater than that of the other three criteria. After determining the value of each criterion, scenarios are ranked in terms of this priority and the results are shown in figure 7b. Scenario 6, 8 and 9 (Sc6, Sc8, Sc9) have the highest score, and the lowest scores are related to scenarios 1 and 5 (Sc1, Sc5). According to the first mode results the scenarios priority for Sc6, Sc8 and Sc9 is 19.7%, 20.3% and 21%, respectively.

Second mode: Top priority of agriculture

Since farming is the main job of most people in Sistan area, the second mode was investigated. In this case, according to the figure 7c the agricultural criteria are the most important ones. This mode is selected to specify the effect of this criterion on the assessment of different scenarios. According to the results observed in figure 7d, Sc10 is selected as the first priority followed by scenarios No.9, 8 and 6. Notably in this mode, Sc3 has a greater priority than Sc7 as shown in figure 7d. According to the second mode results, the scenarios priority for Sc10, Sc9, Sc8 and Sc6 is 22.1%, 19.4%, 18.5% and 12.3%, respectively.

Table 4. Percent of water supply in the critical months for different scenarios

Scenario/Month	May	June	July	August	September
Sc1	100	100	95.52	100	80.41
Sc2	100	100	95.52	100	90.05
Sc3	100	100	99.72	100	96.20
Sc4	100	100	99.72	100	93.65
Sc5	100	100	96.04	100	80.70
Sc6	100	100	99.72	100	98.78
Sc7	100	100	99.72	100	98.40
Sc8	100	100	99.72	100	98.78
Sc9	100	100	99.72	100	98.78
Sc10	100	100	99.06	96.49	82.97

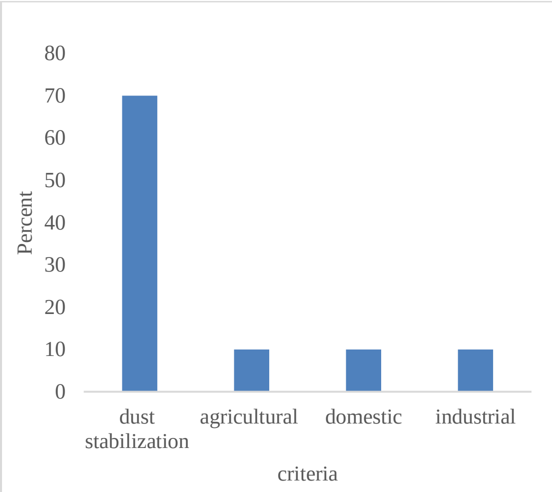

Figure 7-a

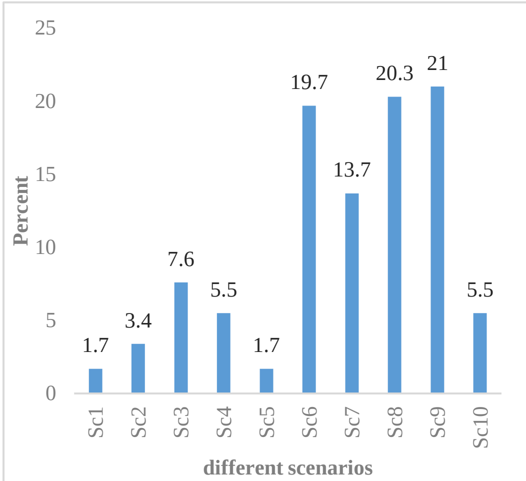

Figure 7-b

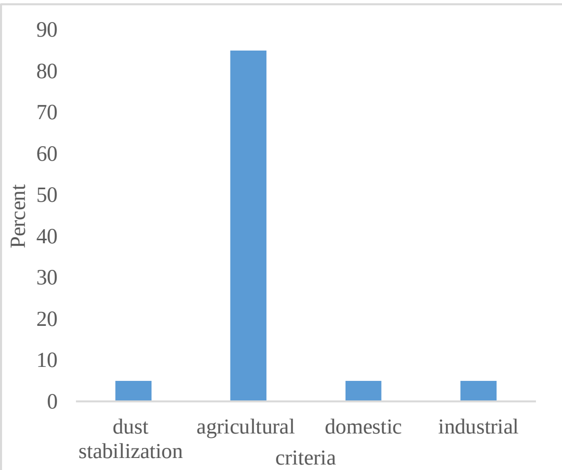

Figure 7-c

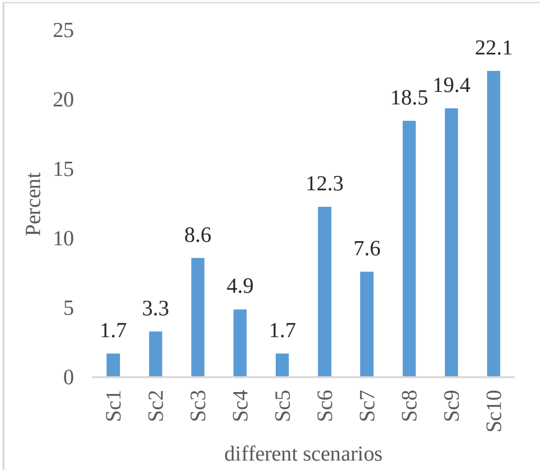

Figure 7-d

Figure. 7. (a) Weighted criteria used for the scenario assessment (Dust stabilization priority), (b) assessment of different scenarios with the dust stabilization priority, (c) weighted criteria used for the scenario assessment (agricultural priority), (d) assessment of different scenarios with the dust agricultural priority

8. Conclusion

Water supply and demand modeling in an arid watershed includes a large amount of fine dust and the 120-day wind blows is performed in this study. A water demand is considered for the dust stabilization in the study area and different hydrological and supply-demand scenarios are defined. Results show the unmet demands of the different scenarios in the region. The highest unmet water demand for dust stabilization sector is in Sc10 in 2015. Sc10 is a combination of Sc9 with a discharge of agreement. The effect of other scenarios is also investigated in the region. According to the results of different scenarios, the amount of unmet demand for dust stabilization sector is reduced by reducing 30 percent of evaporation of Chahnimeh (Sc2), decreasing agricultural land (Sc3), increasing agricultural efficiency (Sc4), municipal wastewater treatment (Sc5) and mixed scenarios Sc6, Sc7 Sc8, Sc9 and Sc10 as compared to the reference scenario (Sc1). The assessment of these different scenarios with the consideration of dust stabilization priority and also agricultural priority is evaluated using the analytic hierarchy method. According to the results, in Sc9, more water demand is provided for the dust stabilization sector (Lake) and damages to this section will be reduced. According to the results, in Sc10, more water demand is provided for the agricultural sector.

9. References

1. Ahmadi, H., Birgani, A., Samani, A., 2005. An investigation of critical area of aolian erosion sediment of Sistan plain during drought years (1997-

2003), Proceeding of 1st National Conference of Wind Erosion, Yazd, Iran

2. Alam, K., Trautmann, T., Blaschke, T., 2011. Aerosol optical properties and radiative forcing over mega-city Karachi. Atmospheric Research, 101(3), 773-782.
3. Alemayehu, T., McCartney, M., Kebede, S., 2010. The water resource implications of planned development in the Lake Tana catchment, Ethiopia.Ecohydrology & Hydrobiology, 10(2), 211-221.
4. Alfarra, A., 2004. Modeling Water Resource Management In Lake Naivasha. Thesis submitted to the International Institute for Geo information Science and Earth Observation.
5. Arranz, R., McCartney, M.P., 2007. Application of the Water Evaluation and Planning (WEAP) model to assess future water demands and resources in the Olifants Catchment, South Africa (Vol. 116). IWMI.
6. Assaf, H, Saadeh, M., 2008. Assessing water quality management options in the Upper Litani Basin, Lebanon, using an integrated GIS-based decision support system. Environmental Modelling & Software, 23(10), 1327-1337.
7. Aydin, M, Yang, SL., Kurt, N., Yano, T., 2005. Test of a simple model for estimating evaporation from bare soils in different environments. Ecological Modeling, 182(1), 91-105.
8. Goudie, A., Middleton, N.J., 2006. Desert dust in the global system. Springer Science & Business Media.
9. Hagan, I., 2007. Modeling the Impact of Small Reservoirs in the Upper East Region of Ghana.
10. Hossenzadeh, S.R., 1997. One hundred and twenty days winds of Sistan. Iran Iranian J Res Geography, 46, 103-127.
11. Lévite, H., Sally, H., Cour, J., 2003. Testing water demand management scenarios in a water-stressed basin in South Africa: application of the WEAP model. Physics and Chemistry of the Earth, Parts A/B/C, 28(20), 779-786.
12. Ludwig F, van Slobbe E, Cofino W. 2014. Climate change adaptation and Integrated Water Resource Management in the water sector. Journal of Hydrology, 518, 235-242.
13. Mehta, V.K., Aslam, O., Dale, L., Miller, N., Purkey D.R., 2013. Scenario-based water resources planning for utilities in the Lake Victoria region. Physics and Chemistry of the Earth, Parts A/B/C, 61, 22-31.
14. Mugatsia, E.A., 2010. Simulation and scenario analysis of water resources management in Perkerra catchment using WEAP model. PhD thesis, Moi University.
15. Mutiga, J.K., Mavengano, S.T., Zhongbo, S., Woldai, T., Becht, R., 2010. Water allocation as a planning tool to minimise water use conflicts in the upper Ewaso Ng'iro North Basin, Kenya. Water resources management, 24 (14), 3939-3959.
16. Rashki, A, Kaskaoutis, D.G., Eriksson, P.G., Qiang M, Gupta, P., 2012. Dust storms and their horizontal dust loading in the Sistan region, Iran. Aeolian Research, 5, 51-62.
17. Rosenberg, D.E., 2008. Integrated water management and modeling at multiple spatial scales. PhD Dissertation, University of California, Davis, CA.
18. Sandoval-Solis, S., McKinney, D.C., 2012. Integrated water management for environmental flows in the Rio Grande, Journal of Water Resources Planning and Management, 140(3), 355-364.
19. Sandoval-Solis, S., McKinney, D.C., Loucks, D.P., 2010. Sustainability index for water resources planning and management, Journal of Water Resources Planning and Management, 137(5), 381-390.
20. Safavi, H.R., Golmohammadi, M.H., Sandoval-Solis S., 2015. Expert knowledge based modeling for integrated water resources planning and management in the Zayandehrud River Basin, Journal of Hydrology, 528, 773-789.
21. Sieber, J., Purkey, D., 2011. Water Evaluation and Planning System USER GUIDE for WEAP21. Stockholm Environment Institute, US Center.
22. Yates, D., Purkey, D., Sieber, J., Huber-Lee, A., Galbraith, H., West, J., Herrod-Julius, S., 2007. A physically based, water resource planning model of the Sacramento Basin, California USA. ASCE Journal of Water Resources Planning and Management, Pp 1-32.