DETERMINING OF DROUGHT PROBABILITY AND DROUGHT RISK FOR DIFFERENT WATER MANAGEMENT SCENARIOS

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ABSTRACT

Drought quantification can be achieved by the probabilistic and statistical methods. The drought effects the social and economical structures and environmental damages . One of the significant environmental effects of the drought is the damage of the habitats of the fish and other hunting animals because of the decreasing water amount in rivers . It seems that it is likely to occur a conflict between the irrigation and ecological purpose usage of water. For avoiding these conflicts it requires to establish well- balanced water sharing strategies . The typical example of this situation is water management problems of Bendimahi Barrage over the Bendimahi River in the province of Muradiye , Van Turkey. This study aimed to investigate the drought risks , periods and volumes of the consequences of this water management strategies of Bendimahi Barrage .

The problem can be defined as the risk of demand exceeding Bendimahi river supplies in drought periods. Because of the mentioned difficulties , the method which proposed by Şen (2003) was used in this study . The series of six month values have been used since the barrage was effective through this period. Primarily Şen 's method has been applied for the demands assumed values (continuos scenario). Components of demand can vary for each month (discrete scenario) Moreover drought probabilities have been determined by using standardized discharge values and safety margin formula . Making the calculation by taking different demand line values for different months in order to drought probabilities or drought risks seems to be a practical approach . This approach would provide solutions for the problems encountered during to risk calculation because of inaccuracy in demand measurement. The shortcomings of the other methods are explained .Drought probabilities of Bendimahi Barrage management programs are quite high for every possible calculation ways . It can be suggested that water management must be accomplished more precisely taking into account all these situations .

Key words : Drought risk, Drought Probability , Water Management Scenario, Demand Line , Bendimahi Barrage

1. INTRODUCTION

Drought is one of the most dangerous disasters which has not been exactly understood even though its effects are being felt strongly. Drought occurrences are rather complex, since they depend on various interactions of different hydrological phenomena such as rainfall, runoff, evapotranspration, infiltration, surface and groundwater storage. All these phenomena have random behavior in different extents, and their consequences as droughts or floods have also random characters, and therefore, their scientific quantification are possible by the probabilistic and statistical methods. The droughts are extreme hydrologic events which may adversely affect the social, economical, cultural, political and other functions of a region. An ever increasing pressure on agricultural products and water resources developments, necessitates scientific and objective assessments of droughts.

On the other hand, the drought not only effects the social and economical situations but also environmental damages . One of the significant environmental effects of the drought the damage of the habitats of the fish and other hunting animals because of the decreasing water amount in rivers and lakes (Knutson et. al. 1998) . This decreasing water situation can be exacerbated due to extreme water usage and inefficient irrigation by the water delivered systems. For that reason it seems that is likely to occur a conflict between the irrigation and ecological purpose usage of water. For avoiding these conflicts it requires to establish well- balanced water sharing strategies . The typical example of this situation is water management problems of Bendimahi Barrage (Regulator) . This study aimed to investigate the drought risks , periods and volumes of the consequences of this water management strategies of Bendimahi Barrage .

2. MATERIAL

Bendimahi Barrage (regulator) is over the Bendimahi River in the province of Muradiye , Van Turkey (Figure 1) . The irrigation water is drawn out from this regulator into two main canals . The left main canal which constructed earlier than the other one has 4.22 m^3/s capacity while the other one has 2.23 m^3/s capacity .The irrigation water is turned into a main canal in the Kevgir Ark region before it reaches regulator .

Bendimahi river has the highest volume flow in rivers of feeding of Lake Van and most important breeding habitat for *Chalcalburnus tarichi* that only one endemic migrant fish lives in Lake Van .Sarı et. al. (2002) has reported that they found the minimal ecological flow rate on Bendimahi River between April and October as 1.22 m^3/s by using Montana Method (Sarı et al., 2002)

For the above mentioned reasons , DSI (State Water Works Association) undertook on 2001 onwards that it would supply the water downstream to Lake Van minimally 1.5 m^3/s or another saying one third of total flow .But it seems to be difficult to provide that much water during the drought years. As expected , in the 2000 – 2001 water year , it was being able to supplied only 0.75 m^3/s water causing so many conflicts over the share of water . In that time , total flow occurred as 1.5 m^3/s in both of main canals . Delivered irrigation water amount has been considered inadequate by the farmers. Since the drought was absent in 2001 – 2002 water year , it seemed that the water problem had been solved. But the problem still persist because the water supplied to main canals can not be measured precisely . In other words , there is uncertainty on the each direction of the three water distribution points.

Firstly the water entering into the canals is not measured properly. Especially the left main canal has been destroyed largely. Water Transport Efficiency is approximately 40 % , at the best estimation The length of 10 km of lower part of main canal has been completely destroyed. At the beginning of secondary and tertiary canal lack of gauging structures. Even these gates have been destroyed on a large scale. Although the right main canals condition seems to be better . The situation quite similar the view point of irrigation water efficiency and measuring amount of water diverted to the secondary. Also the irrigation water is turned into a main canal in the Kevgir Ditch region before it reaches regulator .

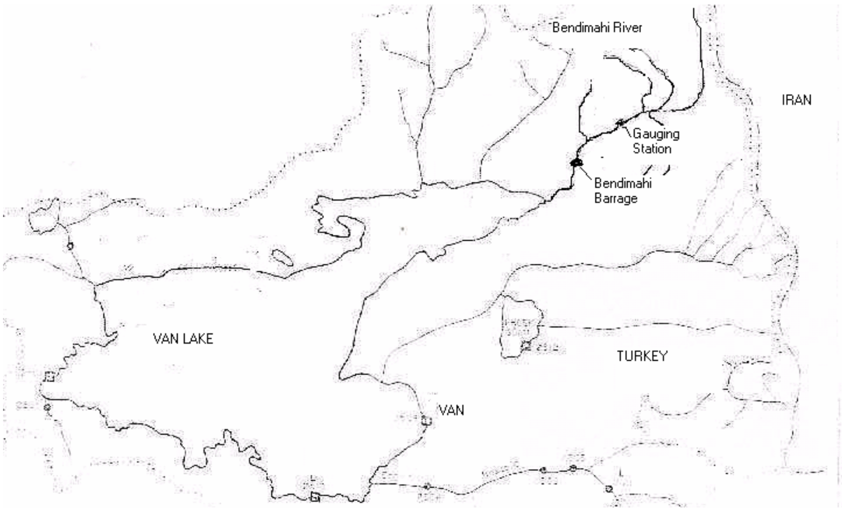


Figure 1. Bendimahi River in Van District Turkey

Barrage's flows are measured Bendimahi Gauge Station . The descriptive statistics of monthly total discharge values of Bendimahi Gauge Station are shown in the following table.

Table 1. The descriptive statistics of monthly total discharge values

variable	N	Mean	Median	St deviation	St error
October	29	15,221	14,700	3,209	0,596
November	29	19,331	18,700	3,569	0,663
December	29	20,124	19,300	4,100	0,761
January	29	17,610	17,300	4,000	0,743
February	29	15,012	14,800	3,476	0,645
March	29	21,20	18,60	9,23	1,71
April	29	68,59	66,50	26,15	4,86
May	29	58,14	49,30	31,68	5,88
June	29	23,09	18,20	11,65	2,16
July	29	15,131	15,100	5,169	0,960
August	29	15,068	14,300	4,333	0,805

3. METHOD

The problem can be defined as the risk of demand exceeding Bendimahi River supplies in drought periods. When wanted to determine this risk by using the reliability analysis . In this example X and R (supply and capacity variables) are monthly stream flows while demand or loading variables are specified Y and L . In this case r risk is simply determined as

$$r = P(R > L) \text{ as} \qquad (1)$$

On the other hand , the reliability , g , is

$$g = P(L < R) = 1 - r \qquad (2)$$

Performance Function is

$$z = R - L \qquad (3)$$

if the z normally distributed , risk becomes

$$r = \phi (\beta) \qquad (4)$$

where : β is cumulative probability of standardized normal variables. If the performance variables normally distributed , β can be defined as done below [Bulu , 2002]

$$\beta = \frac{\left(\mu_R / \mu_L \right) - 1}{\sqrt{\left(\mu_R / \mu_L \right)^2 C_{VR}^2 + C_{VL}^2}} \qquad (5)$$

Here in μ_R, μ_L respectively show the supply and demand mean values while CV_R, CV_L define the variation coefficients. If capacity and loading are independent and log normally distributed, then β can be defined as below [Bulu 2002, Huang 1986]

$$\beta = \frac{Ln\left(\frac{\mu_R}{\mu_L} \sqrt{\frac{1+C_{VL}^2}{1+C_{VR}^2}} \right)}{\sqrt{Ln\left[\left(1+C_{VR}^2\right)\left(1+C_{VL}^2\right) \right]}} \qquad (6)$$

Because of above mentioned reasons none of demand discharge parameters have been measured accurately. In that case we will have to assume that the demands have been normally or log normally distributed. Even because of the same reasons, Reliability Index Formulas (such as Hasofer Lind Reliability Index) are not useful, since demand variables and as well hydraulic variables are not applicable.

In the area of interest the demands can be determined by using empirical water requirement formulas. But Blaney Criddle formula has some inefficiencies in application of SCS, in addition determining the crop pattern is quite tiresome and difficult Because of the mentioned difficulties, the method which proposed by Şen (2003) was used in this study. In this method, in the presence of discharge hydrograph, drought parameters can be easily determined. If the water demand is known and shown as a horizontal line drought parameters can be obtained as depicted in Figure 2.

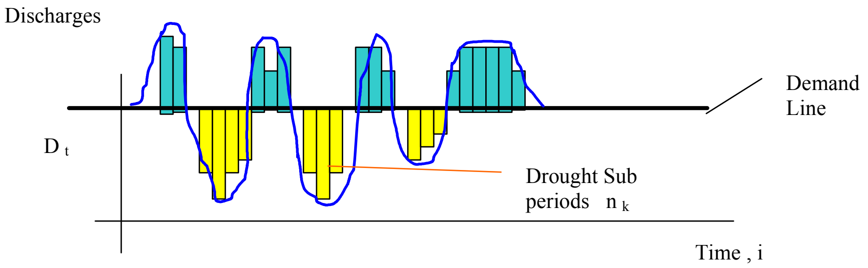


Figure 2 . Drought and watery sub periods

If the observed flow sequences with n times sub periods and drought sub periods is n_k watery sub periods logically becomes $n - n_k$ According to this of drought probability (risk) is

$$Y_k = n_k/n \qquad (7)$$

As for the Watery sub period it is

$$Y_s = 1 - y_k \qquad (8)$$

Mean of drought duration numbers and variance can be determined by through equations below (Şen, 2003)

$$K_s = n\, y_k\,(1 - y\, k) \qquad (9)$$

$$K_v = ny_k(1 - y_k)(1 - 3y_k + 3y_k{}^2) \qquad (10)$$

In this study by using the series of six month values (April , May , June , July , August , September) the reliability analysis has been accomplished . These six month have been considered for this analysis , since the barrage is effective with in this period.

Primarily Şen 's method has been applied for the demands assumed values (continuos scenario) in the calculation of analyses . But demands values vary month to month . Especially demands increases for the first three month because of fish production in the river . Following these months , this part of demand can be reduced .For this reason specifically scenarios for each component of the demand has been proposed (discrete scenarios). In that case demand line is variable for each month .The component of the demand in the questioned area is schematically shown in Figure 3

Moreover, by measuring the fit of monthly mean series to probability distributions for each month it would be possible to calculate the exceeding probabilities. These values make up the reliability threshold.

One of the very common definitions which is frequently used in statistics is the standard sample function or the standard data sequence, [Şen, 2002]. Standard values are one of the indices to specify drought event in any hydrological time series. For instance, in the meteorology literature this parameter is referred to as the Standardized Precipitation Index (SPI) in the case of rainfall series [Sırdaş ,2003]. Standard values, x_i can be obtained by the using the following equation in any time series, X_i,

$$x_i = \frac{X_i - \overline{X}}{S_x} \qquad (11)$$

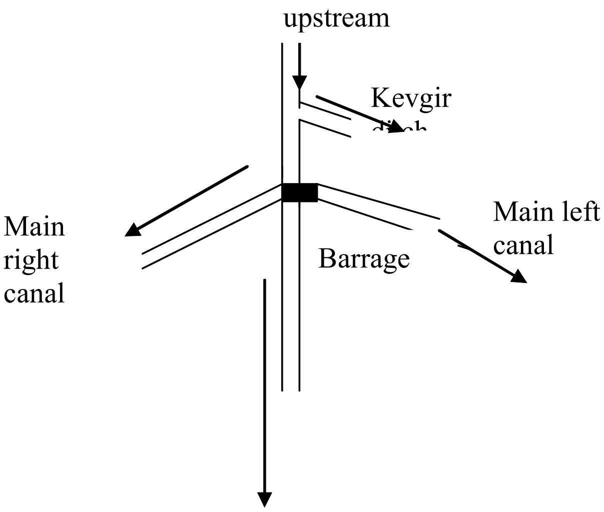


Figure 3. Schematically components of demand

Table 2. Continuos Demand Scenarios

Sce-nario	Right main canal (m^3/s)	Left main canal (m^3/s)	Kevgir ditch (m^3/s)	To down streams for fish production (m^3/s)	Total Discharges
1	2,33	4,22	1	1,5	9,05m^3/s 23,4576 hm^3
2	1,5	3	1	1,5	7 m^3/s 18,144- 18,742 hm^3
3	1,5	2	1	1	5,5 m^3/s 14,256- 14,726 hm^3
4	1,5	1,5	1	0,75	4,75 m^3/s 12,312-12,718 hm^3
5	1	2	1	0,75	3,75m^3/s 9,72-10,044 hm^3

Table 3. Discrete Demand Scenarios

Scenario	Right main canal (m^3/s)	Left main canal (m^3/s)	Kevgir ditch (m^3/s)	To down streams for fish production (m^3/s)	Total Discharges
1	4,22	2,33	1	For April , May and June 1,5 For Jully and August 0,5	For April , May and June 9,05 m^3/s For Jully and August 8,05 m^3/s
2	4,22	2,33	1	For April , May and June 0,75 For Jully and August 0,25	For April , May and June 8,3 m^3/s For Jully and August 7,8 m^3/s
3	1,5	3	1	For April , May and June 1,5 For Jully and August 0,5	For April , May and June 7 m^3/s For Jully and August 6 m^3/s
4	1,5	3	1	For April , May and June 0,75 For Jully and August 0,25	For April , May and June 6,25 m^3/s For Jully and August 5,75 m^3/s
5	1	2	1	For April , May and June 0,75 For Jully and August 0,25	For April , May and June 4,75 m^3/s For Jully and August 4,25 m^3/s
6	1	2	0,25	For April , May and June 0,75 For Jully and August 0,25	For April , May and June 4 m^3/s For Jully and August 3,5 m^3/s
7	1	2	0	For April , May and June 0,25 For Jully and August 0	For April , May and June 3,25 m^3/s For Jully and August 3 m^3/s
8	1	1,5	0	For April , May and June 0 For Jully and August 0	For April , May and June 2,5 m^3/s For Jully and August 2,5 m^3/s

where $\overline{X}$ is the mean and S_x shows the standard deviation of the original time series. Thus, any series can be standardized by Equation (11). In other words, the sequence of the drought variable X_i after standardization as x_i will have zero mean and standard deviation equal to one . Also drought probabilities have been determined by using standardized discharge values in this study

In general , the standardized values under truncation level are termed as 'deficit' but above the truncation level they are called 'surpluses'. The deficit lengths (drought duration's) are shown by L_1, L_2, L_3, ... ,L_m where m indicates the possible dry durations at a given truncation level. On the other hand, as it is commonly used in the literature, division of sum of the drought deficit to the drought duration can be called also as the drought intensity.

4.RESULTS AN DISCUSSION

Long Year's Drought and Watery Periods in July (for 4.75 m3 /s continuos scenario number 4) is shown Figure 4 .Calculated drought and watery probabilities for July according to equation 7 –8 are shown in Figure 5-6 and for all months in Figure 7-8 . As can be deduced from the graphics and curves, drought probability is minimum in May while it its maximum in September. As seen in Figure 7-8 , drought probabilities are higher in July and August Months than September at the minimum and maximum points of demand discharge values . This can be explained by the low standard deviation of September while mean of September is low. Agricultural demand also decreases from the point of irrigation water requirement . For this reason , especially drought probabilities of July and August have been considered to be important.

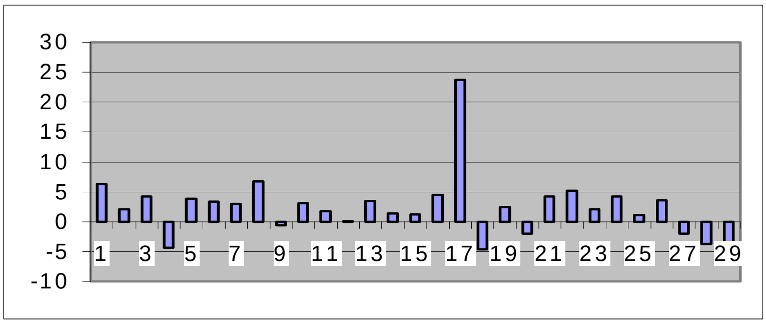


Figure 4. Long Year's Drought and Watery Periods in July (for 4.75 m3 /s , continuos scenario number 4)

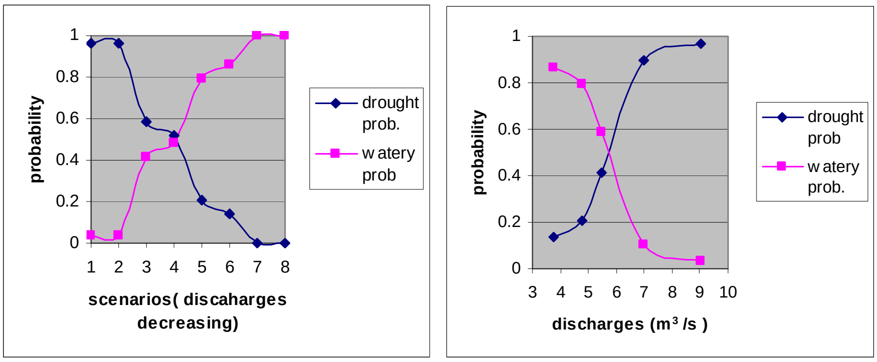


Figure 5-6. Drought and watery probabilities for July at continuous and discrete scenarios

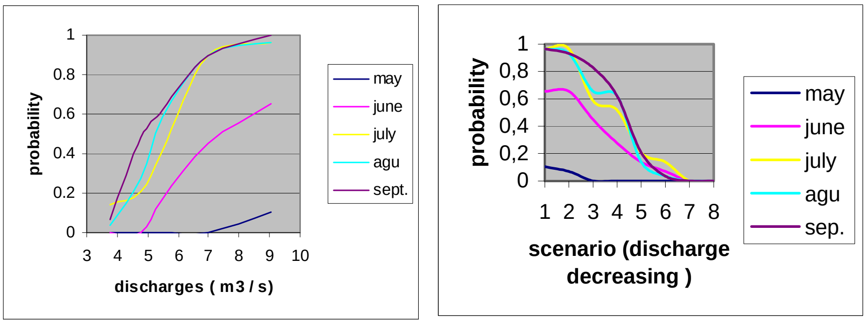


Figure 7-8 Drought probabilities of all months (continuous and discrete scenarios)

The other important points are total probability of 6 month's series and drought duration within during total period. Total period is determined as 29 x 6 = 174 months in our example. Possible drought months have been calculated by using equations 7 and 8. These values are shown in Figure 9 and 10

The variation intervals of probabilities have been observed to get narrow. Because probabilities of watery months have been accumulated for calculating 6 month's total probabilities . Since the watery probability is considered equation 8, drought duration and probabilities do not show the same behavior.

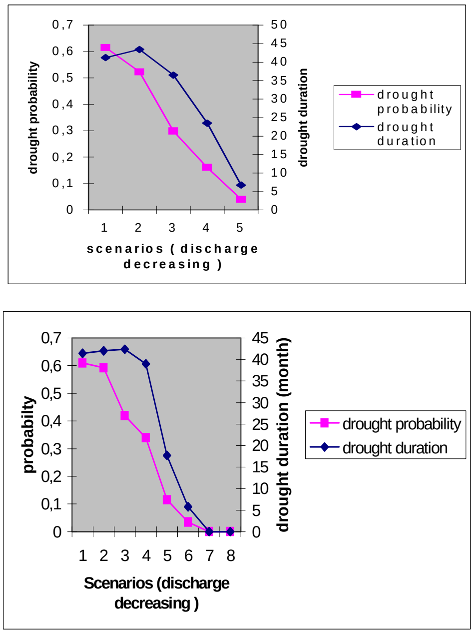


Figure 9- 10. Drought probabilities and duration relationship calculated by equation 7-9 for discrete and continuos scenarios

Drought probabilities can be determined by using standardized discharge values which are defined in equation 11 and by combining truncation levels as demand line .But in this situation it might be obtained only one demand discharge values for six months . As a result , the variation of demand discharge can not be applied . When the truncation levels are taken for different months , the risk prediction would be troublesome. In addition, it might be required to take into account the means of each months and standard deviation for the normalized values calculations.

For the sake of practical application and simplicity, discharges corresponding demand values are used in this graphic. If the demand discharges are accepted as truncation levels , drought deficits obtained by using above mentioned method and drought intensities worked out through equation 11 would be useful for practical purposes . These results are shown in Figure 11. The relationship between drought duration and drought intensity is demonstrated in these Figures. This relation shows different curves for each demand discharges. Taking into consideration return period of demands , drought intensity – duration - return period curves are obtained.

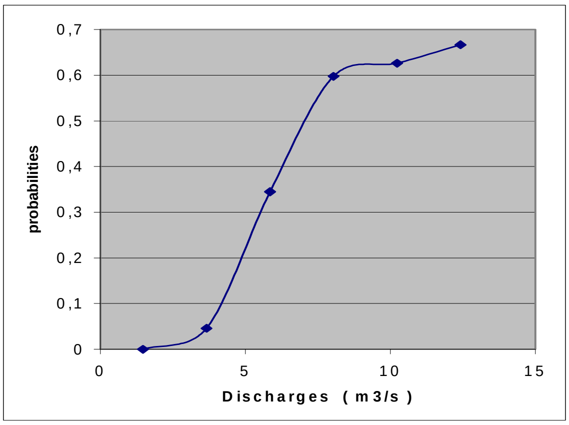


Figure 11. Drought probabilities according to normalized discharge values

From the Figure 12, we can follow the return periods of demand discharges with small values. The increases of drought intensities become evident at the 9.05 m^3/s whose return period is 6 year. In this case droughts can be seen for 3 months of periods.

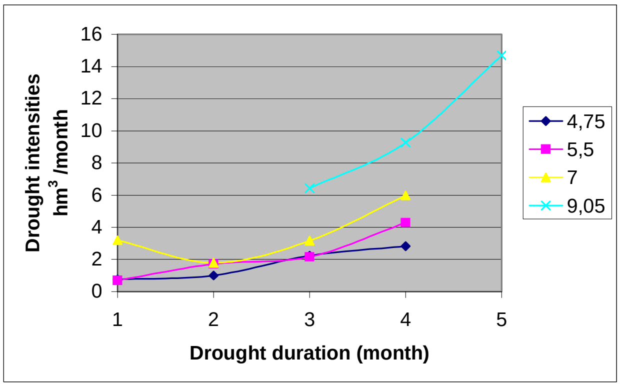
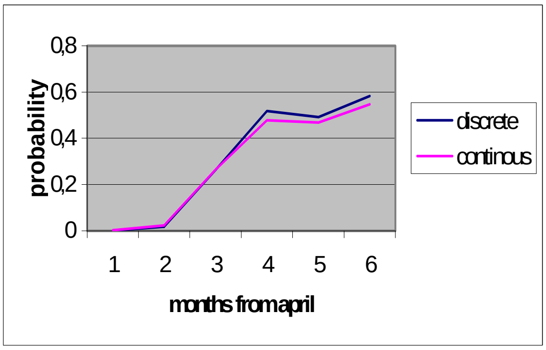
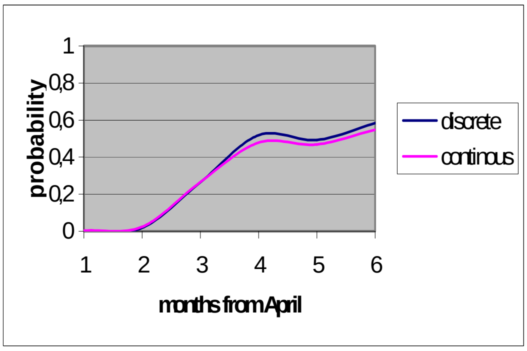


Figure 12. Intensity - Duration relationships for discharges in continuos scenarios



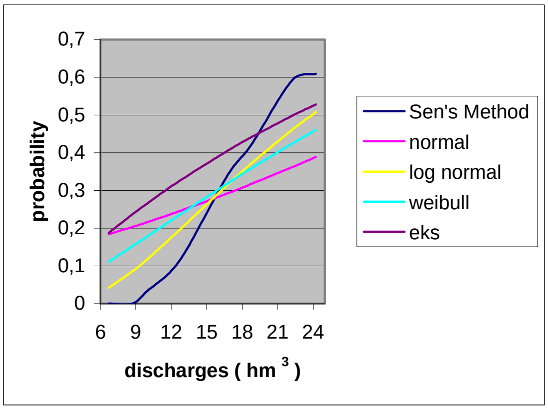
(a)



(b)

Figure 13 Drought probabilities calculated by safety margin formula a- normal b- log normal.

When wanted to compare Sen's method with safety margin or (factor) formula which hypothesis based on supply and demand variables are distributed normally, it is required to obtain β standard normal variables and cumulative probabilities corresponding β . As mentioned above some supposes can be made for supply and demand distributions. It is especially to difficult to say about limitations of some months for demand discharge standard deviation. In the present study, the standard deviation of demand variable has been found by calculating the difference between maximum and minimum demand discharge values.



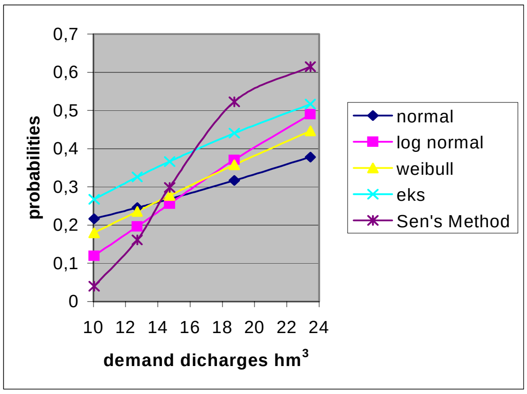


Figure 14-15. Drought risks according to Şen's Method and other probability distributions

In the case of fitting the supply variables to various probability distribution functions, Drought probabilities for these distributions and Sen's Method are shown in Figure14 and 15. In the either scenario, the lowest and highest probabilities are supplied by Sen's Method.

5. CONCLUSIONS

Under the light of above mentioned findings and discussions , it is possible to draw the following conclusions.

Making the calculation by taking different demand line values for different months in order to drought probabilities or drought risks seems to be a practical approach . But it would be difficult to generalize this approach since it reflects its own local conditions of specifically examples . On the other hand the information obtained empirically and verbally is taken into consideration in this approach.

Especially in the present example which the components of demand varies month to month , it would be more useful . Ecological requirements is one of the significant components. In those cases , Sen's method for drought probability calculation is quite simple and practical . This approach would provide of the solutions for the problems encountered during to risk calculation because of inaccuracy in demand measurement. This type of calculation (management) seems to decrease the drought risk . It may not be possible to compare all methods with each others. Moreover , the shortcomings of the other methods are explained above .

Drought probabilities of Bendimahi Barrage management programs are quite high at every calculation way . It has been thought that water distribution to downstream for fish production might increase drought probability . But even in the situation which water is distributed only to the other canals in full capacity , the drought probability is seen to be high level . In the all demand discharges , all methods display maximally ten years of return periods . As a conclusion it can be suggested that water management must be accomplished more precisely without neglecting ecological requirements. Because of that it is must to measure the amounts of water delivered in every components of demands (directions).

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