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# Assessment of irrigation and drainage requirement based on rainfall analysis for Bara Tract of Gujarat

**M. K. KHANDELWAL, A. K. NAYAK, G. GURURAJA RAO, ANIL R. CHINCHMALATPURE, ABHAY NATH AND H Y MUNSHI[1]**

Central Soil Salinity Research Institute, Regional Research Station, Anand 388001

[1] Sardar Sarovar Narmada Nigam Limited, Vadodara

## ABSTRACT

Rainfall analysis for the period 1901-1990 was carried out for determining onset of effective monsoon, rainfall depth-duration relationship, irrigation and drainage requirement. Water requirement and irrigation scheduling of cotton and pigeonpea based on the CROPWAT model revealed that under un-irrigated condition, in an average rainfall year, 80 % of the potential yield can be achieved in both the crops. On the basis of rainfall, design parameters for the rainwater harvesting structure for the region was also developed.

***Key Words :*** Rainfall analysis, CROPWAT model, Water harvesting structure.

The Bara Tract constituting of Vagra, Jambusar and Amod talukas in Bharuch district lies between 21°40' to 22°15' N latitude and 72°32' to 72°55' E longitude between reduced level of 5.1 m and 9.14 m towards the Gulf of Cambay. This area falls under arid and semi-arid type of climate where low rainfall coupled with uncertainty of its occurrence is the major limiting factor for crop growth. Moreover, the potentially saline black soil aggravates the problem. The area is to be supplied with irrigation from Narmada Canal. Hence there is possibility for waterlogging and salinity to develop. For irrigation and crop management strategies, analysis of rainfall to study of onset and withdrawal of effective monsoon, water requirement and irrigation scheduling of crops, surface drainage requirement and design of rain water harvesting structures is needed.

## MATERIALS AND METHODS

The daily rainfall data of 1901-90 for Amod, Jambusar and Vagra talukas of Bharuch district (Gujarat) were collected from India Meteorological Department, Pune. These data were used to study (i) onset and withdrawal of effective monsoon (Ashokraj, 1979), (ii) rainfall depth duration relationships (ILRI, 1999) and (iii) surface drainage coefficients (Khandelwal, 1988, Rao and Dhruvanarayan, 1979). The rainfall data were also used to develop design parameters for rainwater harvesting structures on the unit catchment area basis. The water requirement and irrigation scheduling for cotton and pigeon pea under rainfed and 0, 10 and 20% yield reduction under irrigated conditions were worked out using CROPWAT model (Smith, 1992).

**Table 1:** Onset and withdrawal of effective monsoon based on mean of occurrence for BaraTract

| Station | Earliest possible date (P=0.68) | Mean date | Latest possible date (P=0.68) | Standard deviation (days) | Mean date of withdrawal rainfall (monsoon) |
|---|---|---|---|---|---|
| Amod | Jun 12 | Jun 28 | Jul 15 | 16 | Sep 22 |
| Jambusar | Jun 13 | Jun 29 | Jul 16 | 16 | Sep 20 |
| Vagra | Jun 14 | Jun 29 | Jul 15 | 15 | Sep 23 |
| Bara Tract* | Jun 10 | Jun 23 | Jul 15 | 15 | Sep 18 |

* Estimated/weighted mean

**Table 2:** Start and length of critical dry spells (CDS)

| Station | First CDS date | Length (days) | Second CDS date | Length (days) | Third CDS date | Length (days) | Total (days) |
|---|---|---|---|---|---|---|---|
| Amod | Jul 16 | 21 | Aug 10 | 21 | Sep 5 | 24 | 66 |
| Jambusar | Jul 15 | 21 | Aug 12 | 24 | Sep 6 | 24 | 69 |
| Vagra | Jul 16 | 22 | Aug 12 | 21 | Sep 7 | 28 | 71 |
| Bara Tract | Jul 15 | 21 | Aug 13 | 21 | Aug 30 | 21 | 63 |

**Table 3:** Average rainfall (mm)during different wet spells

| Station | First | Second | Third | Fourth | Total |
|---|---|---|---|---|---|
| Amod | 269.3 (Jun 28-Jul18) | 172.0 (Aug 8-20) | 124.7 (Sep 1-10) | 62.9 (Sep29-Oct 3) | 628.9 |
| Jambusar | 265.0 (Jun 29- Jul 18) | 166.8 (Aug 7-20) | 131.9 (Sep 6-14) | 53.2 (Sep25-28) | 616.9 |
| Vagra | 239.4 (Jun 29-Jul 18) | 159.4 (Aug 7-20) | 113.5 (Sep 3-12) | 27.6 (Oct 3-5) | 539.9 |
| Bara Tract | 267.6 (Jun 23-Jul 15) | 182.8 (Aug 6-21) | 115.8 (Sep 1- 14) | 111.2 (Sep 21- Oct 5) | 677.4 |

**Table 4:** Correlation and regression of 2 to 7 day annual maximum rainfall on 1-day annual maximum rainfall and parameters of normal distribution.

| Station | Storm (day) | Inter cept | Coeffi-cients | F ratio | r | $R^2$ | Normal distribution | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Mean (mm) | STD (mm) |
| Amod | 2 | 19.4 | 1.15 | 80.6 | 0.69 | 47.83 | 108.0 | 29.7 |
| | 3 | 25.3 | 1.31 | 49.4 | 0.60 | 35.99 | 126.3 | 39.0 |
| | 4 | 28.3 | 1.49 | 45.3 | 0.58 | 34.01 | 142.5 | 45.4 |
| | 5 | 32.3 | 1.60 | 43.3 | 0.57 | 33.00 | 155.4 | 49.7 |
| | 6 | 35.8 | 1.74 | 46.6 | 0.59 | 34.65 | 169.9 | 52.8 |
| | 7 | 39.9 | 1.89 | 42.2 | 0.57 | 32.40 | 185.1 | 59.1 |
| Jambusar | 2 | 17.0 | 1.20 | 378. | 0.90 | 81.29 | 114.9 | 49.2 |
| | 3 | 26.2 | 1.31 | 231. | 0.85 | 72.68 | 133.1 | 56.8 |
| | 4 | 40.3 | 1.30 | 176. | 0.82 | 66.97 | 146.6 | 58.8 |
| | 5 | 46.6 | 1.38 | 143. | 0.79 | 62.20 | 159.7 | 64.9 |
| | 6 | 57.9 | 1.39 | 117. | 0.76 | 57.55 | 172.1 | 68.2 |
| | 7 | 67.4 | 1.41 | 108. | 0.75 | 55.50 | 182.6 | 70.0 |
| Vagra | 2 | 14.7 | 1.15 | 189. | 0.83 | 68.34 | 108.5 | 34.8 |
| | 3 | 34.6 | 1.11 | 91.8 | 0.72 | 51.06 | 125.5 | 39.0 |
| | 4 | 41.6 | 1.21 | 74.2 | 0.68 | 45.75 | 140.5 | 44.9 |
| | 5 | 49.5 | 1.23 | 61.8 | 0.64 | 41.26 | 150.1 | 48.0 |
| | 6 | 51.4 | 1.33 | 63.6 | 0.65 | 41.97 | 159.9 | 51.4 |
| | 7 | 53.3 | 1.42 | 60.1 | 0.64 | 40.59 | 169.4 | 55.9 |

## RESULTS AND DISCUSSION

### *Onset and withdrawal of effective monsoon*

The earliest and the latest probable date (P=0.68) of onset of effective monsoon (OEM) vary from June 12-14 to July 15-16 in the region. Standard deviation of dates of OEM of 15 days indicates erratic and inconsistent nature of daily rainfall. Mean date of withdrawal of monsoon is found to be during Sept 19-21(Table 1). On an average the region experienced at least one critical dry spell (CDS) each in the months of July, August and September (Table 2) with length of 21-22 days, 21-24 days and 21-28 days respectively. Rainfall totals (Table 3) during the four wet spells ranged between 540 (Vagra) and 629 mm (Amod).

### *Rainfall depth-duration relationship*

Correlation between 2 to 7 day consecutive annual maximum rainfall and 1-day annual maximum rainfall showed that coefficient of

**Table 5:** Statistical parameters of 1-7 day annual maximum rainfall.

| Station | Storm (day) | min | avg | max | CV ( %) |
|---|---|---|---|---|---|
| Amod | 1 | 38.9 | 77.0 | 142.0 | 23.1 |
| | 2 | 44.0 | 108.0 | 191.7 | 27.4 |
| | 3 | 44.0 | 126.3 | 279.7 | 30.7 |
| | 4 | 48.0 | 142.6 | 289.4 | 31.7 |
| | 5 | 55.0 | 155.4 | 306.4 | 31.6 |
| | 6 | 60.0 | 170.0 | 311.0 | 30.9 |
| | 7 | 60.0 | 185.1 | 324.1 | 31.8 |
| Jambusar | 1 | 23.6 | 81.8 | 345.9 | 45.0 |
| | 2 | 24.4 | 114.9 | 429.7 | 42.6 |
| | 3 | 27.8 | 133.1 | 483.6 | 42.5 |
| | 4 | 27.8 | 146.7 | 483.6 | 39.9 |
| | 5 | 29.7 | 159.7 | 483.6 | 40.5 |
| | 6 | 29.7 | 172.1 | 483.6 | 39.4 |
| | 7 | 29.7 | 182.6 | 483.6 | 38.1 |
| Vagra | 1 | 28.0 | 81.6 | 218.4 | 30.5 |
| | 2 | 30.0 | 108.6 | 263.9 | 31.9 |
| | 3 | 44.0 | 125.5 | 280.1 | 31.0 |
| | 4 | 46.0 | 140.6 | 330.4 | 31.8 |
| | 5 | 48.0 | 150.1 | 362.4 | 31.9 |
| | 6 | 48.0 | 159.9 | 376.4 | 32.0 |
| | 7 | 48.0 | 169.5 | 408.5 | 32.9 |

determination and correspondingly F ratio decreased (Table 4) with increase in rainstorm duration from 2 to 7 days. It clearly represents advance rainstorm with inconsistent rainfall patterns. For most of the regression equations the regression coefficient and intercept increased with increase in rainstorm duration. Values of the mean and standard deviation (parameters for the normal distribution) increased with increase in rainstorm duration from 2 day to 7 days (Table 4).

The coefficient of variation of maximum moving rainfall of different periods increased with increase in the rainstorm duration from 1 to 7 days showing inconsistency. One day annual maximum rainfall showed highest coefficient of variation at Jambusar (45.0 %) varying between 23.6 and 345.9 mm over the period. This was followed by Vagra and Amod (Table 5). Annual rainfall varied from 260.0 to 1247.2 mm with an average of 687.4 mm at Amod, 175.4 mm to 1508 mm with an average of 678.2 mm at Jambusar and 159.to 1195.2 mm with an average of 643.4 mm at Vagra. The coefficient of variation showed 35.0 %, 37.7 % and 35.9 % respectively for the three stations.

***Surface drainage coefficient***

Surface drainage coefficient based on maximum moving rainfall of 7 consecutive days with 7 day tolerance period (Table 6) varied from 25.1 $mmd^{-1}$ to 35.8 $mmd^{-1}$ for Amod, 24.5 $mmd^{-1}$ to 37.2 $mmd^{-1}$ for Jambusar and 22.9 $mmd^{-1}$ to 33.1 $mmd^{-1}$ for Vagra taluka. On an average a surface drainage coefficient of 25 $mmd^{-1}$ for a two year return period is suggested. Since the surface drainage coefficient ranged between 26.3 $mmd^{-1}$ and 28.6 $mmd^{-1}$, it can take care of flood even at 5 year return period. For the same 7 day tolerance period, surface drainage coefficient computed by using USDA-SCS-CN method, varies from 17.9 $mmd^{-1}$ to 20.0 $mmd^{-1}$ for two year return period and 21.1 $mmd^{-1}$ to 23.5 $mmd^{-1}$ for 5 year return period (Table 7). Hence a surface drainage coefficient of 25 $mmd^{-1}$ would be sufficient to tackle drainage problem in 2 to 5 year recurrence interval. Further, a surface drainage coefficient of 30-35 $mmd^{-1}$ is expected to cope up with surface drainage problems with an expected return period of 25 years. It is further noticed that the surface drainage coefficient by

**Table 6:** Surface drainage based on average of rainfall and corresponding rainstorm duration (rainfall-depth duration relationship)

| Station | Return period (year) | Rainstorm duration (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Amod | 2 | 74.1 | 51.6 | 40.0 | 33.8 | 29.5 | 26.9 | 25.1 |
| | 4 | 79.7 | 56.3 | 44.1 | 37.4 | 32.6 | 29.7 | 27.7 |
| | 5 | 81.6 | 57.8 | 45.5 | 38.6 | 33.7 | 30.6 | 28.6 |
| | 10 | 87.9 | 63.1 | 50.0 | 42.6 | 37.1 | 33.7 | 31.6 |
| | 20 | 94.6 | 68.6 | 54.9 | 46.8 | 40.9 | 37.0 | 34.8 |
| | 25 | 96.8 | 70.5 | 56.6 | 48.3 | 42.1 | 38.1 | 35.8 |
| Jambusar | 2 | 75.8 | 53.4 | 41.3 | 34.3 | 29.8 | 26.8 | 24.5 |
| | 4 | 87.4 | 61.2 | 47.2 | 38.9 | 33.9 | 30.4 | 27.6 |
| | 5 | 91.4 | 63.8 | 49.3 | 40.5 | 35.3 | 31.6 | 28.7 |
| | 10 | 104.4 | 72.5 | 55.9 | 45.6 | 39.9 | 35.6 | 32.2 |
| | 20 | 118.3 | 81.7 | 63.0 | 51.2 | 44.7 | 39.9 | 35.9 |
| | 25 | 123.0 | 84.8 | 65.4 | 53.0 | 46.4 | 41.3 | 37.2 |
| Vagra | 2 | 77.5 | 51.4 | 39.7 | 33.3 | 28.5 | 25.2 | 22.9 |
| | 4 | 85.4 | 56.9 | 43.8 | 36.8 | 31.5 | 27.9 | 25.4 |
| | 5 | 88.1 | 58.8 | 45.2 | 38.0 | 32.5 | 28.9 | 26.3 |
| | 10 | 96.9 | 64.9 | 49.8 | 42.0 | 35.9 | 31.9 | 29.1 |
| | 20 | 106.3 | 71.4 | 54.7 | 46.2 | 39.5 | 35.1 | 32.1 |
| | 25 | 109.4 | 73.6 | 56.3 | 47.6 | 40.7 | 36.2 | 33.1 |

graphical method followed next to surface drainage coefficient by rainfall depth-duration relationship and USDA-SCS-CN method.

***Water requirement and irrigation scheduling of crops***

Parameters for computation of water requirement and irrigation schedule attributes of cotton and pigeon pea are presented in Table 8. Water requirement and irrigation schedule under only rainfed condition and 0,10 and 20 % yield reduction for cultivation of pigeon pea and cottonare presented in Tables 9 and 10 respectively. Attributes of water requirement under rainfed and 20 % yield reduction condition for both the crops under irrigation are similar, which means that even under un-irrigated condition 80 % of the potential yield of both the crops can be achieved in an average normal rainfall year.

**Table 7:** Surface drainage coefficient based on USDA-SCS-CN method (CN=88)

| Station | Return period (year) | Rainstorm duration (days) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Amod | 2 | 44.3 | 35.4 | 28.8 | 25.2 | 22.5 | 21.0 | 20.0 |
| | 4 | 49.3 | 39.7 | 32.7 | 28.7 | 25.5 | 23.7 | 22.6 |
| | 5 | 51.0 | 41.2 | 34.1 | 29.8 | 26.6 | 24.6 | 23.4 |
| | 10 | 56.7 | 46.2 | 38.4 | 33.7 | 30.0 | 27.6 | 26.3 |
| | 20 | 62.8 | 51.5 | 43.2 | 37.8 | 33.6 | 30.9 | 29.5 |
| | 25 | 64.9 | 53.3 | 44.7 | 39.2 | 34.8 | 32.0 | 30.5 |
| Jambusar | 2 | 45.8 | 37.1 | 30.1 | 25.7 | 22.9 | 21.0 | 19.4 |
| | 4 | 56.3 | 44.4 | 35.7 | 30.1 | 26.8 | 24.4 | 22.4 |
| | 5 | 59.9 | 46.9 | 37.7 | 31.7 | 28.2 | 25.6 | 23.5 |
| | 10 | 71.9 | 55.1 | 44.1 | 36.7 | 32.6 | 29.5 | 26.9 |
| | 20 | 85.0 | 64.0 | 51.0 | 42.1 | 37.4 | 33.7 | 30.6 |
| | 25 | 89.4 | 67.0 | 53.3 | 43.9 | 39.0 | 35.1 | 31.9 |
| Vagra | 2 | 47.4 | 35.2 | 28.6 | 24.8 | 21.6 | 19.4 | 17.9 |
| | 4 | 54.4 | 40.4 | 32.5 | 28.2 | 24.5 | 22.0 | 20.3 |
| | 5 | 56.9 | 42.1 | 33.8 | 29.3 | 25.5 | 22.9 | 21.1 |
| | 10 | 64.9 | 47.9 | 38.2 | 33.1 | 28.7 | 25.9 | 23.9 |
| | 20 | 73.7 | 54.2 | 42.9 | 37.2 | 32.3 | 29.0 | 26.8 |
| | 25 | 76.6 | 56.3 | 44.4 | 38.6 | 33.4 | 30.1 | 27.8 |

***Pigeonpea***

The total gross irrigation requirement at 66.7 % field application efficiency for optimal cultivation of the test crop in unit area is worked out to be 584.6 mm, 613.2 mm and 787.7 mm under three assumed dates of sowing of Jun 15, Jun 30 and Jul 15 (nearly matching with earliest, mean and latest date of OEM) respectively. The potential water use by the crop for the same optimal cultivation is 758.4 mm, 745.3 mm and 725.5 mm, respectively for the above dates of sowing. Total of rain loss decreased with delay in date of sowing from Jun 15 to Jul 15. Actual irrigation requirement for optimal cultivation increased with delay in date of sowing. With imposition of 20 % yield reduction for all the three dates of sowing. It is noticed that reduction in crop evapotranspiration were 31.7 %, 39.8 % and 46.0 % and reduction in corresponding yield amounts to 25.4 %, 31.9 % and 36.8 %. The computations revealed that with the application of 258 mm, 331 mm and 395 mm supplemental irrigation respectively for the above said dates

**Table 8:** Details of the parameters used in the CROPWAT model.

| Parameters | *Kharif* cotton | *Kharif* pigeonpea |
|---|---|---|
| Date of sowing | Jun 15, 30 and Jul 15 | Jun 15, 30 and Jul 15 |
| Date of harvest | Dec 15,30 and Jan 15 | Dec 15,30 and Jan 15 |
| Crop period (days) | | |
| Initial | 35 | 35 |
| Development | 45 | 45 |
| Mid | 70 | 70 |
| Late | 30 | 30 |
| Total | 180 | 180 |
| Crop coefficient | | |
| Initial | 0.45 | 0.45 |
| Mid | 1.15 | 1.15 |
| Late | 0.60 | 0.60 |
| Rooting depth (m) | | |
| Initial | 0.30 | 0.30 |
| Mid | 1.00 | 1.00 |
| Late | 1.00 | 1.00 |
| Development level | | |
| Initial | 0.60 | 0.60 |
| Mid | 0.60 | 0.60 |
| Late | 0.80 | 0.80 |
| Yield response | | |
| Initial | 0.45 | 0.40 |
| Development | 0.80 | 0.60 |
| Mid | 0.80 | 0.80 |
| Late | 0.30 | 0.60 |

of sowing, potential yield of the crop can be achieved. This can be achieved through utilization of supplementing with irrigation from the rainwater of the three wet spells (Table 9).

***Cotton***

The total gross irrigation requirement at 66.67 % field application efficiency for optimal cultivation of the test crop in unit area is worked out to be 618.3, 616.1 and 514.6mm under three assumed dates of sowing mentioned above. The potential water use by the crop for the same optimal cultivation is 741.7, 724.4 and 708.5 mm, respectively for the above dates of sowing. The effective rainfall for the plants decreased from 551.9 to 348.9 mm with delay in date of sowing from Jun 15 to Jul 15. Actual irrigation requirement for optimal cultivation increased from 189.8 to 359.6 mm with delay in date of sowing from Jun 15 to Jul 15. With imposition of 20% yield reduction in al the three dates of sowing, it was noticed that reduction in crop evapotranspiration were to 20.4 %, 28.3 % and 36.8 % and reduction in corresponding yield were 17.3%, 24.0% and 31.2 %. The computations revealed that with the application of 189, 270 and 360 mm of supplemental irrigation respectively for the above said dates of sowing, potential yield of the crop could be achieved (Table 10).

***Rain water harvesting structure***

The design parameters for a rainwater harvesting structure for the Bara Tract are presented in Table 11. The one day annual maximum rainfall varied from 10.4 to 126.8 mm with average at 46.1 mm and CV of 41.5 %. Storage efficiency of the farm pond varies from 75.03 to 97.55 %, showing only 4.12 % of CV. On the basis of one day annual maximum rainfall, for 1 ha catchment area, the dimension of water harvesting structure should be 5.65 m x 5.65 m at the base with 1.0 m depth in trapezoidal shape. Total losses due to assumed rate of pan

**Table 9:** Pigeonpea cultivation by CROPWAT model.

| Parameter | Sowing-Jun 15 Harvest-Dec 15 | | | Sowing - Jun 30 Harvest - Dec 30 | | | Sowing- Jul 15 Harvest-Jan 15 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Reduction in potential yield (%) | | | | | | | | |
| | 0 | 10 | 20 | 0 | 10 | 20 | 0 | 10 | 20 |
| Total gross irrigation (mm) | 584.6 | 276.8 | 0.0 | 613.2 | 548.9 | 291.0 | 787.7 | 536.3 | 288.2 |
| Total irrigation supply (mm) | 389.7 | 184.5 | 0.0 | 408.8 | 365.9 | 194.0 | 525.2 | 357.5 | 192.1 |
| Total irrigation losses (mm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Moisture deficit at harvest (mm) | 47.9 | 174.1 | 197.2 | 132.1 | 27.1 | 151.1 | 7.0 | 82.2 | 184.6 |
| Actual water use by crop (mm) | 758.4 | 679.4 | 518.0 | 745.3 | 643.4 | 594.7 | 725.5 | 632.2 | 570.1 |
| Potential water use by crop (mm) | 758.4 | 758.4 | 758.4 | 745.3 | 745.3 | 745.3 | 725.5 | 725.5 | 725.5 |
| Efficiency irrigation schedule (%) | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Deficiency irrigation schedule (%) | 0.0 | 10.4 | 31.7 | 0.0 | 13.7 | 20.2 | 348.9 | 12.9 | 21.4 |
| Total rainfall (mm) | 555.0 | 555.0 | 555.0 | 456.4 | 456.4 | 456.4 | 329.9 | 348.9 | 348.9 |
| Effective rainfall (mm) | 500.0 | 500.0 | 500.0 | 346.8 | 415.0 | 413.6 | 18.9 | 328.3 | 329.9 |
| Total rain loss (mm) | 55.4 | 55.4 | 55.4 | 109.6 | 41.4 | 42.8 | 395.6 | 20.6 | 18.9 |
| Actual irrigation requirement (mm) | 258.4 | 258.4 | 258.4 | 398.5 | 330.3 | 331.7 | 94.6 | 397.2 | 395.6 |
| Efficiency rain (%) | 90.0 | 90.0 | 90.0 | 76.0 | 90.9 | 90.6 | 0.0 | 94.1 | 94.6 |
| Reductions in ETC (%) | 0.0 | 10.4 | 31.7 | 0.0 | 13.7 | 20.2 | 0.0 | 12.9 | 21.4 |
| Reduction in yield (%) | 0.0 | 8.3 | 25.4 | 0.0 | 10.9 | 16.2 | 0.0 | 10.3 | 17.1 |

evaporation and seepage rate, varied from 13.21 $m^3$ to 304.51 $m^3$ with average at 152.6 $m^3$ and CV of 38.5 %. Similarly spillage in case of abnormal rains, varied from 1.04 $m^3$ to 2.76 $m^3$ with average at 1.89 $m^3$ and CV of .20.5 %, which is common in semi-arid region. In order to accommodate every possible spillage over the period, the length/width of the pond may be extended by another 0.90 m.

## CONCLUSION

Analysis of daily rainfall time series data of 90 year suggests that in an average rainfall year, it is possible to obtain 80 % of the potential yield of the pigeon pea and cotton crops (sown around onset of effective monsoon) by scientific scheduling irrigation of rain water harvested in rain water harvesting structure. Adoption of surface drainage coefficient for design and execution of surface drains will benefit in controlling waterlogging of the crops during abnormal rainfall years.

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**Table 10:** Cotton cultivation by CROPWAT model.

| Parameter | Sowing-Jun 15 Harvest-Dec 15 | | | Sowing - Jun 30 Harvest - Dec 30 | | | Sowing- Jul 15 Harvest-Jan 15 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Reduction in potential yield (%) | | | | | | | | |
| | 0 | 10 | 20 | 0 | 10 | 20 | 0 | 10 | 20 |
| Total gross irrigation (mm) | 618.3 | 0.0 | 0.0 | 616.1 | 410.1 | 0.0 | 514.6 | 400.6 | 0.0 |
| Total irrigation supply (mm) | 412.2 | 0.0 | 0.0 | 410.7 | 273.4 | 0.0 | 343.1 | 267.1 | 0.0 |
| Total irrigation losses (mm) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Moisture deficit at harvest (mm) | 14.7 | 275.6 | 275.6 | 113.6 | 34.7 | 277.0 | 195.3 | 123.0 | 278.0 |
| Actual water use by crop (mm) | 741.7 | 590.4 | 590.4 | 724.4 | 550.0 | 519.7 | 708.5 | 560.2 | 448.1 |
| Potential water use by crop (mm) | 741.7 | 741.7 | 741.7 | 724.4 | 724.4 | 724.4 | 708.5 | 708.5 | 708.5 |
| Efficiency irrigation schedule (%) | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Deficiency irrigation schedule (%) | 0.0 | 0.0 | 0.0 | 0.0 | 24.0 | 28.3 | 0.0 | 20.9 | 31.2 |
| Total rainfall (mm) | 555.5 | 555.5 | 555.5 | 456.4 | 456.4 | 456.4 | 348.9 | 348.9 | 348.9 |
| Effective rainfall (mm) | 551.9 | 551.9 | 551.9 | 399.5 | 454.0 | 454.0 | 348.9 | 348.9 | 348.9 |
| Total rain loss (mm) | 3.6 | 3.6 | 3.6 | 56.9 | 2.4 | 2.4 | 0.0 | 0.0 | 0.0 |
| Actual irrigation requirement(mm) | 189.8 | 189.8 | 189.8 | 324.9 | 270.5 | 270.5 | 359.6 | 359.6 | 359.6 |
| Efficiency rain (%) | 94.9 | 94.9 | 94.9 | 87.5 | 99.5 | 99.5 | 100.0 | 100.0 | 100.0 |
| Reductions in ETC (%) | 0.0 | 20.4 | 20.4 | 0.0 | 24.0 | 28.3 | 0.0 | 20.9 | 36.8 |
| Reduction in yield (%) | 0.0 | 17.3 | 17.3 | 0.0 | 20.4 | 24.0 | 0.0 | 17.8 | 31.2 |

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**Table 11:** Design of rainwater harvesting structure in the Bara Tract

| Parameters | Min | Avg | Max | CV (%) |
|---|---|---|---|---|
| 1-day annual maximum rainfall (mm) | 10.40 | 46.10 | 126.80 | 41.5 |
| 1-day annual maximum runoff volume ($m^3$) | 14.04 | 62.23 | 171.18 | 41.5 |
| Base width Square shaped Trapezoidal Tank (m) | 1.56 | 5.63 | 11.03 | 29.33 |
| Calculated depth (m) | 1.01 | 1.02 | 1.05 | 0.7 |
| Cross section area ($m^2$) | 3.85 | 7.79 | 13.14 | 20.8 |
| Wetted perimeter (m) | 6.26 | 10.18 | 15.54 | 15.9 |
| Top width (m) | 5.76 | 9.70 | 15.06 | 16.8 |
| Storage efficiency (%) | 75.03 | 92.33 | 97.55 | 4.1 |
| Total volume after rainy days ($m^3$) | 0.87 | 88.50 | 283.07 | 67.5 |
| Theoretical depth after rainy days (m) | 0.32 | 2.61 | 6.16 | 52.4 |
| Adjusted depth water rainy depth (m) | 0.22 | 1.18 | 2.17 | 36.6 |
| Total of losses ($m^3$) | 13.21 | 152.56 | 304.51 | 38.5 |
| Volume after non rainy days ($m^3$) | 0.83 | 87.85 | 281.65 | 67.6 |
| Depth after non rainy days (m) | 0.21 | 1.17 | 2.16 | 36.7 |
| Probable spill ($m^3$) | 1.04 | 1.89 | 2.76 | 20.5 |
| Calculated depth under 'B' | 3.70 | 11.06 | 18.93 | 30.3 |
| Base width under constant 'D' | 1.28 | 5.52 | 11.03 | 32.1 |
| Base width under 'N' | 0.26 | 1.40 | 1.68 | 11.5 |
| Calculated depth under 'N' | 0.55 | 5.43 | 12.61 | 47.5 |
| Net Difference base width between 'N' & 'M' | 0.04 | 0.89 | 1.76 | 43.6 |
| Net Difference top width between 'N' & 'M' | 0.54 | 5.35 | 11.77 | 46.4 |