# Chapter 7
# Irrigation Needs

# CHAPTER - 7

## IRRIGATION NEEDS

International agencies have forecast that India along with some 70 percent of the countries, are expected to experience severe water crisis within next 50 years. India is in a very peculiar situation. A country of such vast size has to be self sufficient in food. Before 50 years, when the population was less than 40 percent of the present population, the country passed through a phase of food crisis. Large quantity of food grains had to be imported. Thanks to the green revolution, which was triggered with thrust on irrigation development that the country reached self sufficiency. A stage has now been reached when we need to trigger another revolution to step up food production to meet the demands of increasing population.

### 7.1 History of Irrigation Development

The history of irrigation development in India can be traced back to prehistoric times. Vedas and ancient Indian scriptures made reference to wells, canals, tanks and dams which were beneficial to the community and their efficient operation and maintenance was the responsibility of the State. Civilization flourished on the banks of the rivers and harnessed the water for sustenance of life. According to the ancient Indian writers, the digging of a tank or well was amongst the greatest of the meritoriomus acts of a man. Brihaspathi, an ancient writer on law and politics, states that the construction and the repair of dams is a pious work and its burden should fall on the shoulders of rich men of the land. Vishnu Purana enjoins merit to a person who effects repairs to well, gardens and dams. (Randhawa, 1992).

In a monsoon climate and an agrarian economy like India, irrigation has played a major role in the production process. There is evidence of the practice of irrigation since the establishment of settled agriculture during the Indus Valley civilization (2500 BC). In more modern times, the introduction of canal irrigation in Punjab has triggered the green revolution in India.

India produces about 200 million tons of food grains to feed the population of over one billion people. In the next 50 years, the population is expected to grow to 1600 million, and the estimated food requirement will be of the order of 450 million tons. The country has to gear to reach this level of production to ensure food security. There has been an argument that the country could import food grains if this target cannot be met. The deficit could be of the order of 50 to 100 million tons which will be difficult to meet through imports, and will also lead to a heavy drain on foreign exchange. A country of our size cannot plan on this basis and has to ensure food security.
The net cultivable area of India is 143 million ha. It would not be possible to stretch it beyond 145 million ha in the next 50 years. For all practical purposes, therefore, one has to assume that the available land for cultivation is fixed. The average food production is about 1.4 tonnes per hectare. This would need to be increased to 3.0 tonnes per hectare in next 50 years. More than two fold increase is nearly impossible with rain-fed agriculture. Steps to increase yield per unit of land would need to be taken.

Presently the production under rain-fed cultivation is about 1.1 tonnes per ha, which at best can be taken to 1.5 tonnes per ha. This would not significantly add to meet the requirement. In case of irrigated agriculture, the production at present is 3.0 tonnes per ha and this can be taken to 4.0 tonnes per ha. Thus with each hectare of land transferred from rain-fed to irrigated, an increase of 2.5 tonnes per hectare is possible. Key to achieving food security therefore lies in increasing area under irrigation.

Out of 143 million hectares of cultivable land about 90 million hectares are rain-fed and area of food crops under irrigation is about 50 million ha. It would be necessary to bring part of the 90 million hectares, not receiving benefit of irrigation, under irrigated agriculture. In this process, by 2050, area under rain-fed cultivation is expected to reduce to 57 million ha and the area of food crops under irrigation should go up to 102 million ha.

How to achieve this target is the problem to be solved. Presently nearly 78% of water harnessed is being used for irrigation. The balance 22% comprises critical uses like domestic requirement. It is impossible to encroach on this usage. On the contrary with increase in population and improvement in life style, the domestic consumption is expected to reach 9% of the total consumption, against 6% as of now. This and other increases would encroach on the irrigation water and what would be left for irrigation would be 68% of the total usage then. Diversion of water used for non agricultural uses for irrigation is therefore not possible.

The next way to make available more water for irrigation is to harness rain water going waste to sea, and store it either above or and below the ground. The total amount of water available through precipitation in the country is 4000 BCM. Out of this the total flow in the river basins is considered as 1870. BCM. The utilizable surface water is estimated at 690 BCM and replenishable ground water as 396 BCM. Rainfall is spread over monsoon months and there is hardly any rain thereafter. Therefore to support irrigation requirement for rabi and hot weather crops, water is required to be stored either underground or above ground. The normal replenishable ground water recharge as already noted is 396 BCM. Artificial re-charge measures such as water-shed development, rain water harvesting, check dams and small dams can at best add 150 BCM. The balance has therefore to come through surface water storages.

Existing irrigation of 50 million ha under food crops and 25 million ha for other crops consumes about 540 BCM. Addition of 50 million ha under food crops and 25 million ha under other crops would need additional 540 BCM. The total irrigation requirement can be placed at 1080 BCM. Out of 540 BCM additional requirement of not more than 150 BCM could be through ground water augmentation. The balance 390 BCM has to come through surface storages. The storage projects under construction and those under consideration will add 200 BCM to existing storage capacity of 174 BCM. Allowing for siltation net 300 BCM will be left. Net addition to existing storages will thus be only 126 BCM. To make up the balance requirement of 264 BCM additional storages will need to be created. The total new development to be achieved is of 150 BCM in underground and 390 BCM above ground making a total of 540 BCM. To be able to achieve this (540 BCM) it is necessary to plan at least for 700 BCM.

Ganga-Brahmaputra-Meghna and west flowing rivers south of Tapi, which constitute 27% of the land area receive 72% of water. The other regions have therefore serious limitations in terms of storages, as also potential for additional ground water re-charge.

Most of the additional demand in these regions would need to be met by tapping the water in water rich regions and transferring to needy areas through inter-basin transfer of water. In this process the concerns of Project Affected People and environment have also to be addressed. This however appears to be an inevitable need for the country. Inter-basin transfer of water is going to be most important programme in years to come as it could provide great relief in meeting the deficit.

It is possible that full development as envisaged may not be achieved in time. This would need consideration and adoption of alternative options. Efficient irrigation systems would need to be encouraged to be able to get more production per unit of water. About 10 percent overall saving in water can be achieved. Conjunctive use of surface and ground water would also help. Tendency to use more water for irrigation results in rise in ground water table. This can best be tackled through vertical drainage. The practice of conjunctive use of surface and ground water therefore is required to be encouraged. It meets the requirement of drainage and helps in saving surface water. In India, cultivable land is limited. Usable fresh water is also limited. The strategies therefore have to aim at increasing production per unit of land and per unit of water.

The need of the hour, therefore, is to increase water use efficiency and practice conjunctive use of surface and ground water. This can be done effectively and quickly if the beneficiaries are involved. Therefore participation of the people in water resources management is very much necessary. Realizing this need, the Government is now introducing Participatory Irrigation Management (PIM) on the projects, where irrigation is being practiced. For new projects, like Sardar Sarovar, conscious efforts are made to plan the canal network in a manner which will make it easy to organize irrigation management with participation of the beneficiaries. With effective participation and improvement in management substantial saving in water is possible.

## 7.2 Participatory Irrigation

The most important aspect of Sardar Sarovar (Narmada) Project is supplying of irrigation water on volumetric basis and enforcing strict rotational water supply by Warbandhi unlike on crop area basis in other irrigation projects so far. Moreover, the water will be supplied to a group of farmers (Water Users Associations – WUAs) and not to individuals so as to attain better water use efficiency. It would be for the Water Users Associations (WUAs) to manage and distribute the water within their block called Village services Area (VSA). The corollary of this management is that the sub, minor and fields channels will be operated and looked after by the WUAs.

The Corporation will operate the canal system up to the village level. Below the Village Services Area level, the system will be fully operated by the Water Users Associations – (WUAs). With the system of fixed annual water allowance pre-decided for the command area, it is easy to convert this water allowance into number of watering, that the farmers will be getting from the system. It will be the need-based privilege of the farmers to avail of the water either in the kharif season or in the rabi season. They would take the decisions themselves on the basis of the rainfall amount and distribution.

Once the WUAs make the schedules, it would be easy to aggregate these at the level of distributaries and the branch level.

The system would be fully computerised and remotely operated up to level of 300 cusec capacity. Thus, the demand of the WUAs is known reasonably in advance, the computerised system would ensure that, the required flow is delivered accurately. In fact the basic purpose of computerising the operations is to make the system more responsive, accurate and easy to operate. The response time is extremely important for the timely deliveries of water to the remote areas. In the Sardar Sarovar Project (SSP) response time will be less than 24 hours, which conventionally would be several days. The Water Users Associations (WUAs) will operate the system within the village service areas on principle of rotational delivery. The farmers will not be required to do any gate operations and will only regulate the hours per ha on their individual field.

### 7.3 Water Need for Crops

Irrigation is now recognized as an important component in the agriculture economy of the regions. As practiced by many growers, it is often based on traditional methods of distribution and application which fail to measure and optimize the supply of water needed to satisfy the variable requirements of different crops. Inadequate irrigation tends to waste water, nutrients and energy, and may cause soil degradation by water-logging and salinisation. In order to achieve higher levels of profitable and sustainable production, it is essential to modernise existing irrigation systems and improve water management. Up-to-date methods of irrigation should likewise be based on sound principles and techniques for attaining greater control over the soil-crop-water regime and for optimizing irrigation in relation to all other essential agricultural inputs and operations.

As in open field, accurate predictions of crop water requirements are necessary for an efficient use of irrigation water for crop production. Furthermore, under open spaces, the predominant role of crop transpiration in decreasing the heat load during warm periods is a supplementary reason to develop irrigation scheduling that allows the maximization of the transpirational fluxes.

For reliable estimates of water requirements, information is needed on the crop environment (climate, soil) and physiological behaviour of the crops. This information has to be stored and processed adequately in order to extract the useful parameters and data that will serve irrigation 'scheduling and management". Practical irrigation scheduling algorithms for crops have been developed during the last twenty years, many of them based on estimates or measurements of the crop transpiration.

### 7.3.1 The Water Cycle

The main process involving the fate of water in agriculture and hence the water requirements of crops, is evapotranspiration, a process that is driven by a constant inflow of energy. In fact, the water balance is intimately and reciprocally related to the cycle and balance of energy (Boulard and Baille, 1993), since the state and content of water in the soil and its vegetative cover is affected by, and in turn, affects, the way the energy fluxes reaching the soil is partitioned and utilized. Control of the soil-plant-atmosphere system must therefore be based on simultaneous consideration of both the water and the energy balance. Two components of the agriculture water cycle are important to measure and to control. The first one is the soil component (or artificial substrate), where the water balance is an account of all quantities of water added to, subtracted from and stored within the root zone during a given period of time.

Accurate estimation of crop water requirement is essential for irrigation scheduling. It can decide the vital stages for irrigation and thus can optimize the irrigation water use. Crop water requirements have been defined as ' The depth of water needed to meet the loss through evapotranspiration of a disease-free crop, growing in large fields under non-restricting soil conditions including soil water and fertility, achieving full production potential under the given growing environment (Doorenbos and Pruitt, 1977). Mathematically crop water requirement (ETcrop) can be expressed as

$$ETcrop = Kc * ET_0$$

Where, Kc is the crop coefficient which varies for different crops and their growth stages and $ET_0$ is the reference crop evapotranspiration.

### 7.3.2 Evapotranspiration (ET)

The combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration is referred to as evapotranspiration (ET). Evaporation is the process whereby liquid water is converted to water vapour (vaporization) and removed from the evaporating surface (vapour removal).

Water evaporates from a variety of surfaces, such as lakes, rivers, pavements, soils and wet vegetation. Transpiration consists of the vaporization of liquid water contained in plant tissues and the vapour removal to the atmosphere. Crops predominately lose their water through stomata. These are small openings on the plant leaf through which gases and water vapour pass.

Evaporation and transpiration occur simultaneously and there is no easy way of distinguishing between the two processes. Apart from the water availability in the top soil, the evaporation from a cropped soil is mainly determined by the fraction of the solar radiation reaching the soil surface. This fraction decreases over the growing period as the crop develops and the crop canopy shades more and more of the ground area. When the crop is small, water is predominately lost by soil evaporation, but once the crop is well developed and completely covers the soil, transpiration becomes the main process factors affecting evapotranspiration.

The principal weather parameters affecting evapotranspiration are radiation, air temperature, humidity and wind speed. The evaporation power of the atmosphere is expressed by the reference crop evapotranspiration (ETo). The reference crop evapotranspiration represents the evapotranspiration from a standardized vegetated surface.

The crop type, variety and development stage should be considered when assessing the evapotranspiration from crops grown in large, well-managed fields. Differences in resistance to transpiration, crop height, crop roughness, reflection, ground cover and crop rooting characteristics result in different ET levels in different types of crops under identical environmental conditions.

Factors such as soil salinity, poor land fertility, limited application of fertilizers, the presence of hard or impenetrable soil horizons, the absence of control of diseases and pests and poor soil management may limit the crop development and reduce the evapotranspiration. Other factors to be considered when assessing ET are ground cover, plant density and the soil water content. The effect of soil water content on ET is conditioned primarily by the magnitude of the water deficit and the type of soil. On the other hand, too much water will result in water logging which might damage the root and limit root water uptake by inhibiting respiration.

### 7.3.3 Crop water requirements

The crop water requirement was estimated with historic climatic data, was collected from Agro-Meteorology Department, Anand Agriculture University, Anand for three stations (1980-2004) of Vadadora, Bharuch and Dahod (Table 7.1 to 7.3). The water requirement of different crops was determined for sowing dates corresponding to the twelve months of the year. A total growth duration of  for each cropping period was disaggregated into weeks/days representing respectively, the early growth, peak vegetative growth, flowering and pod formation, physiological maturity and harvest (Rao and Singh, 2003). The estimation of crop evapotranspiration involved 3 stages.

**A. Calculation of reference crop evapotranspiration (ETo):**

This predicts the effect of climate on the level of crop evapotranspiration. The method developed by Penman (1948) is adopted here:

$$ETo= c\ [W.Rn + (1-W)-f\ (U).\ (ea-ed] \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

Where:

ea-ed = vapour pressure deficit i.e. the difference between saturation vapour (ea) at T mean in mbar and actual vapour pressure (ed) in mbar where $ed = ea.\ \frac{RH}{100}$

f (U) = wind function of $f(U) = 0.27\ (1+\frac{U_2}{100})$ with U in km/day measured at 2m height.................................................... (2)

Rn = total net radiation in mm/day or Rn = 0.75Rs – Rnl where Rs is incoming shortwave radiation in mm/day either measured or obtained from $Rs = (0.25+0.50\ ^n/N)\ Ra$. Ra is extra-terrestrial radiation in mm/day, n is the mean actual sunshine duration in hour/day and N is maximum possible sunshine duration in hour/day. Rnl is net longwave radiation in mm/day is a function of temperature, f(T), of actual vapour pressure f(ed) and sunshine duration

$$f(\tfrac{n}{N});\ \text{or}\ Rnl = f(T).\ f(\tfrac{n}{N}).\ f(ed).$$

W = temperature and altitude dependent weighting factor

c= adjustment factor for ratio U day/U night, for RH max and for Rs.

**B. Crop coefficient (kc)**

Empirically determined crop coefficient relates reference evapotranspiration rate (ETo) to the maximum evapotranspiration rate (ETm) when water supply fully meets the water requirements of the crop. This was obtained based on the date of sowing of the crop, the length of the total growing season disaggregated into:

- Duration of the early growth or initial stage (germination to 10% ground cover)
- Duration of peace vegetative growth or the crop development stage (from 10 to 80% ground cover)
- Duration of flowering and pod formation or the mid-season stage (from 80% of ground cover to start of ripening) and,
- Duration of physiological maturity or late season stage (from start of ripening to harvest).

Crop coefficient (kc) for various crops are presented in Doorenbos and Pruitt (1977) and modified by Doorenbos and Kassam (1979).

Weather parameters, crop characteristics, management and environmental aspects are factors affecting evaporation and transpiration (Table 7.4 to 7.5).

**C. Maximum Evapotranspiration (ETm):**

Maximum evapotranspiration rate of the crop, when soil water is not limited, also called water requirements in mm/day or mm/period. The monthly mean ETo in mm/day and the kc for the crop over each 15-day period.

ETm=kc Eto............................................................... (3)

II Irrigation water Requirement (IWR)

This was calculated as the difference between ETm and effective rainfall (Pe) using the formula of Brouwer and Heibloem (1986) as follows:

Pe = 0.8r – 25, if R > 75mm / month.................................... (4)

Pe = 0.6R – 10, if R< 75mm / month.................................... (5)

Where:

Pe = effective rainfall or the part of the precipitation that is infiltrated and stored in the root zone and which plants can depend on to satisfy the water needs.

R = monthly rainfall.

Based on the above formula the crop water requirements for different crops are calculated. The fortnightly net irrigation requirement is calculated for different crops in all the four regions of the study area, are presented in Table 7.4 to 5.7 and Sugarcane will need maximum irrigation water across all the four regions, ranging between 1400 to 1650 mm, whereas other kharif crops like jowar and bajra will require the least, ranging from 55 to 160 mm of water (Table 7.6 to 7.9).

## 7.4 Irrigation Intensity

Irrigation requirement is determined by Sen (1996) computing irrigation requirement Index ($I_r$) at the block level by using mainly non climatological parameters such as percentage (%) of net sown area ($P_n$), density of population ($P_{dn}$) in terms of net sown area present irrigation intensity ($I_p$) and average annual rainfall (R). he used the following formula to determine irrigation requirement index. (Table 7.10) (Figure 7.1)

$$\frac{I_r = P_n x P_{dn} x I_p}{R}$$

$$\frac{I_p = I_i}{N.S.A.}$$ (Where $I_i$ = Present Irrigated area)

## Table 7.1: Evapotranspiration for Different Crops of Vadodara Region

| SEASON | NAME OF CROP | PROBABLE DATE OF SOWING | NO. OF WEEKS STARTS FROM DATE OF SOWING: 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 21 22 23 24 25 26 27 28 | CROP DURATION IN WEEKS | TOTAL ETc (mm) |
|---|---|---|---|---|---|
| KHARIF | JOWAR | 02 – JULY. | 07 07 09 14 20 25 29 32 33 34 33 32 29 25 20 ---------- | 15 | 349 |
| | BAJRA | 02 – JULY. | 09 10 10 14 22 27 30 32 33 33 32 29 21 13 ---------- | 14 | 315 |
| | MAIZE | 02 – JULY. | 08 09 10 13 17 21 27 31 34 36 35 34 33 30 24 ---------- | 15 | 362 |
| | GROUNDNUT | 18 – JUNE. | 10 10 10 11 14 18 22 26 29 31 32 32 31 29 27 23 19 ---------- | 17 | 374 |
| | SUN -FLOWER | 25 – JUNE. | 10 11 13 16 22 27 30 32 34 32 33 32 28 22 ---------- | 14 | 342 |
| | PULSES | | | | |
| | SOYABEAN | 02 – JULY. | 07 08 11 17 24 29 32 34 33 28 17 ---------- | 11 | 240 |
| | CUCUMBER | 25 – JUNE. | 10 10 10 12 16 22 27 30 32 33 33 32 29 25 19 ---------- | 15 | 340 |
| | BANANA | 02 – JULY. | 11 10 11 13 15 20 24 27 29 30 31 31 30 28 26 ---------- | 15 | 336 |
| | | 01 – JULY. | ---------- 26 23 22 24 29 30 39 40 45 40 42 40 ---------- | | 420 |
| | PADDY | | 48 56 76 83 98 105 113 120 101 98 76 64 53 46 53 57 67 71 ---------- | 30 | **1938** |
| | | 01 – JULY. | ---------- 73 63 61 63 67 71 73 76 ---------- | 08 | 546 |
| RABI | WHEAT | 19 – NOV. | 07 08 10 13 19 23 27 29 31 33 34 35 33 31 27 19 ---------- | 16 | 379 |
| | JOWAR | 01 – OCT | 06 07 10 15 20 24 26 25 24 23 22 22 20 18 16 ---------- | 15 | 278 |
| | PULSES | 15 – OCT | 06 07 08 10 15 21 25 25 25 25 23 22 19 15 09 ---------- | 15 | 255 |
| | PATATOES | 12 – NOV | 09 10 11 13 18 22 23 26 27 28 29 29 27 26 ---------- | 14 | 298 |
| | ONOION (DRY) | 12 – NOV | 12 12 13 15 19 21 22 25 26 27 28 29 29 30 30 30 ---------- | 16 | 368 |
| | OIL SEEDS | | | | |
| | VEGETABLE | 15 – OCT | 06 06 08 11 15 19 22 24 24 24 23 25 25 24 22 19 12 ---------- | 17 | 309 |
| | MAIZE (F) | 12 – NOV | 09 10 10 12 14 18 20 24 26 28 29 30 31 32 32 ---------- | 15 | 325 |
| | SUGARCANE | 12 – NOV | 07 07 08 13 19 23 24 26 27 28 29 ---------- | 11 | 211 |
| | SUGARCANE | 01 – NOV | 51 59 76 83 89 95 108 114 118 114 100 64 53 46 44 36 38 00 00 00 41 36 48 46 ---------- | 21 | 1460 |
| | | 01 - FEB | 34 00 42 46 71 76 92 109 113 109 95 83 69 60 58 63 67 71 81 64 59 53 48 34 ---------- | 23 | 1598 |
| H.W | GROUNDNUT | 22 – JAN. | 08 09 10 13 15 21 29 37 42 47 50 54 56 55 53 48 41 ---------- | 17 | 588 |
| | BAJRA | 12 – FEB. | 08 10 14 22 33 43 49 53 58 59 59 55 40 22 ---------- | 14 | 525 |
| | PULSES | 12 – FEB. | 08 10 16 27 40 49 52 53 45 23 ---------- | 10 | 323 |
| | MELON | 22 – JAN. | 08 10 14 20 28 35 39 42 45 47 49 51 53 53 52 51 ---------- | 16 | 597 |
| | PADDY | 16 – JAN. | --- 73 83 92 98 119 128 109 113 ---------- | 08 | 814 |
| TWO SEASO-NAL | COTTON | 18 – JUNE. | 08 08 08 08 09 11 14 18 22 25 31 35 38 39 40 40 40 38 36 33 29 26 24 22 20 18 16 ---------- | 27 | 656 |
| | CASTER | 23 – JULY. | 05 06 07 08 09 11 13 17 21 25 28 31 33 33 33 31 30 29 37 36 34 23 21 21 21 19 18 16 --- | 28 | 586 |
| | TABACCO | 23 – JULY. | 05 06 06 07 10 12 15 18 22 26 30 33 35 35 33 32 30 29 28 26 25 23 20 20 18 16 ---------- | 26 | 560 |
| | TOMATO | 23 – JULY. | 08 09 10 11 14 18 22 26 30 35 38 39 39 38 34 31 29 26 23 19 16 ---------- | 21 | 515 |
| | BRINJAL & CHILLIES | 23 – JULY. | 08 09 10 12 14 17 20 24 28 32 34 35 35 33 30 27 26 24 22 20 19 ---------- | 21 | 479 |

**Table 7.2: Evapotranspiration for Different Crops of Bharuch Region**

| SEASON | NAME OF CROP | PROBABLE DATE OF SOWING | NO. OF WEEKS STARTS FROM DATE OF SOWING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | CROP DURATION IN WEEKS | TOTAL $ET_C$ (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | | |
| KHARIF | JOWAR | 02 – JULY. | 07 | 07 | 09 | 15 | 20 | 26 | 30 | 32 | 34 | 35 | 35 | 34 | 32 | 28 | 23 | | | | | | | | | | | | | | | 15 | 349 |
| | BAJRA | 02 – JULY. | 09 | 10 | 11 | 15 | 22 | 27 | 30 | 32 | 34 | 34 | 34 | 31 | 23 | 15 | | | | | | | | | | | | | | | | 14 | 315 |
| | MAIZE | 02 – JULY. | 08 | 09 | 11 | 14 | 17 | 22 | 27 | 32 | 35 | 37 | 37 | 37 | 36 | 34 | 27 | | | | | | | | | | | | | | | 15 | 362 |
| | GROUNDNUT | 18 – JUNE. | 10 | 10 | 10 | 11 | 15 | 19 | 23 | 26 | 29 | 31 | 32 | 34 | 34 | 32 | 30 | 26 | 22 | | | | | | | | | | | | | 17 | 374 |
| | SUN -FLOWER | 25 – JUNE. | 10 | 11 | 13 | 17 | 23 | 27 | 30 | 32 | 34 | 33 | 34 | 34 | 31 | 24 | | | | | | | | | | | | | | | | 14 | 342 |
| | PULSES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 | 240 |
| | SOYABEAN | 02 – JULY. | 07 | 08 | 11 | 18 | 24 | 30 | 32 | 34 | 34 | 29 | 18 | | | | | | | | | | | | | | | | | | | 15 | 340 |
| | | 25 – JUNE. | 11 | 11 | 12 | 14 | 16 | 21 | 24 | 28 | 30 | 31 | 33 | 33 | 33 | 31 | 29 | | | | | | | | | | | | | | | 15 | 336 |
| RABI | WHEAT | 19 – NOV. | 09 | 09 | 12 | 17 | 24 | 29 | 33 | 34 | 36 | 38 | 40 | 41 | 39 | 36 | 31 | 22 | | | | | | | | | | | | | | 16 | 379 |
| | JOWAR | 01 – OCT | 07 | 08 | 11 | 17 | 25 | 30 | 32 | 31 | 30 | 29 | 28 | 27 | 25 | 22 | 19 | | | | | | | | | | | | | | | 15 | 278 |
| | PULSES | 15 – OCT | 07 | 08 | 09 | 13 | 18 | 26 | 30 | 31 | 32 | 31 | 29 | 26 | 23 | 17 | 11 | | | | | | | | | | | | | | | 15 | 255 |
| | PATATOES | 12 – NOV | 09 | 10 | 11 | 13 | 18 | 22 | 23 | 26 | 27 | 28 | 29 | 29 | 27 | 26 | | | | | | | | | | | | | | | | 14 | 298 |
| | ONOION (DRY) | 12 – NOV | 12 | 12 | 13 | 15 | 19 | 21 | 22 | 25 | 26 | 27 | 28 | 29 | 29 | 30 | 30 | 30 | | | | | | | | | | | | | | 16 | 368 |
| | OIL SEEDS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | VEGETABLE | 15 – OCT | 06 | 06 | 08 | 11 | 15 | 19 | 22 | 24 | 24 | 24 | 23 | 25 | 25 | 24 | 22 | 19 | 12 | | | | | | | | | | | | | 17 | 309 |
| | MAIZE (F) | 12 – NOV | 09 | 10 | 10 | 12 | 14 | 18 | 20 | 24 | 26 | 28 | 29 | 30 | 31 | 32 | 32 | | | | | | | | | | | | | | | 15 | 325 |
| | | 12 – NOV | 07 | 07 | 08 | 13 | 19 | 23 | 24 | 26 | 27 | 28 | 29 | | | | | | | | | | | | | | | | | | | 11 | 211 |
| H.W | GROUNDNUT | 22 – JAN. | 08 | 09 | 10 | 13 | 15 | 21 | 29 | 37 | 42 | 47 | 50 | 54 | 56 | 55 | 53 | 48 | 41 | | | | | | | | | | | | | 17 | 588 |
| | BAJRA | 12 – FEB. | 08 | 10 | 14 | 22 | 33 | 43 | 49 | 53 | 58 | 59 | 59 | 55 | 40 | 22 | | | | | | | | | | | | | | | | 14 | 525 |
| | PULSES | 12 – FEB. | 08 | 10 | 16 | 27 | 40 | 49 | 52 | 53 | 45 | 23 | | | | | | | | | | | | | | | | | | | | 10 | 323 |
| | MELON | 22 – JAN. | 08 | 10 | 14 | 20 | 28 | 35 | 39 | 42 | 45 | 47 | 49 | 51 | 53 | 53 | 52 | 51 | | | | | | | | | | | | | | 16 | 597 |
| TWO SEASO-NAL | COTTON | 18 – JUNE. | 08 | 08 | 08 | 08 | 09 | 11 | 14 | 18 | 22 | 25 | 31 | 35 | 38 | 39 | 40 | 40 | 40 | 38 | 36 | 33 | 29 | 26 | 24 | 22 | 20 | 18 | 16 | | | 27 | 656 |
| | CASTER | 23 – JULY. | 05 | 06 | 07 | 08 | 09 | 11 | 13 | 17 | 21 | 25 | 28 | 31 | 33 | 33 | 33 | 31 | 30 | 29 | 37 | 36 | 34 | 23 | 21 | 21 | 21 | 19 | 18 | 16 | | 28 | 586 |
| | TABACCO | 23 – JULY. | 05 | 06 | 06 | 07 | 10 | 12 | 15 | 18 | 22 | 26 | 30 | 33 | 35 | 35 | 33 | 32 | 30 | 29 | 28 | 26 | 25 | 23 | 20 | 20 | 18 | 16 | | | | 26 | 560 |
| | TOMATO | 23 – JULY. | 08 | 09 | 10 | 11 | 14 | 18 | 22 | 26 | 30 | 35 | 38 | 39 | 39 | 38 | 34 | 31 | 29 | 26 | 23 | 19 | 16 | | | | | | | | | 21 | 515 |
| | BRINJAL & CHILLIES | 23 – JULY. | 08 | 09 | 10 | 12 | 14 | 17 | 20 | 24 | 28 | 32 | 34 | 35 | 35 | 33 | 30 | 27 | 26 | 24 | 22 | 20 | 19 | | | | | | | | | 21 | 479 |

**Table 7.3: Evapotranspiration for Different Crops of Dahods Region**

| SEASON | NAME OF CROP | PROBABLE DATE OF SOWING | NO. OF WEEKS STARTS FROM DATE OF SOWING | | | | | | | | | | | | | | | | | | | | | | | | | | | | | CROP DURATION IN WEEKS | TOTAL $ET_c$ (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | | |
| KHARIF | JOWAR | 02 – JULY. | 08 | 08 | 10 | 15 | 21 | 26 | 30 | 33 | 34 | 36 | 37 | 36 | 34 | 29 | 24 | | | | | | | | | | | | | | | 15 | 381 |
| | BAJRA | 02 – JULY. | 11 | 11 | 12 | 16 | 23 | 28 | 31 | 33 | 34 | 35 | 36 | 33 | 24 | 15 | | | | | | | | | | | | | | | | 14 | 342 |
| | MAIZE | 02 – JULY. | 09 | 10 | 12 | 14 | 18 | 22 | 27 | 32 | 35 | 38 | 39 | 39 | 38 | 35 | 28 | | | | | | | | | | | | | | | 15 | 396 |
| | GROUNDNUT | 18 – JUNE. | 13 | 12 | 12 | 12 | 15 | 20 | 24 | 27 | 29 | 31 | 33 | 36 | 35 | 34 | 31 | 27 | 23 | | | | | | | | | | | | | 17 | 414 |
| | SUN -FLOWER | 25 – JUNE. | 12 | 13 | 15 | 18 | 24 | 28 | 31 | 32 | 34 | 34 | 35 | 35 | 32 | 25 | | | | | | | | | | | | | | | | 14 | 368 |
| | PULSES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 11 | 253 |
| | SOYABEAN | 02 – JULY. | 08 | 09 | 12 | 19 | 25 | 30 | 33 | 34 | 34 | 30 | 19 | | | | | | | | | | | | | | | | | | | 15 | 368 |
| | | 25 – JUNE. | 13 | 12 | 12 | 15 | 16 | 21 | 25 | 28 | 30 | 32 | 35 | 35 | 35 | 33 | 30 | | | | | | | | | | | | | | | 15 | 372 |
| RABI | WHEAT | 19 – NOV. | 08 | 09 | 11 | 16 | 23 | 25 | 24 | 27 | 31 | 36 | 40 | 42 | 41 | 39 | 34 | 24 | | | | | | | | | | | | | | 16 | 430 |
| | JOWAR | 01 – OCT | 07 | 09 | 12 | 18 | 25 | 30 | 30 | 29 | 28 | 27 | 27 | 26 | 21 | 16 | 15 | | | | | | | | | | | | | | | 15 | 320 |
| | PULSES | 15 – OCT | 07 | 08 | 10 | 13 | 17 | 24 | 28 | 30 | 30 | 29 | 24 | 19 | 18 | 15 | 10 | | | | | | | | | | | | | | | 15 | 282 |
| | PATATOES | 12 – NOV | 10 | 11 | 12 | 15 | 21 | 26 | 25 | 23 | 25 | 28 | 32 | 34 | 33 | 31 | | | | | | | | | | | | | | | | 14 | 326 |
| | ONOION (DRY) | 12 – NOV | 14 | 14 | 15 | 18 | 22 | 26 | 24 | 22 | 24 | 27 | 31 | 34 | 36 | 37 | 37 | 37 | | | | | | | | | | | | | | 16 | 418 |
| | OIL SEEDS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | VEGETABLE | 15 – OCT | 07 | 08 | 11 | 14 | 18 | 22 | 25 | 28 | 28 | 28 | 25 | 22 | 23 | 24 | 24 | 22 | 15 | | | | | | | | | | | | | 17 | 344 |
| | MAIZE (F) | 12 – NOV | 11 | 11 | 12 | 14 | 17 | 21 | 22 | 21 | 24 | 28 | 32 | 35 | 38 | 39 | 39 | | | | | | | | | | | | | | | 15 | 364 |
| | | 12 – NOV | 08 | 08 | 10 | 15 | 22 | 27 | 25 | 23 | 25 | 28 | 32 | | | | | | | | | | | | | | | | | | | 11 | 223 |
| H.W | GROUNDNUT | 22 – JAN. | 09 | 11 | 13 | 17 | 18 | 27 | 37 | 47 | 54 | 60 | 64 | 69 | 75 | 77 | 74 | 67 | 57 | | | | | | | | | | | | | 17 | 776 |
| | BAJRA | 12 – FEB. | 10 | 12 | 18 | 28 | 42 | 55 | 63 | 69 | 74 | 79 | 82 | 76 | 55 | 30 | | | | | | | | | | | | | | | | 14 | 693 |
| | PULSES | 12 – FEB. | 10 | 13 | 20 | 34 | 50 | 63 | 67 | 69 | 58 | 30 | | | | | | | | | | | | | | | | | | | | 10 | 414 |
| | MELON | 22 – JAN. | 09 | 12 | 17 | 25 | 35 | 43 | 49 | 53 | 58 | 60 | 63 | 66 | 70 | 74 | 73 | 70 | | | | | | | | | | | | | | 16 | 777 |
| TWO SEASO-NAL | COTTON | 18 – JUNE. | 09 | 09 | 09 | 09 | 10 | 13 | 15 | 19 | 22 | 25 | 32 | 37 | 42 | 44 | 46 | 47 | 47 | 45 | 44 | 41 | 36 | 31 | 27 | 25 | 23 | 21 | 19 | | | 27 | 747 |
| | CASTER | 23 – JULY. | 06 | 06 | 07 | 08 | 10 | 12 | 14 | 19 | 24 | 28 | 33 | 37 | 39 | 41 | 41 | 39 | 35 | 33 | 31 | 31 | 29 | 27 | 23 | 19 | 19 | 19 | 19 | 18 | | 28 | 667 |
| | TABACCO | 23 – JULY. | 06 | 06 | 07 | 07 | 10 | 12 | 16 | 21 | 25 | 30 | 35 | 38 | 41 | 42 | 41 | 39 | 35 | 34 | 32 | 31 | 29 | 27 | 22 | 17 | 17 | 16 | | | | 26 | 636 |
| | TOMATO | 23 – JULY. | 09 | 09 | 10 | 11 | 14 | 18 | 24 | 29 | 34 | 40 | 44 | 46 | 46 | 46 | 43 | 39 | 33 | 29 | 26 | 23 | 19 | 16 | | | | | | | | 21 | 592 |
| | BRINJAL & | 23 – JULY. | 09 | 09 | 11 | 12 | 14 | 17 | 21 | 26 | 32 | 37 | 39 | 41 | 41 | 40 | 37 | 34 | 30 | 27 | 25 | 24 | 23 | | | | | | | | | 21 | 549 |
| | CHILLIES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Source: Computed by researcher

**Table 7.4: Mean Monthly Solar Radiation Incident at the Earth's Outer Space**

| | NORTH LATITUDE (°N) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | 90° | 80° | 70° | 60° | 50° | 40° | 30° | 20° | 10° | 0° |
| January | - | - | - | 1.3 | 3.6 | 6.0 | 8.5 | 10.8 | 12.8 | 14.5 |
| February | - | - | 1.1 | 3.5 | 5.9 | 8.3 | 10.5 | 12.3 | 13.9 | 15.0 |
| March | - | 1.8 | 4.3 | 6.8 | 9.1 | 11.0 | 12.7 | 13.9 | 14.8 | 15.2 |
| April | 7.9 | 7.8 | 9.1 | 11.1 | 12.7 | 13.9 | 14.8 | 15.2 | 15.2 | 14.7 |
| May | 14.9 | 14.6 | 13.6 | 14.6 | 15.4 | 15.9 | 16.0 | 15.7 | 15.0 | 13.9 |
| June | 18.1 | 17.8 | 17.0 | 16.5 | 16.7 | 16.7 | 16.5 | 15.8 | 14.8 | 13.4 |
| July | 16.8 | 16.5 | 15.8 | 15.7 | 16.1 | 16.3 | 16.2 | 15.7 | 14.8 | 13.5 |
| August | 11.2 | 10.6 | 11.4 | 12.7 | 13.9 | 14.8 | 15.3 | 15.3 | 15.0 | 14.2 |
| September | 2.6 | 4.0 | 6.8 | 8.5 | 10.5 | 12.2 | 13.5 | 14.4 | 14.9 | 14.9 |
| October | - | 0.2 | 2.4 | 4.7 | 7.1 | 9.3 | 11.3 | 12.9 | 14.1 | 15.0 |
| November | - | - | 0.1 | 1.9 | 4.3 | 6.7 | 9.1 | 11.2 | 13.1 | 14.6 |
| December | - | - | - | 0.9 | 3.0 | 5.5 | 7.9 | 10.3 | 12.4 | 14.3 |

**Table 7.5: Mean Monthly Values Of Possible Sunshine Hours, Northern Hemisphere**

| LA°TITUDE | MONTH | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NORTH (°N) | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
| 0° | 12.1 | 12.1 | 12.1 | 12.1 | 12.1 | 12.1 | 12.1 | 12.1 | 12.1 | 12.1 | 12.1 | 12.1 |
| 10° | 11.6 | 11.8 | 12.1 | 12.4 | 12.6 | 12.7 | 12.6 | 12.4 | 12.9 | 11.9 | 11.7 | 11.5 |
| 20° | 11.1 | 11.5 | 12.0 | 12.6 | 13.1 | 13.3 | 13.2 | 12.8 | 12.3 | 11.7 | 11.2 | 10.9 |
| 30° | 10.4 | 11.1 | 12.0 | 12.9 | 13.7 | 14.1 | 13.9 | 13.2 | 12.4 | 11.5 | 10.6 | 10.2 |
| 40° | 9.6 | 10.7 | 11.9 | 13.2 | 14.4 | 15.0 | 14.7 | 13.8 | 12.5 | 11.2 | 10.0 | 9.4 |
| 50° | 8.6 | 10.1 | 11.8 | 13.8 | 15.4 | 16.4 | 16.0 | 14.5 | 12.7 | 10.8 | 9.1 | 8.1 |

Source: Ganshyam Das (2000), Hydrology and Soil Conservation Engineering, Prentic Hall of India Private Limited, N Delhi

**Table 7.6: Fortnightly Net Irrigation Requirement In Region – I**

| Sr. No. | Crop Name | May II | June I | June II | July I | July II | Aug. I | Aug. II | Sept. I | Sept. II | Oct. I | Oct. II |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *L Paddy* | 14 | 160 | 109 | 71 | 5 | 28 | 67 | 10 | 0 | 8 | |
| 2 | Other Kharif | | | 23 | 19 | 2 | 18 | 63 | 9 | 0 | 8 | |
| 3 | Kharif Groundnut | 76 | 4 | 23 | 32 | 4 | 18 | 60 | 9 | 0 | | |
| 4 | Hy. Jowar | | | | | | | | | | | |
| 5 | Hy. Bajara | 26 | | | | | | | | | | |
| 6 | Wheat | | | | | | | | | | | |
| 7 | Other Vegetables | | | | | | | | | | | |
| 8 | Rabi Pulses | | | | | | | | | | | |
| 9 | Mustard | | | | | | | | | | 76 | 20 |
| 10 | Potato | | | | | | | | | | | 76 |
| 11 | H. W. Fodder | 0 | | | | | | | | | | |
| 12 | H. W. Jowar | 0 | | | | | | | | | | |
| 13 | H. W. Groundnut | 39 | 0 | | | | | | | | | |
| 14 | H. W. Pulses | 0 | | | | | | | | | | |
| 15 | Lucerne | | | | | | | | | | | |
| 16 | Tobacco | | | 8 | 0 | 0 | 0 | 0 | 0 | 17 | 26 | 26 |
| 17 | L. S. Cotton | 76 | 12 | 0 | 0 | 10 | 0 | 16 | 21 | 57 | 83 | 83 |
| 18 | Castor | 0 | 0 | 23 | 4 | 3 | 0 | 20 | 18 | 51 | 76 | 76 |
| 19 | Tur | 0 | 60 | 0 | 0 | 6 | 0 | 14 | 18 | 51 | 83 | 54 |
| 20 | Sugarcane | 160 | 95 | 59 | 9 | 2 | 0 | 14 | 17 | 51 | 83 | 54 |
| 21 | Fruit Crop | 89 | 55 | 48 | 7 | 3 | 0 | 9 | 0 | 25 | 50 | 50 |
| 22 | Banana | 115 | 70 | 38 | 3 | 0 | 0 | 11 | 2 | 32 | 36 | 36 |

Table 7.6 (contd)

| Sr. No. | Crop Name | Nov. I | Nov. II | Dec. I | Dec. II | Jan. I | Jan. II | Feb. I | Feb. II | Mar. I | Mar. II | Apr. I | Apr. II | May I | Total mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | ***L Paddy*** | | | | | | | | | | | | | | **472** |
| 2. | **Other Kharif** | | | | | | | | | | | | | | **142** |
| 3. | **Kharif Groundnut** | | | | | | | | | | | | | | **226** |
| 4. | **Hy. Jowar** | 76 | 18 | 20 | 40 | 55 | 55 | 65 | 0 | | | | | | **329** |
| 5. | **Hy. Bajara** | | | | | | | 76 | 23 | 49 | 85 | 113 | 113 | 96 | **581** |
| 6. | **Wheat** | 76 | 18 | 27 | 50 | 58 | 58 | 72 | 57 | 0 | | | | | **416** |
| 7. | **Other Vegetables** | 76 | 30 | 25 | 33 | 45 | 52 | 66 | 66 | 0 | | | | | **393** |
| 8. | **Rabi Pulses** | 76 | 18 | 27 | 50 | 58 | 58 | 72 | 0 | | | | | | **359** |
| 9. | **Mustard** | 20 | 40 | 50 | 53 | 58 | 52 | 0 | | | | | | | **369** |
| 10. | **Potato** | 21 | 21 | 33 | 50 | 58 | 58 | 69 | 28 | 0 | | | | | **414** |
| 11. | **H. W. Fodder** | | | | | | | | 76 | 25 | 33 | 94 | 118 | 70 | **416** |
| 12. | **H. W. Jowar** | | | | | | | | 76 | 25 | 33 | 94 | 18 | 70 | **416** |
| 13. | **H. W. Groundnut** | | | | | | 76 | 23 | 23 | 54 | 82 | 108 | 108 | 105 | **618** |
| 14. | **H. W. Pulses** | | | | | | | | 76 | 25 | 47 | 113 | 118 | 60 | **439** |
| 15. | **Lucerne** | 76 | 28 | 24 | 45 | 50 | 50 | 62 | 62 | 81 | 81 | 102 | 0 | | **661** |
| 16. | **Tobacco** | 21 | 21 | 16 | 0 | | | | | | | | | | **135** |
| 17. | **L. S. Cotton** | 65 | 58 | 42 | 0 | | | | | | | | | | **523** |
| 18. | **Castor** | 59 | 51 | 0 | | | | | | | | | | | **381** |
| 19. | **Tur** | 52 | 0 | | | | | | | | | | | | **353** |
| 20. | **Sugarcane** | 54 | 54 | 0 | 76 | 21 | 21 | 49 | 49 | 81 | 94 | 118 | 118 | 160 | **1468** |
| 21. | **Fruit Crop** | 40 | 40 | 34 | 34 | 39 | 39 | 49 | 49 | 60 | 60 | 75 | 75 | 89 | **1021** |
| 22. | **Banana** | 34 | 34 | 33 | 33 | 45 | 45 | 66 | 66 | 94 | 94 | 118 | 118 | 115 | **1238** |

**Table 7.7: Fortnightly Net Irrigation Requirement In Region – II**

| Sr. No. | Crop Name | May II | June I | June II | July I | July II | Aug. I | Aug. II | Sept. I | Sept. II | Oct. I | Oct. II |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ***L Paddy*** | 14 | 158 | 103 | 54 | 45 | 46 | 46 | 52 | 76 | 0 | |
| 2 | **Other Kharif** | | | 5 | 0 | 70 | 01 | 6 | 36 | 0 | | |
| 3 | **Kharif Groundnut** | | | | | | | | | | | |
| 4 | **Hy. Jowar** | | | | | | | | | | | |
| 5 | **Hy. Bajara** | 26 | 0 | | | | | | | | | |
| 6 | **Wheat** | | | | | | | | | | | |
| 7 | **Other Vegetables** | | | | | | | | | | | |
| 8 | **Rabi Pulses** | | | | | | | | | | | |
| 9 | **Mustard** | | | | | | | | | | 76 | 20 |
| 10 | **Potato** | | | | | | | | | | | 76 |
| 11 | **H. W. Fodder** | 0 | | | | | | | | | | |
| 12 | **H. W. Jowar** | 0 | | | | | | | | | | |
| 13 | **H. W. Groundnut** | 39 | 0 | | | | | | | | | |
| 14 | **H. W. Pulses** | 0 | | | | | | | | | | |
| 15 | **Lucerne** | | | | | | | | | | | |
| 16 | **Tobacco** | | | 2 | 0 | 0 | 1 | 1 | 0 | 18 | 26 | 26 |
| 17 | **L. S. Cotton** | 76 | 8 | 3 | 0 | 10 | 0 | 6 | 9 | 60 | 83 | 83 |
| 18 | **Castor** | | | 5 | 4 | 3 | 0 | 14 | 7 | 54 | 76 | 76 |
| 19 | **Tur** | | 31 | 4 | 0 | 6 | 0 | 4 | 7 | 54 | 76 | 76 |
| 20 | **Sugarcane** | 160 | 74 | 52 | 9 | 2 | 4 | 4 | 7 | 54 | 83 | 83 |
| 21 | **Fruit Crop** | 89 | 37 | 24 | 7 | 2 | 4 | 4 | 0 | 28 | 50 | 50 |
| 22 | **Banana** | 115 | 51 | 32 | 4 | 0 | 5 | 5 | 0 | 35 | 36 | 36 |

Table 7.7 Contd.

| Sr. No. | Crop Name | Nov. I | Nov. II | Dec. I | Dec. II | Jan. I | Jan. II | Feb. I | Feb. II | Mar. I | Mar. II | Apr. I | Apr. II | May I | Total mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | ***L Paddy*** | | | | | | | | | | | | | | **600** |
| 2. | **Other Kharif** | | | | | | | | | | | | | | **55** |
| 3. | **Kharif Groundnut** | | | | | | | | | | | | | | **94** |
| 4. | **Hy. Jowar** | 76 | 18 | 20 | 40 | 55 | 55 | 65 | 0 | | | | | | **329** |
| 5. | **Hy. Bajara** | | | | | | | 76 | 23 | 49 | 85 | 113 | 113 | 96 | **581** |
| 6. | **Wheat** | 76 | 18 | 27 | 50 | 58 | 58 | 72 | 57 | 0 | | | | | **416** |
| 7. | **Other Vegetables** | 76 | 30 | 25 | 33 | 45 | 53 | 66 | 66 | 0 | | | | | **394** |
| 8. | **Rabi Pulses** | 76 | 18 | 27 | 50 | 58 | 58 | 58 | 72 | 0 | | | | | **359** |
| 9. | **Mustard** | 20 | 40 | 50 | 53 | 58 | 52 | 0 | | | | | | | **369** |
| 10. | **Potato** | 21 | 21 | 33 | 50 | 58 | 58 | 69 | 28 | 0 | | | | | **414** |
| 11. | **H. W. Fodder** | | | | | | | | 76 | 25 | 33 | 94 | 118 | 70 | **416** |
| 12. | **H. W. Jowar** | | | | | | | | 76 | 25 | 33 | 94 | 118 | 70 | **416** |
| 13. | **H. W. Groundnut** | | | | | | 76 | 23 | 23 | 54 | 82 | 108 | 108 | 105 | **618** |
| 14. | **H. W. Pulses** | | | | | | | | 76 | 25 | 47 | 113 | 118 | 60 | **439** |
| 15. | **Lucerne** | 76 | 28 | 24 | 45 | 50 | 50 | 62 | 62 | 81 | 81 | 102 | 0 | | **661** |
| 16. | **Tobacco** | 21 | 21 | 16 | 0 | | | | | | | | | | **132** |
| 17. | **L. S. Cotton** | 65 | 58 | 42 | 0 | | | | | | | | | | **504** |
| 18. | **Castor** | 59 | 51 | 0 | | | | | | | | | | | **349** |
| 19. | **Tur** | 52 | 0 | | | | | | | | | | | | **310** |
| 20. | **Sugarcane** | 54 | 54 | 0 | 76 | 21 | 21 | 49 | 49 | 81 | 94 | 118 | 118 | 160 | **1427** |
| 21. | **Fruit Crop** | 40 | 40 | 34 | 34 | 39 | 39 | 49 | 49 | 60 | 60 | 75 | 75 | 89 | **978** |
| 22. | **Banana** | 34 | 34 | 34 | 34 | 45 | 45 | 66 | 66 | 69 | 94 | 118 | 118 | 115 | **1216** |

**Table 7.8: Fortnightly Net Irrigation Requirement in Region – III**

| Sr. No. | Crop Name | May II | June I | June II | July I | July II | Aug. I | Aug. II | Sept. I | Sept. II | Oct. I | Oct. II |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ***L Paddy*** | 14 | 161 | 104 | 55 | 49 | 56 | 71 | 60 | 75 | 0 | |
| 2 | **Other Kharif** | | | 18 | 0 | 10 | 4 | 23 | 14 | 34 | 0 | |
| 3 | **Kharif Groundnut** | 76 | 19 | 0 | 0 | 4 | 5 | 19 | 11 | 0 | | |
| 4 | **Hy. Jowar** | | | | | | | | | | | |
| 5 | **Hy. Bajara** | 27 | | | | | | | | | | |
| 6 | **Wheat** | | | | | | | | | | | |
| 7 | **Other Vegetables** | | | | | | | | | | | |
| 8 | **Rabi Pulses** | | | | | | | | | | 63 | 19 |
| 9 | **Mustard** | | | | | | | | | | | 73 |
| 10 | **Potato** | | | | | | | | | | | |
| 11 | **H. W. Fodder** | 0 | | | | | | | | | | |
| 12 | **H. W. Jowar** | 0 | | | | | | | | | | |
| 13 | **H. W. Groundnut** | 40 | | | | | | | | | | |
| 14 | **H. W. Pulses** | 0 | | | | | | | | | | |
| 15 | **Lucerne** | | | | | | | | | | | |
| 16 | **Tobacco** | | | 6 | 0 | 0 | 0 | 0 | 0 | 18 | 27 | 29 |
| 17 | **L. S. Cotton** | 76 | 16 | 0 | 0 | 13 | 0 | 28 | 18 | 59 | 84 | 91 |
| 18 | **Castor** | | | 18 | 4 | 4 | 0 | 20 | 15 | 53 | 76 | 83 |
| 19 | **Tur** | | 71 | 0 | 0 | 9 | 0 | 26 | 15 | 53 | 76 | 83 |
| 20 | **Sugarcane** | 161 | 102 | 56 | 7 | 4 | 11 | 26 | 15 | 53 | 84 | 91 |
| 21 | **Fruit Crop** | 90 | 62 | 42 | 0 | 0 | 0 | 10 | 0 | 26 | 49 | 55 |
| 22 | **Banana** | 116 | 77 | 36 | 4 | 3 | 0 | 11 | 0 | 33 | 33 | 39 |

| Table 7.8 contd. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sr. No.** | **Crop Name** | **Nov. I** | **Nov. II** | **Dec. I** | **Dec. II** | **Jan. I** | **Jan. II** | **Feb. I** | **Feb. II** | **Mar. I** | **Mar. II** | **Apr. I** | **Apr. II** | **May I** | **Total mm** |
| 1. | ***L Paddy*** | | | | | | | | | | | | | | **645** |
| 2. | **Other Kharif** | | | | | | | | | | | | | | **103** |
| 3. | **Kharif Groundnut** | | | | | | | | | | | | | | **134** |
| 4. | **Hy. Jowar** | 76 | 20 | 23 | 50 | 65 | 65 | 76 | 0 | | | | | | **375** |
| 5. | **Hy. Bajara** | | | | | | | 76 | 24 | 54 | 98 | 123 | 123 | 97 | **622** |
| 6. | **Wheat** | 76 | 20 | 33 | 61 | 68 | 68 | 85 | 68 | 0 | | | | | **479** |
| 7. | **Other Vegetables** | 76 | 33 | 29 | 39 | 52 | 62 | 77 | 77 | 0 | | | | | **445** |
| 8. | **Rabi Pulses** | 76 | 20 | 33 | 62 | 68 | 68 | 85 | 0 | | | | | | **412** |
| 9. | **Mustard** | 23 | 47 | 63 | 65 | 68 | 62 | 0 | | | | | | | **410** |
| 10. | **Potato** | 23 | 23 | 40 | 62 | 68 | 68 | 82 | 33 | 0 | | | | | **472** |
| 11. | **H. W. Fodder** | | | | | | | | 76 | 26 | 36 | 102 | 129 | 71 | **440** |
| 12. | **H. W. Jowar** | | | | | | | | 76 | 26 | 36 | 102 | 129 | 71 | **440** |
| 13. | **H. W. Groundnut** | | | | | | 76 | 24 | 24 | 60 | 94 | 117 | 117 | 106 | **658** |
| 14. | **H. W. Pulses** | | | | | | | | 76 | 26 | 53 | 121 | 129 | 61 | **466** |
| 15. | **Lucerne** | 76 | 34 | 30 | 56 | 59 | 59 | 74 | 74 | 94 | 94 | 113 | 0 | | **763** |
| 16. | **Tobacco** | 25 | 25 | 20 | 0 | | | | | | | | | | **150** |
| 17. | **L. S. Cotton** | 78 | 70 | 52 | 0 | | | | | | | | | | **585** |
| 18. | **Castor** | 72 | 62 | 0 | | | | | | | | | | | **407** |
| 19. | **Tur** | 62 | 0 | | | | | | | | | | | | **395** |
| 20. | **Sugarcane** | 65 | 65 | 0 | 76 | 25 | 25 | 58 | 58 | 94 | 108 | 130 | 130 | 161 | **1605** |
| 21. | **Fruit Crop** | 48 | 48 | 42 | 42 | 47 | 47 | 58 | 58 | 69 | 69 | 82 | 82 | 90 | **1116** |
| 22. | **Banana** | 41 | 41 | 42 | 42 | 53 | 53 | 77 | 77 | 108 | 108 | 129 | 129 | 116 | **1368** |

**Table 7.9: Fortnightly Net Irrigation Requirement In Region – IV**

| Sr. No. | Crop Name | May II | June I | June II | July I | July II | Aug. I | Aug. II | Sept. I | Sept. II | Oct. I | Oct. II |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *L Paddy* | 14 | 161 | 113 | 58 | 46 | 70 | 70 | 88 | 78 | 0 | |
| 2 | Other Kharif | | | 32 | 0 | 9 | 18 | 22 | 41 | 38 | 0 | |
| 3 | Kharif Groundnut | 76 | 20 | 0 | 0 | 18 | 18 | 37 | 0 | | | |
| 4 | Hy. Jowar | | | | | | | | | | | |
| 5 | Hy. Bajara | 27 | | | | | | | | | | |
| 6 | Wheat | | | | | | | | | | | |
| 7 | Other Vegetables | | | | | | | | | | | |
| 8 | Rabi Pulses | | | | | | | | | | | |
| 9 | Mustard | | | | | | | | | | 75 | 21 |
| 10 | Potato | | | | | | | | | | | 76 |
| 11 | H. W. Fodder | 0 | | | | | | | | | | |
| 12 | H. W. Jowar | 0 | | | | | | | | | | |
| 13 | H. W. Groundnut | 40 | | | | | | | | | | |
| 14 | H. W. Pulses | 0 | | | | | | | | | | |
| 15 | Lucerne | | | | | | | | | | | |
| 16 | Tobacco | | | 11 | 0 | 0 | 0 | 3 | 6 | 19 | 30 | 30 |
| 17 | L. S. Cotton | 76 | 16 | 0 | 0 | 12 | 10 | 27 | 47 | 64 | 93 | 93 |
| 18 | Castor | | | 32 | 5 | 3 | 0 | 15 | 43 | 58 | 85 | 85 |
| 19 | Tur | | 73 | 0 | 0 | 8 | 14 | 25 | 43 | 58 | 85 | 85 |
| 20 | Sugarcane | 161 | 103 | 65 | 9 | 1 | 25 | 25 | 43 | 58 | 93 | 93 |
| 21 | Fruit Crop | 90 | 63 | 64 | 0 | 0 | 4 | 6 | 16 | 29 | 57 | 57 |
| 22 | Banana | 116 | 78 | 45 | 6 | 1 | 5 | 6 | 23 | 37 | 41 | 41 |

Table 7.9 Contd.

| Sr. No. | Crop Name | Nov. I | Nov. II | Dec. I | Dec. II | Jan. I | Jan. II | Feb. I | Feb. II | Mar. I | Mar. II | Apr. I | Apr. II | May I | Total mm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | ***L Paddy*** | | | | | | | | | | | | | | **698** |
| 2. | **Other Kharif** | | | | | | | | | | | | | | **160** |
| 3. | **Kharif Groundnut** | | | | | | | | | | | | | | **171** |
| 4. | **Hy. Jowar** | 76 | 20 | 23 | 50 | 65 | 65 | 76 | 0 | | | | | | **375** |
| 5. | **Hy. Bajara** | | | | | | | 76 | 24 | 54 | 98 | 123 | 123 | 97 | **622** |
| 6. | **Wheat** | 76 | 20 | 33 | 61 | 68 | 68 | 85 | 68 | 0 | | | | | **479** |
| 7. | **Other Vegetables** | 76 | 33 | 28 | 39 | 52 | 62 | 77 | 77 | 0 | | | | | **444** |
| 8. | **Rabi Pulses** | 76 | 20 | 33 | 62 | 68 | 68 | 85 | 0 | | | | | | **412** |
| 9. | **Mustard** | 22 | 47 | 62 | 65 | 68 | 62 | 0 | | | | | | | **422** |
| 10. | **Potato** | 23 | 23 | 40 | 62 | 68 | 68 | 82 | 33 | 0 | | | | | **475** |
| 11. | **H. W. Fodder** | | | | | | | | 76 | 26 | 36 | 102 | 129 | 71 | **440** |
| 12. | **H. W. Jowar** | | | | | | | | 76 | 26 | 36 | 102 | 129 | 71 | **440** |
| 13. | **H. W. Groundnut** | | | | | | 76 | 24 | 24 | 60 | 94 | 117 | 117 | 106 | **658** |
| 14. | **H. W. Pulses** | | | | | | | | 76 | 26 | 53 | 121 | 129 | 61 | **466** |
| 15. | **Lucerne** | 76 | 34 | 27 | 56 | 59 | 59 | 74 | 74 | 94 | 94 | 111 | 0 | | **758** |
| 16. | **Tobacco** | 25 | 25 | 20 | 0 | | | | | | | | | | **169** |
| 17. | **L. S. Cotton** | 78 | 70 | 52 | 0 | | | | | | | | | | **638** |
| 18. | **Castor** | 72 | 62 | 0 | | | | | | | | | | | **460** |
| 19. | **Tur** | 63 | 0 | | | | | | | | | | | | **454** |
| 20. | **Sugarcane** | 65 | 65 | 0 | 76 | 25 | 25 | 58 | 58 | 94 | 108 | 129 | 129 | 161 | **1669** |
| 21. | **Fruit Crop** | 48 | 48 | 42 | 42 | 47 | 47 | 58 | 58 | 69 | 69 | 82 | 82 | 90 | **1168** |
| 22. | **Banana** | 41 | 41 | 42 | 42 | 53 | 53 | 77 | 77 | 108 | 108 | 129 | 129 | 116 | **1415** |

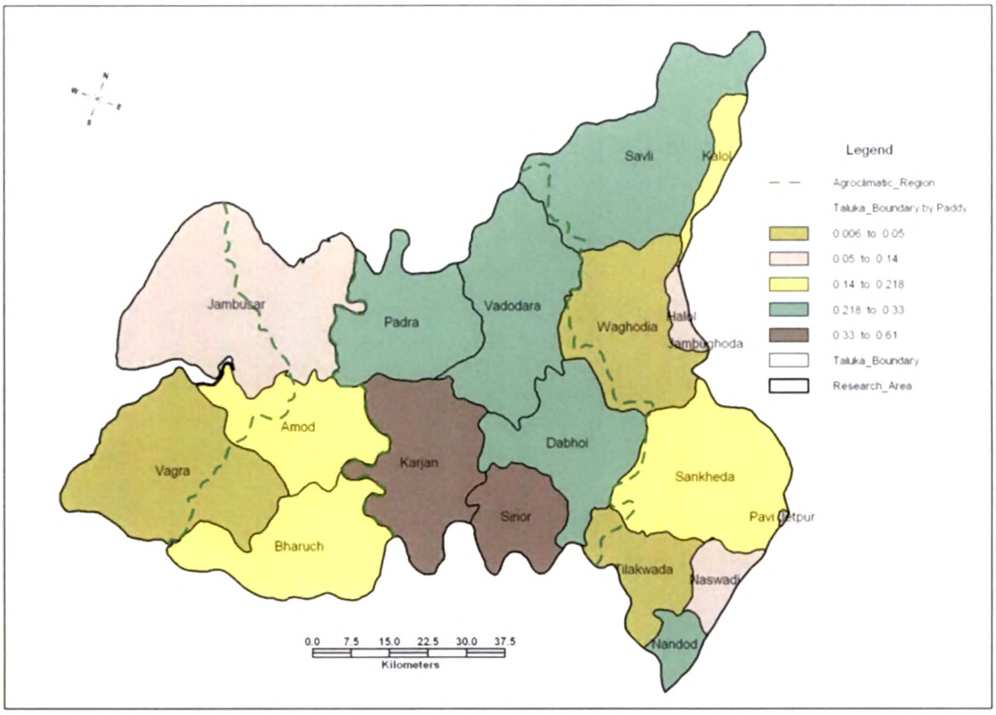
## Table: 7.10: Irrigation Potential in SSP Command Area Phase – I

| Sr. NO. | Region | Taluka | District | NO OF HABITED VILLAGES | TOTAL AREA | CULTIVABLE sAREA | % OF CULTIVABLE AREA TO TOTAL AREA | IRRIGATED AREA | % OF IRRIGATED AREA TO TOTAL CULTIVABLE AREA | IRRIGATED POTENTIAL CREATED BY SSP (CCA) ha | % INCREASE OF IRRIGATED AREA BY SSP TO TOTAL CULTIVABLE AREA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | | | | | Ha | Ha | % | Ha | % | Ha | % |
| 1 | I | NANDOD | NARMADA | 32 | 8427 | 7489 | 88.86 | 933 | 12.45 | 5437 | 72.59 |
| 2 | | TILAKWADA | | 97 | 24441 | 19024 | 77.84 | 6848 | 3.60 | 13436 | 70.63 |
| 3 | | NASVADI | VADODARA | 217 | 53334 | 30554 | 57.29 | 1350 | 4.42 | 6732 | 22.03 |
| 4 | | SANKHEDA | | 181 | 68987 | 53896 | 78.13 | 9884 | 18.34 | 31795 | 58.99 |
| 5 | | PAVI JETPUR | | 2 | 529 | 369 | 69.75 | - | - | 189 | 51.21 |
| 6 | | WAGHODIA | | 94 | 54877 | 42161 | 76.83 | 3499 | 8.30 | 30555 | 72.47 |
| 7 | | SAVLI | | 137 | 79200 | 62511 | 78.93 | 14752 | 23.60 | 37648 | 60.22 |
| 8 | | JAMBUGHODA* | PANCHMAHAL | 1 | 292 | 210 | 71.91 | - | - | 24 | 11.42 |
| 9 | | HALOL* | | 5 | 2557 | 2234 | 87.36 | 194 | 8.68 | 565 | 25.29 |
| 10 | | KALOL* | | 10 | 5852 | 4836 | 82.63 | 788 | 13.46 | 3180 | 65.75 |
| | | **TOTAL** | | **776** | **298496** | **223284** | **74.80** | **38248** | **17.12 38248** | **129561** | **17.12 58.02** |
| 11 | II | VADODARA | VADODARA | 94 | 69343 | 40850 | 82.10 | 13885 | 33.99 | 25397 | 62.17 |
| 12 | | DABHOI | | 118 | 63218 | 50962 | 83.77 | 15013 | 29.46 | 31798 | 62.40 |
| 13 | | SINOR | | 40 | 29351 | 23182 | 83.90 | 14641 | 63.16 | 14895 | 64.25 |
| 14 | | KARJAN | | 93 | 60187 | 50755 | 86.59 | 14282 | 28.14 | 44287 | 87.26 |
| 15 | | PADRA | | 82 | 53520 | 41375 | 79.28 | 13678 | 33.06 | 32916 | 79.56 |
| | | **TOTAL** | | **427** | **275619** | **207124** | **83.17** | **71499** | **34.51** | **149293** | **72.07** |
| 16 | III | BHARUCH | BHARUCH | 93 | 60853 | 40850 | 83.52 | 10903 | 83.52 | 49689 | 21.44 |
| 17 | | VAGRA | | 50 | 65636 | 50962 | 61.34 | 1155 | 61.34 | 30230 | 2.86 |
| 18 | | JAMBUSAR | | 32 | 27858 | 23182 | 76.68 | 5721 | 76.68 | 14924 | 26.77 |
| 19 | | AMOD | | 41 | 54479 | 50755 | 60.53 | 0 | 60.53 | 26599 | 0 |
| TOTAL | | | | **216** | **208826** | **145441** | **69.64** | **17779** | **12.22** | **121442** | **83.49** |
| 20 | *IV* | VAGRA | BHARUCH | 31 | 40228 | 24680 | 61.35 | 708 | 61.35 | 18529 | 2.86 |
| 21 | | JAMBUSAR | | 20 | 17074 | 13094 | 76.68 | 3507 | 76.68 | 9147 | 26.78 |
| 22 | | AMOD | | 26 | 33391 | 20215 | 60.54 | 0 | 60.54 | 16302 | 0 |
| | | **TOTAL** | | **77** | **90693** | **57989** | **63.93** | **4215** | **7.26** | **43978** | **75.83** |
| | | **TOTAL** | | **1496** | **847051** | **633838** | **74.82** | **131651** | **20.77** | **444274** | **70.09** |

**129561**

Source: Chief Engineer Canal – I, SSNNL

## Irrigation Intensity In The Study Area - 1980-81




## Irrigation Intensity In The Study Area - 2000-01

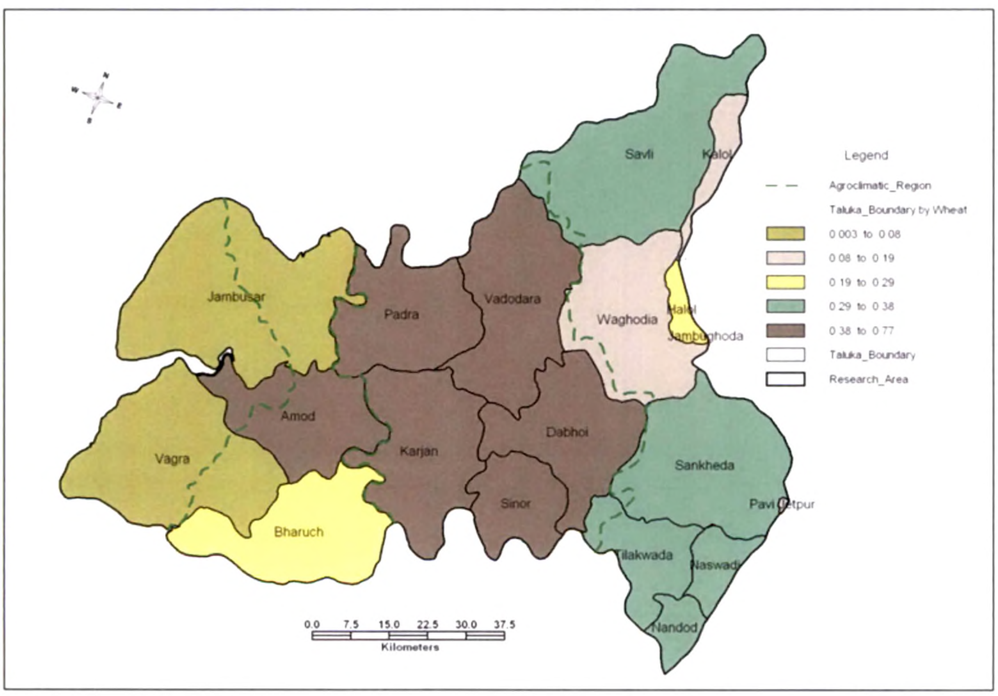



Figure 7.1

## References


Boulard T. and Baille A. (1993). A simple greenhouse climate control model incorporating the effects of aeration and evaporation cooling. Agriculture and Meteorology , Vol-65: 145-57.

Brouwer, G. and Herbloem M. (1986). Irrigation water needs. Irrigation water management Training Manual No. 3 FAO Rome Italy, 58pp.

Doorenbos J. and Kassam A.H. (1979). Yield response to water FAO irrigation and Drainage paper No. 33:1-193. FAO, Rome Italy.

Doorenbos, J and and Pruitt, W 1977 – Guidelines for predicting crop water requirements. FAO Irrigation and Drainage Paper No.24: 1 – 144. FAO Rome Italy.

Penman H.L. (1948),. Natural evaporation from open water, bare soil and grass. Proc. R. Soc. Land. Ser. A, 193:120-145.

Randhawa, M. S. (1992) A history of agriculture in India Volume – 1, 2, 3, - (Indian Council of Agriculture Research, New Delhi, India)

Rao, A.S. Singh, R.S. (2003). Evapotranspiration, water use efficiency and thermal time requirements of green gram. Indian J. of Agricultural Sciences 73(1) 18-22.

Sen S. (1996) “Need for irrigation and its spatial pattern in East and West Singhbum District Bihar” India Journal of Landscape and ecological studies, Vol 19, No 2 pp 80-94)

MAIN CANAL

CANAL NETWORK

WATER PIRACY