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No. : INCOH/SAR-20/2000

WATER MANAGEMENT IN COMMAND AREAS

B.M. SAHNI

INDIAN NATIONAL COMMITTEE ON HYDROLOGY
(Committee Constituted by Ministry of Water Resources, Govt. of India)

INCOH SECRETARIAT
NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247 667, INDIA

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B.M. SAHNI
Professor and Head, Irrigation Engineering
Water and Land Management Institute
Aurangabad

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Dr. K.K.S. Bhatia
Member Secretary, INCOH &
Scientist F
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PREAMBLE

Water is the most essential natural resource for life next to air and is likely to become a critical scarce resource in many regions of the world. The availability of water resources in India shows a great deal of spatial and temporal variability. The growth process, the increase in population and the expansion of economic activities inevitably, lead to increasing demands for water for diverse purpose. Hence overall national planning and resource management in respect of water with emphasis on allocation of priorities among the diverse use is necessary.

Consumptive uses of water are (a) rural and municipal water supply, (b) industrial water supply and (c) irrigated agriculture. However, the principal consumptive use of water is for irrigation. The Planning Commission recognised the crucial importance of developing irrigation to increase agricultural production and accordingly, assigned a very high priority to it in the plans. Giant schemes like the Bhakra Nangal, Hirakud, Damodar Valley, Nagajunasagar, Rajasthan Canal project etc. were taken up to increase the irrigation potential and thereby contribute to maximising the agricultural production.

The population in the country is steadily growing and is expected to approach 160 crores by 2050. The per capital food availability is at present low and needs to be increased. This rate of growth in food grain production can be achieved through extension of irrigated areas and by increasing the grain yield per unit area assuming that there may not be any significant increase in net sown area. It has been established that productivity of irrigated areas is atleast double, if not more than, that of unirrigated areas in respect of wheat and rice crops. This calls for better water management in the projects to bring more area under irrigation, reduce the cost/ha and thereby increase production.

The Indian National Committee on Hydrology is the apex body on hydrology constituted by the Government of India with the responsibility of coordinating the various activities concerning hydrology in the country. The Committee is also effectively participating in the activities of UNESCO and is the National Committee for International Hydrology Programme (IHP) of UNESCO. In pursuance of its objective of preparing and periodically updating the state-of-art in hydrology in the world in general and India in particular, the committee invites experts in the country to prepare these reports on important area of hydrology. Realising the importance of irrigation water management, the committee considered its appropriate to get prepared a state of art in this important area.

This state-of-art report analyses and reviews the present practices of water management being followed in projects of the country. The report also attempts to cover various technical, social, economic and organisational aspects related to the command area management and suggests possible action for improving the water management.

The Indian National Committee on Hydrology with the assistance of its erstwhile Panel on Surface Water has identified this important topic for preparation of this state-of- art report and the report has been prepared by Dr. B.M. Sahni of Water and Land Management Institute, Aurangabad. The guidance, assistance and review etc. provided by the panel are worth mentioning.

It is hoped that this state-of-art report would serve as a useful reference material to practising engineers, researchers, field engineers, planners and implementation authorities, who are involved in correct estimation and optimal utilisation of the water resources of the country.

(S.M. SETH)
Executive Member, INCOH
& Director, NIH
Roorkee

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INTRODUCTION

About sixty percent of India's food production depends on irrigation. Since independence, large investments to the extent of almost 10% of the country's total public investment have been made on the development of water resources for irrigation through execution of major and medium irrigation schemes. The total area under irrigated agriculture in India at present is about 87 million hectares (CADNEWS, 1997) - more than anywhere else in the world. Per hectare investment in irrigation projects has increased from Rs.1500 during the first five year plan (1951-56) to about Rs.40,000 during the seventh plan (1985-90) according to Navalawala (1992) and is estimated to reach Rupees one lakh during the ninth plan (1997-2002). For example, an expenditure of around Rs.10,000 crore is expected to be incurred in the on-going Krishna Valley Projects which will bring 1.13 million hectares under irrigation in Maharashtra (LT, 19 July 1998). Hence it is necessary to have better water management in the projects to bring more area under irrigation, reduce the cost/ha and increase production.

Until recently, the major thrust in the Water Resources Sector has been on constructing new irrigation projects and not enough attention paid to the utilisation of the potential created at huge costs. The gap between the irrigation capability created and its utilisation has shown an ever increasing general trend (See Fig.1). At the end of Eighth FYP (1992-97), about 10 million hectare irrigation potential remained un-utilised. One can argue that often the estimate of both the potential created and that utilised are not realistic and hence the gap is probably not as bad as generally made out to be. The estimates given by the irrigation and agriculture departments are also seen to differ widely. Mohan (1990) has discussed several factors which should be taken into account to arrive at realistic estimates of irrigation potential created and utilised. Nevertheless, there is no denying of the fact that for most projects the irrigation utilisation is far below their potential.

With the introduction of HYVs of various crops, and improved fertilisers and other inputs the objectives of irrigation projects are also undergoing evolution from protection to production to intensification in order to draw the maximum benefit from other inputs. On the other hand, with increasing demand of water for domestic, industrial and other uses, progressively less water will be available for irrigation. This call for water conservation and more efficient and economic use of available water in the command areas.

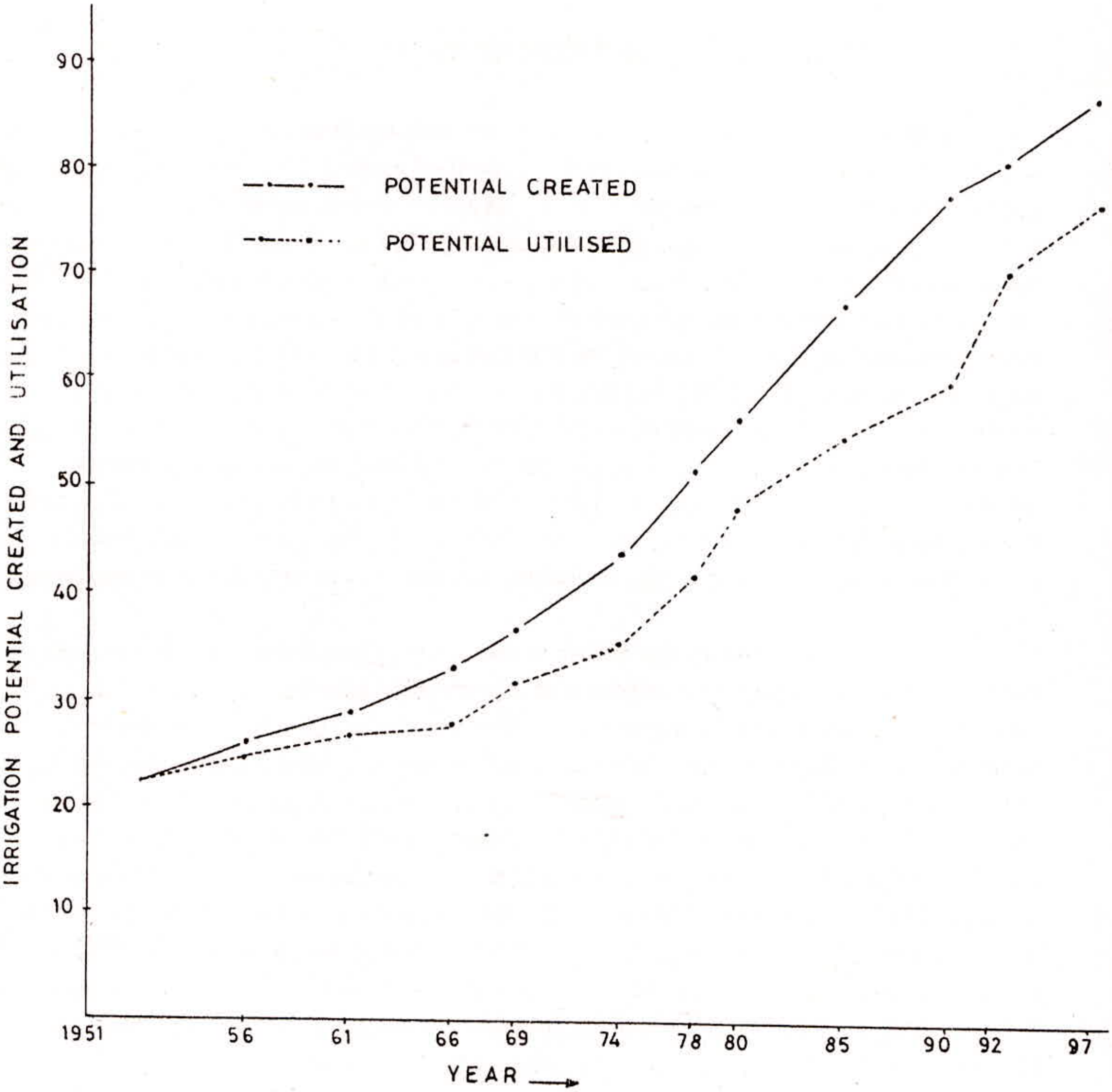


FIG. 1 : DEVELOPMENT OF IRRIGATION POTENTIAL AND ITS UTILISATION IN MAJOR MEDIUM AND STATE SECTOR MINOR IRRIGATION PROJECTS IN INDIA.

(This graph is prepared based on data drawn from Navalwala, 1992 and CADNEWS, 1997).

A third important issue, which has drawn the attention of water managers, is the fact that most irrigation projects in the country are performing at very low level of efficiency. Several factors related to the main system operation and maintenance as well as those concerned with the on farm water application contribute to the overall low efficiency of an irrigation project. Besides low on farm irrigation water use efficiency, low cropping intensity and crop yields which are hardly one forth to one fifth of the potential obtainable through scientific management of water and other inputs a conspicuous non-uniformity of the water availability between head reaches and tail end of the distribution network is also an important manifestation of the lack of proper management of available water resources. It is encouraging that there is now a growing awareness about and appreciation for concepts such as the soil water-plant relationships, the farmers' role in water management and the socio-economic aspects of irrigation management which when put to practice can result in a significant improvement in the water use efficiency.

This state-of-the-art report reviews the present water management practices in irrigation project commands, addresses the various emerging issues related to complex inter relationship of various technical, social, economic and organisational aspects and possible future strategies for improved water management for sustained irrigated agricultural development.

CROP WATER REQUIREMENT AND IRRIGATION SCHEDULING

Irrigation water management basically depends on two questions namely, 'how much to irrigate' and 'when to irrigate'. Answers to these questions are dependent on soil moisture contents, evapotranspiration, the relationship between soil-moisture content and the relationship between crop yield and soil-moisture stress. Evapotranspiration or the consumptive use of a crop itself is a function of nature of the crop, its growth stage and meteorological factors. Thus irrigation scheduling is a complex function of soil, crop and climatic conditions.

ESTIMATION OF DEPTH OF APPLICATION

Traditionally, the amount of water to be delivered to the field has been decided on the 'duty' concept. Ad hoc charts or tables prepared based on past experience have been used. A serious limitation of these methods is that they are location specific and therefore have limited applicability. In Maharashtra and many other southern states the AI/DC (Area irrigated per day cusec) method has been used. In a mixed cropping pattern, ad hoc conversion factors are used to express the duty for seasonal crops in terms of equivalent area of sugarcane (OFD Manual, GOM). The irrigation depth to be applied season wise or rotation wise is then calculated using the base period.

It is well established that the actual water required by a crop for its normal growth varies with its growth stage. The traditional methods do not take this into account and therefore, the crop in question may either be over irrigated or under irrigated during individual irrigation period. The modern scientific irrigation practice is based on the estimation of actual crop water requirement.

Management Allowed Deficit Approach

The total available water (TAW) for the plant in the soil, at any given point of time, is the difference between the field capacity (FC) of the soil and the permanent wilting point (PWP). It various with the soil type from a minimum of 60 mm/m of soil depth for sand to a maximum of 240 mm/m for silty clay loam. Out of this TAW, the plant draws water at different rates, being maximum when the soil is at the field capacity and goes on decreasing till PWP is reached. Just before PWP, the plant is able to draw water which is just sufficient to survive, but not enough for its growth. For healthy plant growth, it is, therefore, not advisable to let water in soil deplete below certain limit depending on the crop. Upto this soil moisture deficit, the plant can draw water sufficient not only for its survival but also for its normal growth. At this stage the management must apply water and hence it is called management allowed deficit (MAD).

With MAD approach, the irrigation requirement will be equal to (FC-MAD) and the irrigation interval must be equal to the time which the soil moisture content takes to decrease from field capacity to MAD level

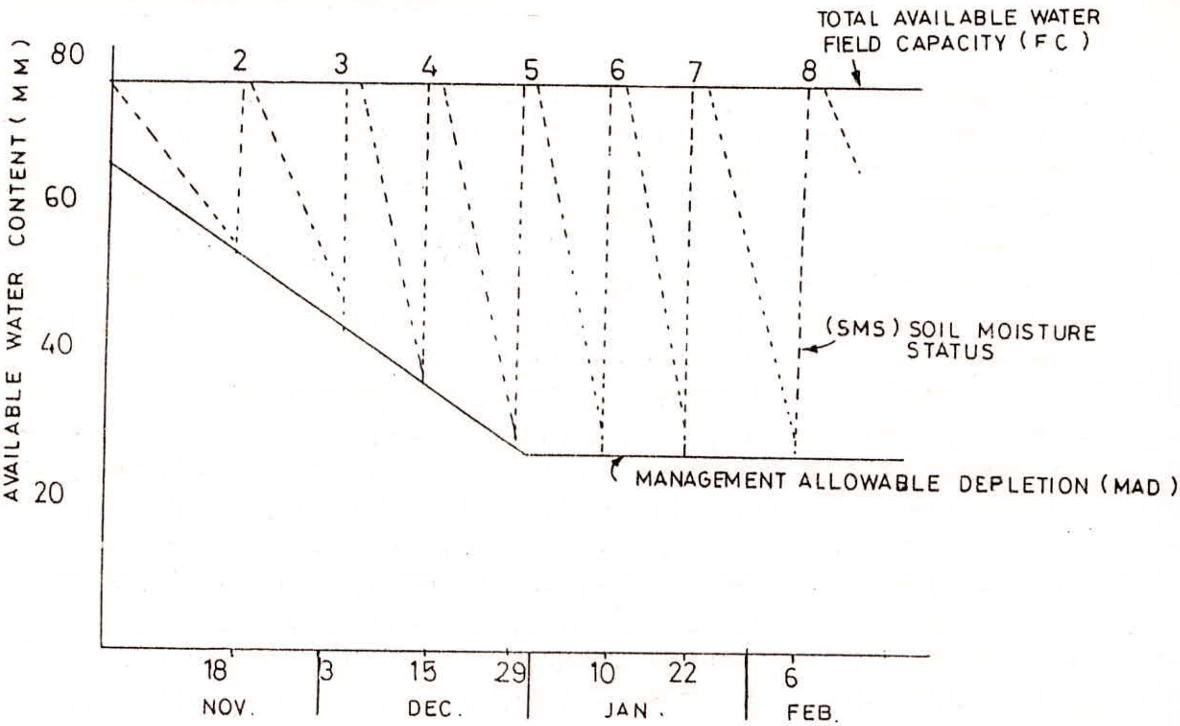
The MAD approach of irrigation scheduling can be used when water supply is adequate. A typical irrigation schedule for wheat worked out on MAD approach for the moderately coarse textured soils of Loni Minor Irrigation Scheme in Maharashtra is shown in Fig.2 (Kulkarni and Sahni, 1997). Thus, in order to satisfy full water requirement of wheat crop, i.e. 481 mm, in all 8 irrigations are required to be applied inclusive of pre-sowing irrigation. In MAD approach variable depths and variable intervals are required to be followed. During the three year detailed field studies of Loni MIS (1991-92 to 1993-94) when the overall management of the scheme was handed over to WALMI (Water and Land Management Institute), Aurangabad, following constraints in adoption of MAD approach were observed (Kulkarni & Sahni, 1997):

- mixed and dynamic cropping pattern with varying dates
- variable soil types and depths spread over the command area
- rotational water supply system
- lack of adequate and stable water discharge at the outlet and turnout level, and
- inadequate water storage in the reservoir

The MAD approach of irrigation scheduling can be adopted when water supply is adequate and available 'on demand' basis. Further, if the MAD approach is to be introduced in the canal commands, it may require curtailing of the existing irrigable command area (ICA). Thus, owing to various constraints, it is generally not possible to adopt MAD approach of irrigation scheduling in the canal commands in India.

Use of Soil Tensiometers

The soil moisture content against time can be monitored in the field with the help of tensiometers installed in the root zone by calibrating moisture tensions. When the tension reaches the predetermined value corresponding to MAD, irrigation is to be applied and the difference in the initial and final reading will indicate the depth of water to be applied. This is a precise method but labourious and time consuming.



ROTATION NO.	DATE	DEPTH MM
1	18 NOV.	23
2	3 DEC.	33
3	15 DEC.	40
4	14 DEC.	50
5	10 JAN.	50
6	22 JAN.	50
7	6 FEB.	50

DATE OF SOWING
1st. November.

FIG. 2 : IRRIGATION SCHEDULING FOR WHEAT BASED ON MAD CONCEPT FOR LONI M.I. SCHEME, MAHARASHTRA.

Use of Lysimeters

Another field method for direct and accurate determination of evapotranspiration of a given crop (ETc) is to measure the same directly with the help of lysimeter. Out of the several types available, the weighing type lysimeters are preferred as they are more accurate and reliable. However, because of the high cost and complexity in construction and installation, their use is limited to research work and to correlate / check the results obtained by other methods.

Estimation of Evapotranspiration & Irrigation Scheduling Using Climatological Data

As explained above, the actual measurement of evapotranspiration on field by lysimeter or by tensiometers is generally not practical. Also, in irrigation planning in the command areas, it is necessary to estimate in advance the total water requirement of the crops to be grown - both season wise and for the whole irrigation calendar year - for water budgeting.

Several empirical methods are available for estimation of crop water requirement which have been developed by correlating various climatological parameters (solar radiation received, temperature, wind velocity, relative humidity, sunshine hours) with actual evapotranspiration measured by lysimeters. Each method has its advantages and limitations. For detailed description of various methods, the reader is referred to FAO Publication No:24 (Dooanbos' and Pruitt, 1977). Out of these the most widely accepted and used now is the modified Penman Equation:

$$ET_o = C\,[\,(W.R_n) + (1-W)\,f(u)\,(e_a - e_d)\,] \qquad (1)$$

where,

ET_o = reference crop evapotranspiration

C = adjustment factor for day and night wind velocities and Different humidity levels

W = weighing factor for altitude and temperature Effect on radiation

Rn = net radiation in equivalent evaporation in mm/day

$f_{(u)}$ = wind function or the effect of wind on ETo, expressed in terms of Equivalent evaporation in mm/day

E_a = saturation vapour pressure in mb
E_d = actual vapour pressure in mb

The basic data required for computing ET_o by Modified Penman Method pertaining to the period under consideration are as follows:

- latitude and longitude of the site,
- mean maximum and minimum temperature,
- maximum and minimum relative humidity,
- day time wind velocity,
- day to night time wind ratio,
- mean actual sunshine hours,

Tables are available for calculating the radiation and aerodynamic terms in the above equation (FAO, 24).

Having determined the evapotranspiration of reference crop (ETo), that for a given crop ETc is then computed by

$$ET_c = K_c * ET_o \quad (2)$$

Where Kc is the crop co-efficient. While ET_o considers all the climatological factors, K_c for a given crop takes care of crop characteristics, stage of growth, growing season. When crop water requirement (CWR) is computed for immediate irrigation, the climate data for the previous rotation period can be used for computation. This gives the ET losses in the preceding rotation and these losses can be recouped in the soil by way of irrigation. If, however, the CWRs are required for project planning for a long range all the available data (at least for the 15 to 20 years) is analysed to get 75% dependability values for various parameters for each fortnight to obtain fortnightly values of ET_o for the entire year. Simple computer programmes are available to facilitate these computations.

For determining Kc values , the procedure laid out in FAO paper No:24 is as follows:

Step 1 The crop growth period is divided into four stages namely,

i) initial stage: when the soil cover by the crop is less than 10%

ii) crop development stage: the end of initial stage till crop cover is about 70 to 80%

iii) mid season stage: from the end of the second stage to the start of maturity

iv) late season stage: from the end of the third stage to full maturity

The periods of these stages depends not only on crop characteristics and soil but also on sowing dates. These stages are, therefore, determined by local observations.

Step 2 Average value of Kc for the initial stage is obtained from a nomogram giving its relationship to ETo and frequency of irrigation and / or significant rain. The mid season value of Kc and one at the end of the last stage are obtained from a table giving Kc values for crop growth stage and ranges of prevailing relative humidity and wind speed. Both the nomogram and this table are available in the FAO Paper cited.

Step 3 A smooth curve is then drawn from which Kc value for each fortnight can be obtained.

The above procedure is followed for all the crops in the command area to determine the fortnightly individual crop water requirement and hence the total requirement for all the crops for each fortnight.

Sometime in addition to crop consumptive use water is also required for land preparation (LP) such as for paddy and leaching (LR). On the other hand, part of the total water requirement in the soil may be met with by effective rainfall (ER), stored initial moisture content (SM), and ground water contribution (GW). Hence the net irrigation requirement (NIR) in the root zone is calculated as :

$$NIR = ET_c + LP + LR - (ER + SM + GW) \quad (3)$$

The irrigation requirement at the field head or any other off-take point in the system can be worked out by applying appropriate efficiency factor.

The irrigation schedule or the irrigation interval for specific crop at specific growth stage can be calculated by the relationship

$$I = \frac{(P * Sa) * D}{ETc} \quad (4)$$

where,

I	=	irrigation interval in days
P	=	MAD of available soil moisture in fraction
Sa	=	available soil water capacity in mm/m of soil depth,
D	=	rooting depth of the crop

Since, D and ETc of a given crop will vary over a growing season, so will be the irrigation interval. A relationship between irrigation interval in days versus period (fortnight number) is plotted for all crops in a given season. The lower most irrigation interval at which all crops in all their stages never undergo any moisture stress is selected as the ideal irrigation interval for that season. Some adjustments are sometime made in deciding allowable interval if the ideal interval works out to be too small.

DEFICIT IRRIGATION SCHEDULING AND CROP YIELD

The ETc calculated in the foregoing paras refers to a condition where available water in the soil is adequate hence can be considered as potential or maximum evapotranspiration (ETm). The actual rate of water uptake by the crop from the soil is determined by whether the available water in the soil is adequate or whether the crop will suffer from stress inducing water deficit. The actual evapotranspiration ETa = ETm when available soil water is adequate. However, ETa < ETm when available soil water is limited. ETa can be calculated by the relation

$$ETa = Ks * ETm \quad (5)$$

where Ks is the stress factor given by

$$Ks = 1 - 0.61 \, p^2, \quad 0 \leq p < 1 \quad (6)$$

and p is the proportion of the total soil water that can be depleted without causing the Eta to become less than ETm, called the soil water depletion factor. It mainly depends on the crop and magnitude of ETm (Doorenbos and Kassam, 1979). Average stress factor over the period upto which the given soil water depletion has occurred is then given by

$$Ks = 1 - 0.204 \, p^2 \quad (7)$$

Normally, it would be desirable to avoid the stress condition to get maximum crop yield per unit area. But some time the stress condition can not be avoided because of inadequate water available for irrigation or longer irrigation interval imposed by system constraints. In fact, sometimes it may even be desirable to artificially induce slight stress in order to spread the irrigation over larger area in the command. It is readily seen from eq.(7) that for practical purposes ETa = ETm upto 40% depletion in the available soil water.

YEILD RESPONSE TO STRESS

Maximum yield of a crop (Ym) is obtained when water supply is adequate and maximum rate of evapotranspiration ETm is maintained throughout its growing season, other inputs being at their recommended optimum level. When ETa drops below ETm, the yield also decreases and this decrease is proportional to the deficit in ETm. The relationship is given by

$$[\,1 - Ya/Ym\,] = Ky\,[\,1 - ETa/ETm\,] \qquad (8)$$

where,

Ya = actual yield

Ym = maximum or potential yield

Ky = yield response factor which varies with crop and growth periods

The reduction in yield can be computed for the entire period if the deficit in water is evenly spread over the growth period. However, if the deficit is different over different growth periods, the deficit in yield for each period has to be calculated and then summed up for all these contributions.

The deficit irrigation can be achieved either by reducing the depth of water application in the existing rotation on by increasing the rotation period without altering the depth of application. Since the reduction in depth of application has other limiting factors, increasing the interval (lower irrigation frequency) is more convenient. Yet another method usually practiced is to select the depletion level and then compute the rotation period and depth of application. This method has the advantage of ensuring the available water at a definite level of depletion.

To maximise the crop yield per unit area full irrigation requirement is to be applied frequently (shorter irrigation interval) to maintain available water in soil to such a level which does not allow any stress throughout the growth period. For this, generally available water is not allowed to deplete beyond 40% level. However, if the total water available for irrigation is inadequate (scarcity condition), low frequency deficit irrigation scheduling may be practiced. The available soil water may be allowed to a larger percentage level say, 75% (in vertisols) by giving irrigation at longer interval. This will induce water stress which in turn reduce evapotranspiration of the crop resulting in deficit irrigation. The field research has shown that reasonable crops yields can be achieved even when water supplies are limited (Mayee and Shelke, 1986; Rodge, 1986). Though crop yield per unit area unit area will be reduced to some extent with deficit irrigation it will have the following benefits:

- Application efficiency is increased
- There will be considerable saving of water, thereby irrigation benefits can be extended to larger area. The total production in the project command will increase and the water use efficiency (yield per unit of water) can be optimised
- Waterlogging and salinity problems in heavy soils can be prevented.

METHODS OF IRRIGATION

The overall irrigation project efficiency is dependent both on the efficiency of the conveyance system comprising of main and branch canals, distributaries, minors, subminors and field channels and on the efficient use of water reaching the farm gate. The latter depends on the water application method used to distribute the water over the entire field. The irrigation method chosen should aim at

- applying the right amount of water to meet the crop water requirement on the root zone duly accounting for the application efficiency,
- ensuring uniformity of application of water on the entire field,
- minimising the losses of run-off and / or deep percolation,
- avoiding damage to the land due to soil erosion and waterlogging and loss of nutrients due to over irrigation,
- achieving maximum water use efficiency.

Several water application methods are in practice and each has its advantages in efficiencies and costs and limitations of application. These can be broadly classified as (a) Surface or gravity methods (b) pressurised irrigation (sprinkler, drip etc.).

SURFACE IRRIGATION METHODS

In the surface (gravity) irrigation method, water is applied at almost constant rate at the upper end of the field to be irrigated. This water spreads across the width of the field and flows down to the other end by gravity in the form of a sheet. The rate of advance mainly depends on the inflow rate (the stream size) and the surface roughnes and to some extent on the slope in the direction of irrigation which is usually very gentle (less than 0.6% to zero), while cross slope is negligible (less than 0.2% to zero). The surface rougnesss keeps changing during irrigation as the clods dissolve and the vegetation bends due to flow of water. At some point after the inflow is stopped, the water sheet starts receeding starting at the upstream end of the field. The infiltration at any point depends on opportunity time that is the time elapsed between the time when the advancing water front actually reaches the point and the time when it disappears from the soil surface. To avoid or minimise excessive deep percolation due to ponding at the downstream end, it is recommended to cut off the inflow before the advance front reaches the downstream end.

The surface irrigation methods being practiced by the farmers are as follows:

Wild Flooding

Water is applied to the entire field without any control often without guide bunds and land levelling. This methods involves least labour requirement but leads to tremendous water wastage and damage to the land. This practice must be avoided.

Basin Irrigation

It is the oldest and most common method of irrigation in India and several paddy growing countries. Bunds are constructed around small parcels of land depending on the topography, soil intake characteristics and inflow rate. These parcels (basins) are levelled and water is ponded in them.

Historically, the check basin method was used for paddy cultivation, basins are also now used in various forms suitable for vegetables and orchards. On steep slopes, contour basin irrigation is practiced. In many parts of the country where this method is used for paddy cultivation, the field to field irrigation is practiced without any field channels. This practice needs to be replaced by a better controlled supply of water to individual fields. In Konkan region of Maharashtra, which has traditionally been a rice growing area, crop diversification project was undertaken but this was not possible with the traditional field to field irrigation and hence a buried pipe distribution system has been introduced in several projects with EEC assistance (Shinde, 1997).

Basin irrigation is favoured by moderate to slow intake soils and besides paddy by leafy vegetable, coriander and lucern. The irrigation and cross slopes of the basin should not exceed 0.3% and 0.2% respectively.

Border Irrigation

In this method the water is applied to the individual strips or borders between parallel ridges from an equaliser. In graded borders, the water travesses the field due to evaluation difference. Slope of $\leqslant$ 0.6 % is recommended in the direction of irrigation. No cross slope is required but for practical reasons a very slight slope not exceeding 0.2% could be given. In level borders water ponds evenly over the soil surface. Border irrigation is suited to medium and fine textured soils and to all close growing row crops such as wheat, groundnut, sorghum, maize, mung, gram, etc. In areas having slopes greater than 2 to 3 % the land is converted into a series of borders along the contours.

Furrow Irrigation

An alternative to flooding the entire field surface is to construct small channels along the primary direction of water movement. The furrows serve as channels to guide and convey the irrigation water and for disposal of excess water. Water from those channels moves both laterally and vertically to moisture the root zone. It is quite convenient to practice cut-off of stream at 80% or any other suitable level along the furrow to save water. Alternate furrow irrigation also saves considerable water. Corrugation or shallow furrows are used for irrigation of close growing crops on rolling lands. Furrow irrigation is easily adoptable for contour cultivation.

Furrows provide better on farm water management capabilities under most surface irrigation conditions. A smaller wetted area, as compared to border and basins can reduce evaporative losses on widely spaced crops. Furrows provide operational flexibility important for achieving high irrigation efficiencies. Accumulation of salts on the ridges between the furrows is one disadvantage with this method. Alternate furrow irrigation and leaching of salts by periodic flooding of land after erasing the furrows (and leaving the field fallow for a while) can minimise this problem.

Surpentine Furrows-cum-basin Irrigation

Majority of the sugarcane growing farmers in Maharashtra have been using this traditional technique of irrigation. It can be practiced on lands with steep slopes without requiring land levelling. The water is released at the highest spots for a predetermined area called a 'bara' (or block). The water then flows by gravity following the zigzag path in the surpentine furrows and the farmer is free to do other activities until the block area is irrigated. Therefore, it is convenient to irrigate sugarcane fields by this technique even during night. This is one main reason why night irrigation is very much in vogue in the sugarcane belt of Western Maharashtra.

This technique has several disadvantages. The farmers apply about 4000 mm of water when only about 2000 mm is enough under surface irrigation considering net irrigation requirement of 1400 mm and 30 % field application losses. Ponding of water persists for long time creating poor soil aeration condition, waterlogging and soil salinity in the ill drained soils and loss of nutrients due to deep percolation. The result is low field application efficiency and poor yields.

The field results have shown that by simply switching over to straight furrows oriented approximately parallel to contour, one can achieve upto 50 % saving in water and at the same time about double the yield (Table 1).

Table 1. Irrigation efficiencies and sugarcane yields observed in surpentine furrows, straight furrows and straight furrows with surge irrigation technique

Sr.No.	Location & Method Of Surface Irrigation	Plot	Total depth Of water Applied (mm)	Cane yield T/ha	Irrigation Efficiencies in (%)*		
					Ea	Er	Ed
1(a)	WALMI, Aurangabad Farm; Surpentine Furrow	B-3	4500	75	22	99	92
		C-2	3000	65	46	100	92
1(b)	WALMI, Aurangabad Farm; Straight Furrow	B-4	2100	125	82	76	78
		B-4	2000	125	93	78	83
2(a)	Farmer's field at Pimpri Raja Tq.Aurangabad; Straight Furrow	A	2200	120	70	90	84
		B	2100	120	74	90	90
2(b)	Farmer's field at Pimpri Raja Tq. Aurangabad Straight Furrow With surge irrign.	A	2000	125	97	83	91
		B	2000	125	96	84	95

* E_a = Application efficiency, E_r = Requirement efficiency; E_d = Distribution uniformity

Other Innovations in Surface Irrigation

The common practice of farmers to let the water into their fields from the head ditch or equaliser is to break the bunds of the ditch at convenient location and again close it after accomplishing the irrigation. Instead of this traditional labourious practice, it is a lot more convenient to use **syphon tubes** to let out the design discharge from the ditch accurately. The discharge let out is dependent on the pressure head and the internal diameter of the syphon tube and can be accurately determined. A simple table can be prepared for the farmer to read discharge and required duration of flow. For furrow irrigation, a suitably selected syphon tube can be used to divert the flow into each furrow. The flow can be immediately stopped on completion of irrigation by simply removing the syphon tube. For border irrigation 2 or 3 or more syhpon tubes can be used evenly spaced across the width of the border. This will ensure uniform spread of water in the border. Many farmers in Maharashtra who had seen the demonstration of the use of this simple device during the farmers training courses conducted by WALMI Aurangabad are already using them in their fields.

Another useful innovation is the use of plastic or aluminium **gated pipes** with rubber or metal slide gates for furrow and border irrigation.

Surge flow is a recent management practice that can be applied to several surface irrigation conditions. It can be used either to cut back the inflow at the completion of advance and minimise tail water and / or to accelerate the advance phase on problem soils. This techniques involves giving water to the field intermittently which significantly reduces the intake. The effect of surging is associated with the accelerated development of thin surface seal of very fine soil particles created by the water movement. During the drainage period the buildup of negative pressure consolidates this thin seal, thereby reducing permeability, and infilteration rate. With this it becomes easier to complete the advance phase and hydraulic performance of the water application systems improves. Surge flow regime reduces temporal and spatial variability in advance phase (Walker and Skogerboe, 1987).

The surge technique is not difficult to practice and has been successfully used on some progressive farmers field growing sugarcane in Maharashtra State. Further improvement in field application efficiency and distribution uniformity is achieved by this management techniques without any loss in the yield (Table 2).

PRESSURISED IRRIGATION METHOD

A pre-requisite for efficient gravity irrigation is precise land shaping and grading. Apart from economic considerations, there is often a serious restriction imposed on the degree of land levelling permissible in areas having steep of rolling topography because excessive cut would remove most of the fertile top soil. This constraint becomes even more critical in areas where, in addition, the soil cover is shallow. In such conditions even a moderate land levelling would remove the soil and expose underlying rocks or regoliths. Gravity irrigation methods, therefore, are not suited to such conditions. Under open canal conveyance and distribution system and with surface irrigation methods, less than 50 % of the water released reaches the root zone. In major gravity irrigation profects, the overall efficiency ranges from 30 to 35 %. Though higher efficiencies in gravity irrigation can be obtained in the command area under certain conditions as discussed earlier, some deep percolation losses are inevitable. Proper drainage net work is also essential to avoid waterlogging and salinity. Pressurised irrigation methods are free from these limitations. In sprinkler irrigation 60 to 75 % and in drip irrigation 80 to 90 % efficiency can be easily achieved (Sahni, 1998). It has been established that in addition to considerable saving in water, crop yields are much better with these methods as compared to gravity (surface) methods or irrigation. Also, fertilisers can be applied in solution alongwith water which is more efficient. The reasons attributed to increased yields are :

- Water is applied once in 3 to 6 days period in sprinkler irrigation (as against 7 to 15 days in surface irrigation) which in turn reduces the soil moisture stress to some extent. Further the water application being better controlled, only the needed water can be given and no runoff is allowed in the system.
- In micro irrigation, water is applied in small doses daily or frequently and hence the growth is uniform. As there is no moisture stress the crop growth is not affected at all. Only just right quantity of water is given to each plant to meet its evapotranspirational requirement. Comparison of the soil moisture availability in the above three methods is shown in Fig.3 (INCID, 1994).

Table 2 : Summary of field studies on sprinkler and flow irrigation: water saving and productivity

Sr.No	Crops & station	Delta in cm		Saving of Water (%)	Yield Q/ha		Increase in Yield (%)
		Flow Irriga-tion	Sprinkler Irriga tion		Flow Irriga-tion	Sprinkler Irriga tion	
1)	Wheat(HD-2189)						
	a)Vadgaon	64.0	44.1	31.0	21.75	23.25	7.0
	b)Phaltan	57.3	42.6	26.0	22.00	25.60	16.4
	c)Akola	91.2	48.0	47.0	20.70	21.70	5.0
2)	Rabi Jowar; -Phaltan	64.7	53.7	17.0	15.40	20.00	30.00
3)	Rabi Gram; -Phaltan	59.3	54.4	8.3	14.30	17.80	24.50
4)	HW Groundnut						
	a) Vadgaon	82.0	56.0	32.0	11.00	12.50	14.00
	b) Phaltan	86.6	54.9	36.6	12.90	18.30	42.00
5)	Kharif Gr.nut; -Akola	25.5	19.1	25.0	4.10	4.70	15.0
6)	Kharif Jowar; -Phaltan	33.8	29.5	13.0	31.50	34.50	9.5
7)	Kharif Bajara; -Phaltan	26.8	21.0	22.0	22.00	23.00	5.0
8)	Sugarcane (Co740); -Vadgaon	279.3	190.40	32.0	135*	151*	12.0

* Sugarcane yield in tonnes

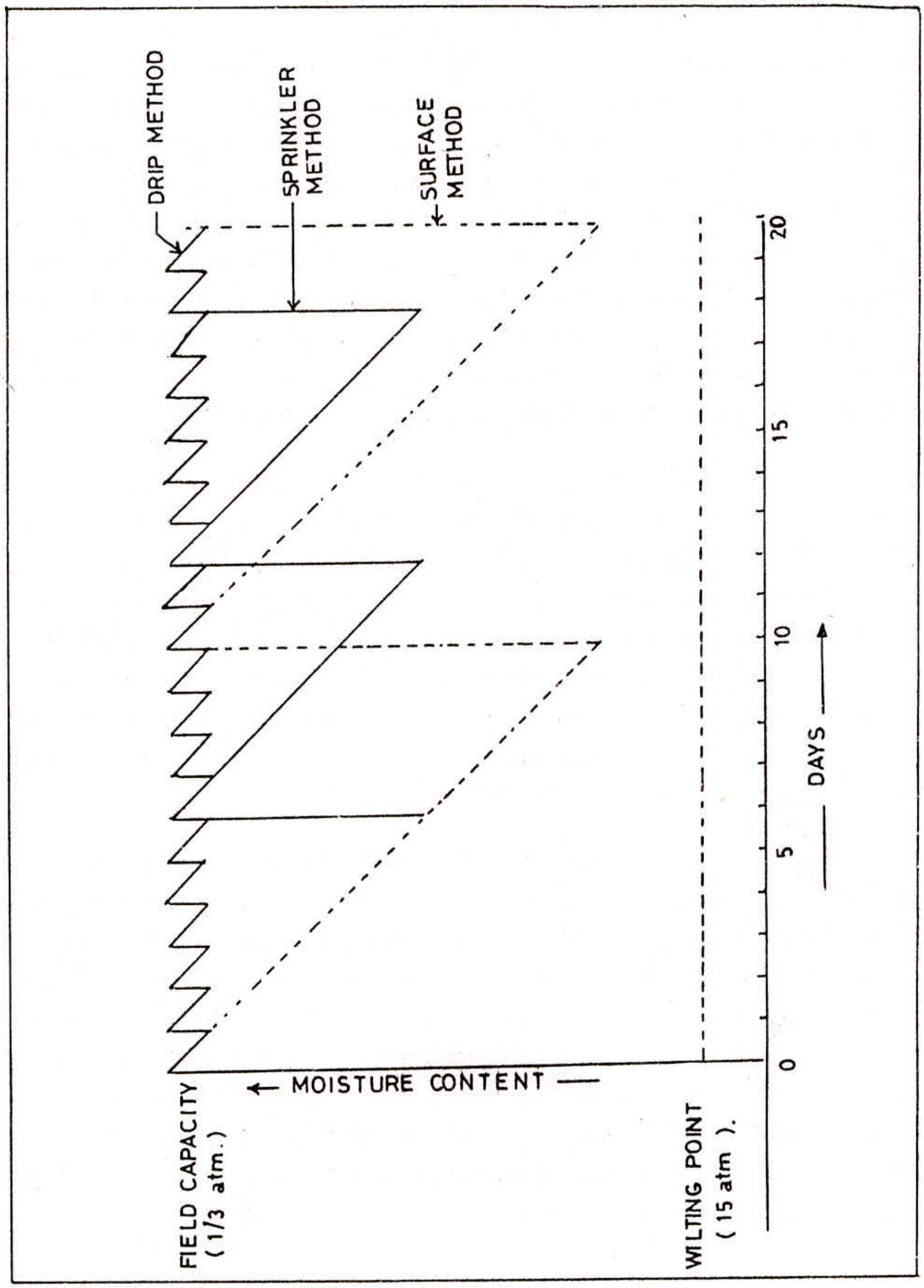


FIG. 3 : MOISTURE AVAILABILITY FOR CROPS IN DIFFERENT IRRIGATION METHODS.
(Source : INCID , 1994).

Sprinkler Irrigation

In this method, water is carried through a net work of pipes under medium or high pressure and is spread like light rain/drizzle. The system consists of pumping unit main, submain and lateral pipes, couplers, risers and sprinkler heads. With careful selection of nozzle sizes of the sprinkler heads, operating pressures, lateral spacing and sprinkler spacing on lateral, the amount of irrigation water required to refill the crop root zone can be applied nearly uniformly at rate to suit the soil intake rates, thereby obtaining efficient irrigation. Both the rotating head and perforated pipe sprinkler systems are used in India. Rain gun sprinkler systems, recently introduced in Indian market, are becoming popular with progressive farmers. Further details regarding planning, design, operation and maintenance of sprinkler system in Indian conditions can be found in Shivnappan (1987) and Sahni (1996).

The sprinkler irrigation was first introduced mainly in hills for plantation crops like tea, coffee, etc. in the Western Ghats and in the North Eastern States. Subsequently, when water scarcity and waterlogging and salinity problems in command areas started manifesting on a big scale, the government induced the farmers to adopt sprinkler irrigation wherever possible through subsides. Harayana is the leading state in the country as far as sprinkler irrigation in concerned. Presently, this method of irrigation is extensively used in canal command areas of Harayana, Madhya Pradesh, Rajasthan, etc. It is very well suited to all closely spaced crops except rice, i.e. cereals, oil seeds, pulses and other cash crops.

Studies conducted at various institutions in the country and at farmers field have proved that there is about 30 to 50 % saving in water and yield increase is about 10 to 40 % for various crops with sprinkler irrigation compared with surface irrigation. Results from various field studies conducted by Directorate of Irrigation and Research Development, Maharashtra are summarised in Table 2 (Sahni, 1988). The data collected from 22 farmers in Haryana have indicated that by introducing sprinkler method, area of irrigation has increased by 38%, crop intensity is increased from 66 to 121%, saving in human labour and above all net income of the farmers. The benefit - cost ratio for plastic sprinkler and metalic sprinkler have been worked out to 4.65 : 1 and 3.42 : 1 respectively (Shivanappan, 1998).

Micro Irrigation

Micro irrigation is well suited to all row crops and especially for wide spaced high value crops. The required quantity of water to meet the evapotranspirational requirement is provided to each plant daily at the root zone. Hence there is very little loss of water by evaporation. The area under micro irrigation has increased in India from 1000 ha in 1985 to 60,000 ha in 1993 and 1,70,000 ha in 1997 covering about 30 different crops (Shivanappan, 1998). Maharashtra is the leading state with about 60,000 ha area under micro irrigation.

The drip system essentially consists of a pump or overhead tank, a main, sub-main, laterals, dripers or emitters, filters, fertiliser tanks or venturi pumps, and other accessories. Filters (sand and screen filters) are very essentially for drip system to present clogging of drippers, to deliver the required quantity at the root zone. Biwall system is used for closely spaced crops like sugarcane, vegetables, cotton, etc. Micro sprinklers and micro sprayers are essentially a combination of sprinkler and drip irrigation. Water is sprinkler or sprayed around the root zone of the trees with a small sprinkler working under low pressure. This unit is fixed in a net work of tubing but can be shifted from place to place around the area. Water is given only to the root zone area as in the case of drip irrigation but not to the entire ground surface as done in case of sprinkler irrigation. This method is very much suited to tree / orchards crops. Details of selection, planning, design, operation and maintenance for Indian conditions can be found in literature (e.g. Shivanappan, 1980; Sahni, Mrs. 1996).

The cost of micro irrigation system depends on the type of crops grown, spacing adopted, water requirement, location of water source etc. It varies from Rs.15,000 per ha for wide spaced crops like coconut, mango, etc. to Rs.40,000 per ha for closely spaced row crops like sugarcane, vegetables and cotton.

The studies conducted by various institutions have revealed the water saving by drip irrigation compared to surface irrigation about 40 to 50 % and increase in yield upto 100% (Table 3).

Table 3 Water used and yield for various crops in micro and conventional methods

Sr. No.	Crops	Yield (Quintal/Ha)			Water Supplied (CM)		
		Conventional	Drip	Increase in Yield %	Conventional	Drip	Water saving %
1)	Banana	575.00	875.00	52	176.00	97.00	45
2)	Grapes	264.00	325.00	23	53.20	27.80	48
3)	Mosambi (in 1000 Nos.)	100.00	150.00	50	166.00	64.00	61
4)	Pomogranate (in 1000 Nos.)	55.00	109.00	98	144.00	78.50	45
5)	Sugarcane	1280.00	1700.00	33	215.00	94.00	56
6)	Tomato	320.00	480.00	50	30.00	18.40	39
7)	Cotton	23.00	29.50	27	89.53	42.00	53
8)	Brinjal	280.00	320.00	14	90.00	42.00	53
9)	Papaya	134.00	234.80	75	228.00	73.30	68
10)	Chillies	42.33	60.88	44	109.71	41.77	62
11)	Sweet Potato	42.44	58.88	39	63.14	25.20	60

Source: National Committee on the use of plastics in agriculture (NCPA) status, Potential and application for adoption of drip and sprinkler system. Pune (1990)

The B.C. ratio for drip system based on interviews with farmers in Maharashtra and Tamilnadu is found to range 1.31 to 2.60 for various crops except grapes excluding the proporation of water saving. In case of grapes, it is about 13.35. If water is also taken into account the ratio goes up from 2.78 to 11.05 for various crops and 30.0 for grapes. This explains why grape growers in Maharashtra have adopted drip irrigation in such a big way.

Steps for Further Promotion of Pressurised Irrigation in Canal Commands

At present, most of the pressurised irrigation is being practiced by farmers on wells where either canal water is not available or supply is inadequate. There is a need to promote use of sprinkler and drip methods of irrigation in conjunction with canal supplies wherever possible with a view to increase the overall efficiency of water use in the canal command areas. Where soils have high moisture retentivity such as in black cotton soils of Maharashtra, sprinkler irrigation can be used directly on canals by adjusting the number of hours of operation and the discharge in sprinkler system to suite the rotation period in the canal command. In other places, where the soils have low water holding capacity either due to medium to coarse texture or very shallow to shallow depths, it may be necessary to construct farm ponds to store canal water to enable more frequent irrigation by sprinkler method. On the other hand, the drip irrigation can not be used directly on canal water since in this method water is given in small doses very frequently. The adoption of drip irrigation with canal supply will always require construction of farm ponds. However, the additional investment on this account has been shown to be economically viable (Holsambre, Sahni and Bhalage, 1998).

Since the canal water is available to the farmer at a very cheap rate and the initial cost of the drip and sprinkler system is quite high, suitable changes in the water allocation and management practice and pricing structure of canal water and incentives such as free electric energy besides government subsidies, may have to be considered for including the farmers in the canal command areas to adopt pressurised irrigation methods. The project authorities can then save a lot of expenditure on maintenance of the micro distribution net work in addition to considerable saving of water.

By introducing pipe conveyance system clubbed with sprinkler and drip irrigation, it is possible to extend the existing irrigation facilities to a much larger area with the same quantity of water. Maharashtra government has decided to give sanction for many lift irrigation schemes only if the water is conveyed through pipes and used by drip and sprinkler methods. The Gujarat government is planning to bring large areas under irrigation by introducing micro irrigation methods in Sardar Sarovar Project (INCID, 1994).

Under the present water allocation policy of Irrigation Department in Maharashtra 5.65 % of net volume of water available at canal head is sanctioned for lift from reservoir provided drip irrigation is used as the method of water application. This is a positive step as an indirect way of promoting pressurised irrigation in irrigation projects (Kulkarni and Sahni, 1998).

WATER DISTRIBUTION IN COMMAND AREAS

Water distribution that is, conveyance of water from the source to the field head, is the most important link between the supplier (Irrigation Department) and the farmers. In India, generally rotational methods of distribution of water are followed using supplier controlled schedules (frequency) with either constant or variable amount of water application. The rotation may be between (i) sections of main / branch canal (ii) distributaries and minors, (iii) outlets, (iv) individual farmers or groups of farmers. Different types of rotation methods of water distribution followed in the country are discussed here.

WARABANDI

This system is widely practiced in northern states of Punjab, Harayana, Rajasthan, Uttar Pradesh, Bihar, etc. for more than a century. Warabandi means fixation ('bandi') of turns ('wari'). Most of the irrigation schemes in these states are of run-of-the river type. In this system, the water is allocated to cultivators in proportion to their land holding with no restriction on the crop(s) grown. The main canal feeds two or more branches which operate by rotation and may or may not be able to run full. This constitutes the primary distribution system and runs continuously throughout the irrigation season. Branch canals supply water to a number of distributaries - the secondary distribution system - which must run at full supply level by rotation. Distributaries feed water courses called gults - the tirtiary system - through ungated, fixed discharge outlets which are generally semimodular type (Malhotra, 1982). Water courses run at full supply level when the distributary is running and the water is allocated between the farmers on a water course by a time roster.

Water Allocation

In Warabandi System, the infrastructure is sized so that the capacity of successive channels is proportional to the area served. Each unit of culturable command is allocated a certain rate of flow termed as **water allowance** which is the basis of designing the carrying capacity of distributaries and water courses. The outlets to water courses are so constructed that all of them on a distributary draw their authorised share concurrently. The value of the water allowance at water course head is 2.4 cusecs per 1000 acres of culturable command area (CCA).

Management

The distribution of water in warabandi is a two tier operation. Upto outlet it is managed by Government Agency. The distributaries are always run full in 8-day periods. The distribution of water coming out of an outlet ('mogha') is managed by cultivators. The distribution water is done on a 7-days rotation basis with the help of an approved roster which divides 168 hours (i.e. 7 days) in proportion to size of the holdings. The outlets have no gates and it is illegal to keep any of them closed when the parent distributary is in operation. The distributary runs for 8-days so that all water courses can get water atleast for 7 full days (Malhotra , 1982).

Along the water course the water distribution proceeds from head to tail. Each cultivator is entitled to receive the entire water in a water course only on a specific day of the week at a specified time. There is no provision in this system to compensate any individual farmer, who fails to receive his share of water for any reason, including those for which he is not responsible such as fault in operation or breaches in canal etc. Also this system does not compensate for the losses in the water course.

No distributary operates for the entire period of the crop(s). The ratio of the operating period of a distributary to the total crop period called its **Capacity factor** is a compramise between demand and supply.

Roster of Turns

When the water is delivered in the water course, it takes some time to each delivery point called nakka. This time of filling is called Bharai. The total time of filling is debited to the common pool time of 168 hours and credited to the individual account of each farmer. At the end of the rotation, the whole length of the water course which has been filled with common pool time, is utilised by the last farmer. Hence, part of total bharai time considering sudden reduction of supply is debited to the account of the last (tail-end) farmer. This is called the Jharai time which is credited to the common pool. Thus,

Net running time in hours per unit of CCA

$$= \frac{168 - \text{Total Bharai} + \text{Total Jharai}}{\text{Total area}}$$

And, the total time for each farmer (hours)

= Net time unit area * his area + his Bharai - his Jharai,

where Jharai is zero for all farmers except for the last.

Although, each cultivator's right to share water is guaranteed under section 68 of the North India Canal and Drainage Act of 1873 and canal officer can enforce this right if he receives a complaint, farmers themselves keep vigilance acting in their own interest. This is one of the major strengths of the system. A second major strength is the equity. In the event that river flows fall below the combined capacity of the system, a schedule is adopted which rotates priorities between groups of branch canals and distributaries, the number of groups being determined by the variability of supply (Berkoff, 1987).

Impressed by some of the achievements and success of warabandi in Punjab and Harayana, initiatives have recently been made under World Bank supported RWS projects (under NWMP) to transfer its organisational and technical design principles into irrigation schemes elsewhere in the country. One of the most frequently mentioned projects of this kind is the Sreeram Sagar or Pochampad Project in Andhra Pradesh (Singh, 1983; Berkoff, 1987, Huppert, 1987).

SHEJPALI

This method of distribution of water is practiced in Maharashtra, Gujarat and Karnataka. Most of the irrigation preojects in these states are storage scheme with direct canals from the storage or from the pick-up weir on the river below the storage. Distribution of water essentially follows rotation-cum-demand approach. The word 'demand' is used in restricted sense as follows (SUryawanshi, 1982). Farmer in the command area has to apply for the area and crops to be irrigated in each season except for perennial crops for which long term sanction (6 to 12 years basis) is given. Demand given by the farmer is sanctioned as per the crop pattern of the project and availability of water. Water is supplied in each rotation according to crop requirement.

Management

At the end of the kharif season the water available in the reservoir is known. Based on this, crops to be grown with extent of areas for each crop are decided before the start of rabi season (15th October). Preliminary Irrigation Programme (PIP) is prepared in the office of the Executive Engineer Incharge of the Project for proper utilisation of the stored water considering the duties of the various crops, river gains, evaporation and seepage losses in reservoir, losses in conveyance system and commitments for non-irrigation purposes. This is essentially water budgeting.

Public notices are then issued inviting application for water from farmers for seasonwise sanctions. If the area demanded for irrigation is more, suitable cut is applied, guaranting minimum area of upto 2 acres to small farmers. The cultivators are informed in advance about the area sanctioned by issuing passes to them.

Rotation programme i.e., days 'off' and 'on' is prepared and published. Water is supplied to the crops at predecided rotation period of 14 to 21 days.

Having fixed the rotation periods and the area to be permitted during the season, the quantity required to be released from the storage in each rotation is calculated on the basis of observed AI/DC or ETc and losses. Generally in Rabi season, AI/DC of 4 is taken at distributory head and 6 at outlet head.

After scrutinising and sanctioning the indent by Executive Engineer, the water is released and supplied from tail to head reach of the canal. On each outlet, the canal inspector prepares a list of sanction holders, their sanctioned area of calculates the total quantity of water in terms of day cusecs and the total time for which a particular outlet is required to run. A time table known as Pali-patrak giving the date and time for which water will be supplied to each sanction holder in his beat is prepared by canal inspector for each outlet and is communicated to irrigators by calling a meeting.

Supply is rotated tail to head among farmers on each outlet, among different distributaries and in different sections of canal.

At the end of each rotation AI/DC statement are prepared and after completion of each season completed Irrigation Report (CIR) is prepared which includes abstract of water utilised for irrigation and non-irrigation uses, rotationwise discharge utilised by each sub-division, cropwise area irrigated in each rotation, duty of water utilised on canal and distributary, conveyance losses, and graph showing planned and actual drawal from the storage. This CIR is compared with PIP to evaluate the performance of the system and management staff (WALMI, 1987).

Outlets and Water Supply in Field Channels

All outlets in irrigation commands in Maharashtra are non-modular type and of standard size generally 30 to 40 cm diameter fixed at the bed level of the parent channel and are provided with lift type gates to control the water supply. A constant discharge of 30 lps (about 1 cusec) is maintained at the outlet head. The time allotted to the farmers at the tail end is required to be adjusted to account for the conveyance losses in the field channel. When the time allotted to each irrigator is rigidly prescribed, the distribution system is called the Rigid Shejpali or Rotational Water Supply (RWS).

OTHER DISTRIBUTION SYSTEMS

Uttar Pradesh

In Uttar Pradesh the water distribution method is essentially similar to Warabandi as practiced in Punjab and Haryana. It is called **Osrabandi**. Two forms of Oscrabandi exist namely, Thokwari and Chakwari. In **Thokwari**, cultivators join together to form a number of groups known as 'thoks'. Head of each group is known as 'Thokdar' who is given a list of irrigators belongings to his Thok and the time entitlement noted against each. The share of water of different Thoks in decided on area basis. Thokwari often breaks down due to disputes arising out of discrimination practiced by Thokdars, poor maintenance of field channels and defiance by powerful farmers (Agrawal, 1980; Singh, 1980). In **Chakwari** system, introduced after land consolidation or 'chakbandi' share of water is disttributed chakwise i.e.cultivatorwise. This system is now preferred.

In the Punjab and Haryana model of warabandi, while working out the time allottment for each irrigator, the Bharai and Jharai of water course is taken into consideration. However, these are not considered in Osrabandi model of U.P. As a result, Irrigator having chaks farther away from the outlet are losers.

Madhya Pradesh

In Madhya Pradesh, different water distribution methods are practiced. While the Punjab or U.P. model is followed in the northern part of the state, it is the Shejpali system of Maharashtra which is followed in the Southern part. This dual situation is the result of merger of units from adjoining states after state reorganisation.

In Madhya Pradesh, Vindhya Pradesh and Bhopal region, where Rabi irrigation is comparatively much more than Kharif, the responsibility of irrigation beyond the outlets rests with Irrigation Department. In this region mixed cropping pattern prevails. On the other hand, in the old Mahakoshal region which is mostly rice growing area, the distribution of water beyond the outlet is the responsibility of Irrigation Panchayats (IPs). In M.P., the formation of IPs is compulsory under the M.P.Irrigation Act, modified in 1974. Each village has its own IP which has a small committee consisting of a Sarpanch and two or more members elected once in 3 years and serves on an average 250 ha (Raju, 1992).

Long term agreements for supply of water are made in the rice zone for 5 to 10 years village wise or project wise whereas short term agreements are made in the wheat and mixed crop zone. Individually and cropwise for the crop period. Mostly uncontrolled types of outlets are used for distributaries, minors, etc. and controlled outlets for the main canals and branch canals.

Tamilnadu Model

The rotational water supply method practiced in Tamilnadu is known as Varavaram. Paddy is the main crop both in Kharif and rabi seasons. During Kharif season, in the Cauvery system all channels run continuously without any control till the maturity of the paddy crop. Distribution below the outlet is by farmers who practice field to field irrigation. In lower Bhawani Project, the distributaries fun in rotation in alternate years supplying water to two crops in a year - paddy and an irrigated dry crop for the full area covered by these distributaries which run continuously throughout the crop seasons that is, January to April and August to December Kathapalia, 1980. During Rabi season, rotational system of water distribution is used. Water to each cultivator is supplied at an interval of 1.5 to 4 days for paddy and larger interval for other crops. The water supply in the distributaries is maintained at the designed level whenever the channel is running. The outlets from the distributary run simultaneously and their size is related to the area to be irrigated according to the planned cropping pattern.

USE OF WATER IN COMMAND AREAS

As discussed earlier, the total quantum of surface water available for irrigation in various project commands will continue to diminish with time coupled with which is the urgent need to bring more and more cultivable area under irrigation and to address the common problem of uncertain and inaequate water supply in the tail reaches of the command. On the other hand, according to a Ministry of Water Resources report (1991) a total of 5.8 million ha. of cultivable land is suffering from waterlogging and soil salinity the commands of major and medium irrigation projects in the country. Therefore, the need for promoting the integrated or conjunctive use of surface and ground water in the canal command areas has been emphasised over the last two decades by various researchers and policy makers (e.g. Irrigation Commission Report, 1972; National Water Policy; 1987 Sahni, 1987; Bahadur, 1993). While the main objective of the conjunctive use is to achieve optimal utilisation of the total water resource from these two sources and maximise agricultural production per unit of water, important objectives are:

- reclamation of waterlogged soils and prevention of occurrence of drainage problems in the susceptable parts of irrigation command areas,
- maintaining the integrity of the aquifer system with respect to quantity and quality of ground water in space and time,
- controlling sea water ingress into the coastal aquifers and checking the con tamination of fresh water by its over exploitation in fresh water - saltwater inland aquifer systems.

PRESENT STATUS OF CONJUCTIVE USE

To make any conjunctive use plan effectively functional, whether in an existing or a new irrigation project, it is important to recognise the diversity of circumstances of conjunctive use resulting from location specific hydrogeological, climatic, cropping pattern, social, economic and institutional considerations and a variety of combinations thereof in different regions of the country and also changing scenario over time (Sahni, 1997).

The surface (canal) water is developed, owned and managed by government whereas the wells in the command are mostly constructed, owned and operated privately. Therefore, while the project authorities have full control over canal water management, they have no direct control over groundwater use in those irrigation commands. This becomes a major constraint in effective planning of conjunctive use and its implementation in such project areas. On the other hand, we have the Punjab and Haryana augmentation tubewell programme where both sources are being developed and managed by the government and as such, is an example of successful implementation of conjunctive use (Sahni, 1997). Examples of present status of conjunctive use in India drawn from Haryana, Maharashtra, Karnataka etc. are presented here.

Haryana

In the 1950s it was observed that while the command of lower reaches of Western Jamuna Canal (WJC) were facing scarcity of canal supply, waterlogging was developing in the upper reaches. In order to solve this twin problems, first a battery of about 250 deep tubewells was constructed along the WJC each continuously discharing on an average about 1.5 cusecs into the canal. This management technology proved very useful and construction of such augmentation tubewells (ATWs) continued. At present there are 1643 ATWs with capacity varying from 1 to 7 cusecs (Tanwar, 1997). The independent electric feeder lines permit continuous operation of those wells unaffected by local power distribution schedule.

Direct Irrigation tube wells (DITs) of an average capacity of 1 to 1.5 cusecs have been constructed where canal irrigation facilitates do not exist. Each tube well is provided with a lined water course are buried pipe line system to serve a group of farmers. At present, there are 1546 DITs duly energised .

Both ATWs and DITs are constructed , owned, operated by state agency namely, Haryana State Minor Irrigation and Tube Wells Corporation which raises the water bill to be canal authorities on the basis of monthly electric units consumed.
The third category is the shallow tube wells (STWs) constructed owned, the operated by the farmers. These wells having discharge capacity varying from 0.2 to 1 cusecs have helped the farmers in the command to practice intensive irrigation with more flexible supply to meet water requirement of high yielding varieties of the crops. Mainly farmers are using sprinkler irrigation on these wells.

Uttar Pradesh

The U.P. Government has proposal to construct small tubewells of 0.5 to 0.7 cusec capacity at the head of every water course in the command area to enable supply of water during the periods of canal closure. Thereby, the cultivators will be in a position to get the required quantity of water either from the canal or from the tubewell throughout the cropping season. In this proposal, the land and investment required for the construction and lining of separate channels for tubewells will be saved. Such a system will be specially beneficial to the small and marginal farmers who are unable to afford their own tubewells and will also save them from exploitation by the rich farmers who have their own tubewells.

Maharashtra

In Maharashtra, the ground water development in the canal commands is entirely farmers own initiative in the form of dugwells or dug-cum-bore wells. The prevalent Maharashtra Irrigation Act, 1976 and Bombay Canal Rules, 1934 only provide for some limited indirect regulation of ground water in canal commands:

(1) Any farmer planning to construct a well in the command is required to inform the canal authorities failing which he may be penalised albeit, the penalty amount is a paltry Rs.100/-

(2) Irrigation water from the wells located within 35 meters from the nearest boundary of the canal is charged at 50% of the canal water rate.

(3) Areas identified as canal-irrigated may also receive ground water if canal supply becomes short, by informing the Executive Engineer concerned within 8 days and charge payable for this is 50% of the normal canal water rates. On the other hand, area designated as groundwater irrigated at no time may be irrigated by canal water.

(4) Well water, if transported by the surface water channel, is charged at the full canal rate.

(5) In major irrigation projects, 'x-limit' or the maximum area (%) is permitted under sugarcane is prescribed. But no such restriction applies if one grows it exclusively on well irrigation.

In addition to the above provisions in Irrigation Act and Rules, an indirect control on possible over exploitation of ground water is also exercised by financing institutions by following the minimum well spacing restrictions. But this control can not be exercised if the farmer uses his own resources to construct the well.

There is at present no single organization in the state directly responsible for conjunctive use management in irrigation project commands.

Technical, social and economic problems arising out of uncontrolled ground water extraction by private initiative in Maharashtra have been brought out through several case studies by Sahni (1987), Sahni and Jangle (1988), Sahni (1998 a, 1998 b, 1999 a, 1999 b).

Karnataka

Another example of scarcity induced development of conjunctive use is seen in the command of Gokak Canal, one of the oldest irrigation systems in Karnataka. The system is designed essentially for protective irrigation with duty of 40 hectares per cusecs. Further, the area, to be irrigated increased considerably over period of time and the sugarcane area is also reported to increase (Venkatta Reddy, 1988). In order to ensure uniform distribution of available canal water the Irrigation Department introduced RWS in the early 1960 with a rotation period of 21 days in rabi. This together with shift in the cropping pattern to more water demanding modern HYUs and water intensive commercial crops induced the farmers to construct dug wells to supplement inadequate canal supplies.

CWC GUIDELINES

Recognising the urgent need of conjunctive use concept, Central Water Commission (CWC) is now ensuring, in accordance with the National Water Policy of 1987, that new projects which do not take into account conjunctive use are not recommended for obtaining planning commission's clearance. CWC, in March 1995, issued general guidelines for planning conjunctive use. The detailed action plans to implement it have to be drawn by respective states considering local conditions. The above report also recognises the importance of working out accurate groundwater balance with the joint efforts of geohydrologists, surface water hydrologists hydrometeorologists, and planners of the projects. However, to begin with it suggests the use of NABARD guidelines for establishing preliminary ground water balance based on some rules of thumb for estimating recharge in command areas arising from seepage from canals, field channels and tanks and return flow from irrigation fields.

In addition to estimating net annual ground water recharge, the report also stresses on taking into account (i) the miminim necessary withdrawal in order to avoid large imbalance leading to large rise in groundwater table and (ii) the maximum permissible with drawals with a view to maintain ecology and not allowing ground water to deplete. These guidelines for extraction in command areas as percentage of additional recharge caused by the project are given in Table 4.

Table 4 Guidelines for ground water extraction

Present Groundwater Status		Min.Necessary Additional withdrawal (%)	Max.Permissible Withdrawal
Depth of Gr.Water	Trend		
Less than 2 m.	Rising	70	100
Less than 2 m.	Generally stready	50	80
Less than 2 m.	Falling	30	60
2 m. to 6 m.	Rising	60	90
2 m. to 6 m.	Steady	40	70
2 m. to 6 m.	Falling	20	60
More than 6 m.	Rising	50	80
More than 6m.	Steady	30	60
More than 6 m.	Falling	0	40

STRATEGIES FOR CONJUNCTIVE USE

Following strategies may be adopted for conjunctive use in a given project considering local conditions:

a) Allocation in space, i.e. allocating parcels of land permanently to a particular use
b) Allocating the two sources in time, i.e. on a given part of the command in a particular season only surface water is used and in other season only ground water is used.
c) Combination of model 1 and 2 in which
i) Some areas are permanently on surface water
ii) Some areas are permanently on ground water and
iii) Some areas are supplied with surface water in one season and ground water in another
d) Variation of strategy c(iii) in which both ground water and surface water are used,

the intra annual regime of the uses varies from year to year. This could involve ground water partly for carry over purposes; and likewise, may require larger use of surface water in years when it is in surplus.

The above guidelines can also be used for planning and dealing with conjunctive use in existing project commands. Any scheme for modernisation and improvement of existing commands need to include conjunctive use proposals.

SPECIAL SITUATIONS WITH FRESHWATER - SALTWATER INTERFACE

In coastal areas of Saurashtra, Maharashtra, Kerala, Karnataka, Tamilnadu and West Bengal, the development of fresh water is constrained by induced ingress of sea water into coastal aquifers. In these areas, therefore, maximising the quantity of water supply can not be the objective of conjunctive use development but instead of the water quality considerations and maintaining the integrity of the aquifer will predominate. Therefore, the CWC note suggests that in irrigated commands located in coastal areas say within 50 km of the sea, depending upon the local hydrogeological conditions, all recommended values for ground water extraction given in Table 4 be reduced by about 20%.

Similarly, there are inland areas also where problems of freshwater-water-saltwar interface occur. For example, in canal irrigated central and south - western regions of Haryana due to brackish saline ground water, poor natural drainage and absence of outlet for the disposal of drainage effluent, the water table had shown a rising trend ever since the canal irrigation was brought in this tract. Thus, in order to prevent further salinisation, lowering and stablisation of water table below the critical depth by installing appropriate drainage system was a must.

Development of usual quality ground water in areas where waters of relatively good quality are underlain by highly saline ground waters involves manipulation of fresh water without disturbing saline water. Shallow 'skimming wells' are the best technological option in such cases. For designing skimming wells the important points of considerations are the thickness of the overlying fresh water zone, depth of well penetration in fresh water, their spacing and pumping rates. Sahni (1972) has developed design and operation criteria for skimming wells applicable to wide range of field conditions. Applications of skimming well concept in Haryana have been reported by Gupta and Tyagi, 1986 and Singh and Kumar; 1994 and others. This system besides checking the problem of waterlogging and salinity, also provides additional usable water. The corresponding reduction in the canal water supply can be made in that part of the command which can be used elsewhere where inadequate supply is received.

IRRIGATION WITH SALINE WATER

In arid and semi-arid regions, where fresh water supplies are limited, use of ground water even if it is saline is unavoidable for promotion of irrigated agriculture. Research conducted during the past few decades has shown that these waters can be profitably used for growing field crops provided special land and water management practices are adopted which mitigate the salinity hazards (Mass and Haffman, 1977; Gupta, 1990; Tyagi, 1992, etc.). Saline/sodic waters could be applied to crop in three possible ways:

a) application after blending with fresh water from canals;

b) cyclic use of canal and ground water;

c) application of saline water alone.

The first two options constitute conjunctive use. The choice of the alternative depends on quantity and quality of water available from the two sources, soil type, salt tolerance of the crops to be grown, and the climate. In those parts of the command where canal supply is not available, there is no escape from using the third option. In this water should be applied by drip irrigation.

Recently, considerable research has been conducted on technical aspects of the blending process within the water distribution network in the command areas (e.g. Jury et.al.,1980; Tyagi and Tanwar, 1986). The blending can be done in the main canals and distributaries or in the watercourses. Farmers in Haryana have installed shallow tubewells along the water courses to blend the saline ground water with canal water. A mixing distance of 15-20 m. is generally allowed before using the water (Tyagi, 1992). Care has to be exercised to ensure that additional water needed for salinity control does not exceed the net gain in the amount of blended water..

WATERLOGGING AND SOIL SALINITY IN COMMAND AREA AND APPROPRIATE MANAGEMENT STRATEGIES

CRITERIA FOR WATERLOGGING AND SOIL SALINITY

The growth of irrigation in India since the advent of Five year plans has been phenomenal. This has also to some extent subjected certain tracts of lands to waterlogging and salinity problems. Several Commissions and Committees have in the past emphasised the need for evolving an appropriate strategy to combat the adverse effects of irrigation.

Waterlogging may be either due to surface inundation of the fields or rise in watertable or both, as a result of excess rain / irrigation. With reference to sub soil water condition, the area is considered as waterlogged if the water table rises to such an extent that the soil in the root zone remains fully saturated for prolonged period thereby adversely affecting the soil environment for normal crop growth. The actual depth of water table, when it starts affecting the yield of the crop adversely, may vary over a wide range from zero for rice to about 1.5 m for other crops depending on their rooting depth.

However, various states have been adopting different criteria for categorization of waterlogged areas as shown in Table 5 below

Table 5: Norms for Categorisation of waterlogged areas in different states

State	Water Table depth below the ground level (metre)
Uttar Pradesh	
(Sharda Sahayak Project)	
i) Worst Zone	Less than 1
ii) Bad Zone	1 - 2
iii) Alarming Zone	2 - 3
iv) Safe Zone	More than 3
Punjab	
v) Very critical	0 - 1.5
vi) Critical	0 - 2
Haryana	
vii) Critically waterlogged	0 - 1.5
viii) Moderately waterlogged	1.5 - 3
Karnataka	
(Tungabhadra Command)	0 - 2
Himachal Pradesh	0 - 2
Maharashtra	
ix) Fully waterlogged	Water at Surface
x) Waterlogged	0-1.2

It was recognized by the working group of Ministry of Water Resources that as a result of this non-uniformity in the criteria for describing waterlogged area, reliable data for total area affected by waterlogging in the country is lacking. The working group (1991) therefore, adopted the norms for irrigated lands as in Table 6.

Table 6 : Working Group, MOWR Criteria for Waterlogged Areas

Sr.No.	Depth of Water Table (m)	Irrigated area considered as
1)	0 - 2	Waterlogged
2)	2 - 3	Potential for waterlogging
3)	More than 3,	Safe

The US Salinity Laboratory (USSL) has suggested classification of soils with respect to salinity according to electrical conductivity of soil saturation paste extract (SPS) and soil sodicity (alkalinity) according to the exchangable sodium percentage (ESP). These criteria adopted by the MOWR working group are given in Table 7.

Table 7: Classification of salt affected soils on the basis of chemical characteristics (USSL)

Sr.No.	Class	Ece	ESP	PH	Indian Local
1)	Saline Soils	>4	< 15	> 8.5	Thur, Vippu, Lona, Shora, Soula, Pokhali, Khar and Kari
2)	Saline-alkali soils	>4	> 15	Variable	Usar, Kallar, Karl, Chopan, Bari, Reh Choudu Kshar and Fougu
3)	Non saline or alkali	<4	> 15	> 8.5	Usar, Rakkar, Bara soil chopan kari

EXTENT OF AFFECTED AREA

The working group (1991) has estimated that 2.46 Mha area is affected by waterlogging and 3.30 Mha affected by soil salinity including 0.24 Mha under alkali soils and thus a total area of 5.76 Mha is suffering from waterlogging and salinity problems in the commands of major and medium projects in the country.

EFFECTS OF WATERLOGGING AND SOIL SALINISATION

Surface inundation and waterlogging of the soil profile adversely affects soil aeration as a result of which the plant roots do not receive the required quantity of oxygen, aerobic micro-organisms stop growing and may even die. Subsequently, anaerobic bacteria proliferate. While in the aerobic conditions the organic matter present in the soil decomposes to release nutrients for the plants, decomposition of organic matter under anaerobic conditions produces toxic substances (H_2S, CH_4 etc.) Waterlogging tends to destroy the soil structure which in turn adversely affects root development and soil aeration. Proper soil temperature plays an important part in many physical, chemical and biological activities in the soil especially in the temperate climate zones. The well drained soils warm up faster than waterlogged soils . The low soil temperatures hamper germination of seeds, restricts development of root system, affects rate of growth and final ripening. Prolonged inundation results in progressive rise in water table which can eventually invade the root zone. Waterlogging causes soil salinisation and promotes weed growth and incidence of peasts and diseases in plants.

Soil salinisation causes several adverse affects. Highly deterorated alkali soils have very low water intake rates. Yields of crops are reduced and in extreme cases the crops fail either due to inadequate uptake of moisture and nutrients and injurious effects of salts or deteriorated physical soil conditions. Choice of the crops becomes limited due to their sensitivity to salinity.

CAUSES OF WATERLOGGING AND SOIL SALINITY

The twin maladies of waterlogging and soil salinity are closely related and interlinked. Accumulation of salt on the soil surface or in the root zone in irrigated fields in caused by precipitation of dissolved salts in irrigation water and shallow ground water when salinisation exceeds the leaching of salts. The waterlogging can occur due to several natural and manmade causes. The common natural causes are:

- Flat topography and absence of outfalls
- Unfavourable geology such as presence of an impermeable stratum at shallow depth.
- Heavy soils especially black cotton soils which are prone to waterlogging because of their low permeability
- Shallow water table

The common manmade causes for waterlogging in command areas are:

- Excessive / uncontrolled irrigation
- Wrong layout of fields and lack of land shaping / grading
- Inappropriate choice of crop and water application method in relation to type and depth of soil and climate
- Leakages from canal structures
- Seepages from conveyance and distribution network and borrow pits not connected to nalla or stream
- Encroachment and obstruction of natural / field drains by the cultivators.

PREVENTIVE AND REMEDIAL MEASURES AND STRATEGIES

A two prolonged approach is required to tackle drainage problems in command areas namely:

i) taking adequate preventive measures especially in the new irrigation systems to avoid or minimise the development of waterlogging on the soil salinisation;
ii) taking appropriate remedial measures to mitigate the problems where they have already developed.

Preventive Measures

The preventive measures include efficient water management both on farm and in the main system, practicing slightly deficit irrigation in vertisols which are more prone to waterlogging and to avoid other manmade causes mentioned earlier. Encouraging sprinkler and / or drip irrigation wherever feasible appropriate crop rotation and judiciously planned integrated use of surface and ground water in the command areas discussed in previous chapters are also important preventive management strategies. Such integrated use planning in Haryana, Punjab and Uttar Pradesh has been found to be very useful but much efforts in this direction are still needed.

There is an increasing awareness of the need of incorporating carefully planned drainage system as an integral part of any irrigation project right all the design stage. The lesson learnt from the experience of several irrigation projects in the past which have resulted in large tracts of once good agricultural land due to neglect of drainage that irrigation and drainage must go hand in hand has been amply emphasised by Fukuda (1978) by coining the word 'irrinage'.

In Maharashtra, concept of an 'X' limit is used as an important preventive measure. Maharashtra produces almost one third of Country's sugarcane and there are more than hundred co-operative sugar factories in the state. It is a very attractive cash crop in Maharashtra especially because such sugar factories extend a lot of support to member sugarcane growers in terms of loans, arranging planting material and transportation of the produce from their fields to the factories. Sugarcane is a water intensive perennial crop. Irrigation to this crop in deep black cotton soil areas poses real problem of waterlogging based on large scale field research, which determines the maximum peremissible area under perennial crops in the command of each outlet depending upon the soil type and drainage characteristics with a view to protect these lands from waterlogging hazards. In deep B.C. soil areas it is not to exceed 7 to 10 percent of the total irrigable area.

Structural Remedial Measures

Remedial measures for reclaiming agricultural lands affected by waterlogging and soil salinity problems include surface drainage schemes and various sub-surface drainage systems namely, open ditch systems (for lands with shallow water table and where shallow rooted crops are to be grown), rubble drains, clay tile or concrete pipe drains, slotted PVC pipe and corrugated plastic pipes horizontal drains, vertical drains and chimney drains. The use of plastic pipes for drainage schemes strated in the 1960 and corrugated pipe have now become very popular in drainage works. In recent years a considerable work has been carried out in investigation, research and execution of sub-surface drains in several states in the country especially Haryana, Punjab, Rajasthan, Maharashtra and Gujarat.

In Haryana the Central Soil Salinity Research Institute, Haryana Agricultural University and Haryana Agricultural Department have undertaken research and operational pilot projects on subsurface drainage with the Netherlands bilateral assistance. The World Bank is assisting the North West Drainage studies under Haryana Water Resources Consolidation Project (1995-2000). These projects include subsurface horizontal drainage and skimming well (vertical) drainage.

The Rajasthan Agricultural Drainage Research Project (RAJAD) is under implementation with Canadian Assistance in Chambal command. Under this project, corrugated plastic pipe with synthetic envelop material are being used for horizontal subsurface drains.

In Maharashtra , where the horizontal sub-surface drains have often been found to be in effective in deep B.C.soil areas where excess water also occurs under artesian pressure in the underlying murum layer, a recent innovation of chimney drains have been installed in two pilot projects undertaken in at Katepurna in Purna and at Mahakala in Jayakwadı and found to be very effective under such conditions in draining out both the excess water in the upper layer of soil as well as that contained in the muruni layer under artesian pressures. The design of chimney is shown in Fig.4(Sahni, 1988).

In Gujarat, Pilot subsurface horizontal drainage project have been undertaken in collaboration of CSSRI, Karnal. The relative benefits and performance of different filter materials like gravel, geotextile, plastic net and coir are being examined in these experiments.

Non-structural Remedial Measures

Leaching of salts through the soil and flushing through open or sub-surface drains and taking up ameliorative and agrenomic practices are useful nonstructural remedial measures for controling soil salinity and alkanity. Chamical treatments of soil by addition of chemicals such as gypsun have proved to be helpful in reducing the salinity lavel. Different technology have been adopted depending on the extent of the problem extent of minimum improvement aimed at, economy of chemicals to be used, possibility of alternative crop planning, availability of funds, etc. Special programmes for reclaiming usar lands are in operation in Utter pradesh, Haryana, Rajasthan, Gujarat and maney other parts of the country for the last nearly four decades under the plans of Ministry of Agriculture under the guidance and research programmes of ICAR, Agricultural Universities and other Central and State institutions. The results are found to be enconranging.

In areas where topography does not permit gravity surface drains and wnere ground water is saline, water table control can be obtained by bio-drainage to some extent. The potential of certain forest species to draw more water than the agricultural crops because of their deeper root systems, higher transpiration rates throughout the year and ability to minimise recharge from rain by intercepting it on their foliage, provides a techniques for keeping water table under control. These trees and other phreatophytes (Sahni, 1976) in fact work as biological pumps which can transpire large quantities of water Eucalyptus is a deep rooted (20 m.) fast growing tree and pumps 3 - 6 mm/day water from the soil and is a very useful tree to reclaim waterlogged areas. Likewise, Tamarix Aphylla is another useful phreatophyte whose deep penetrating and extensive roots use abundant ground water thereby lowering the water table.

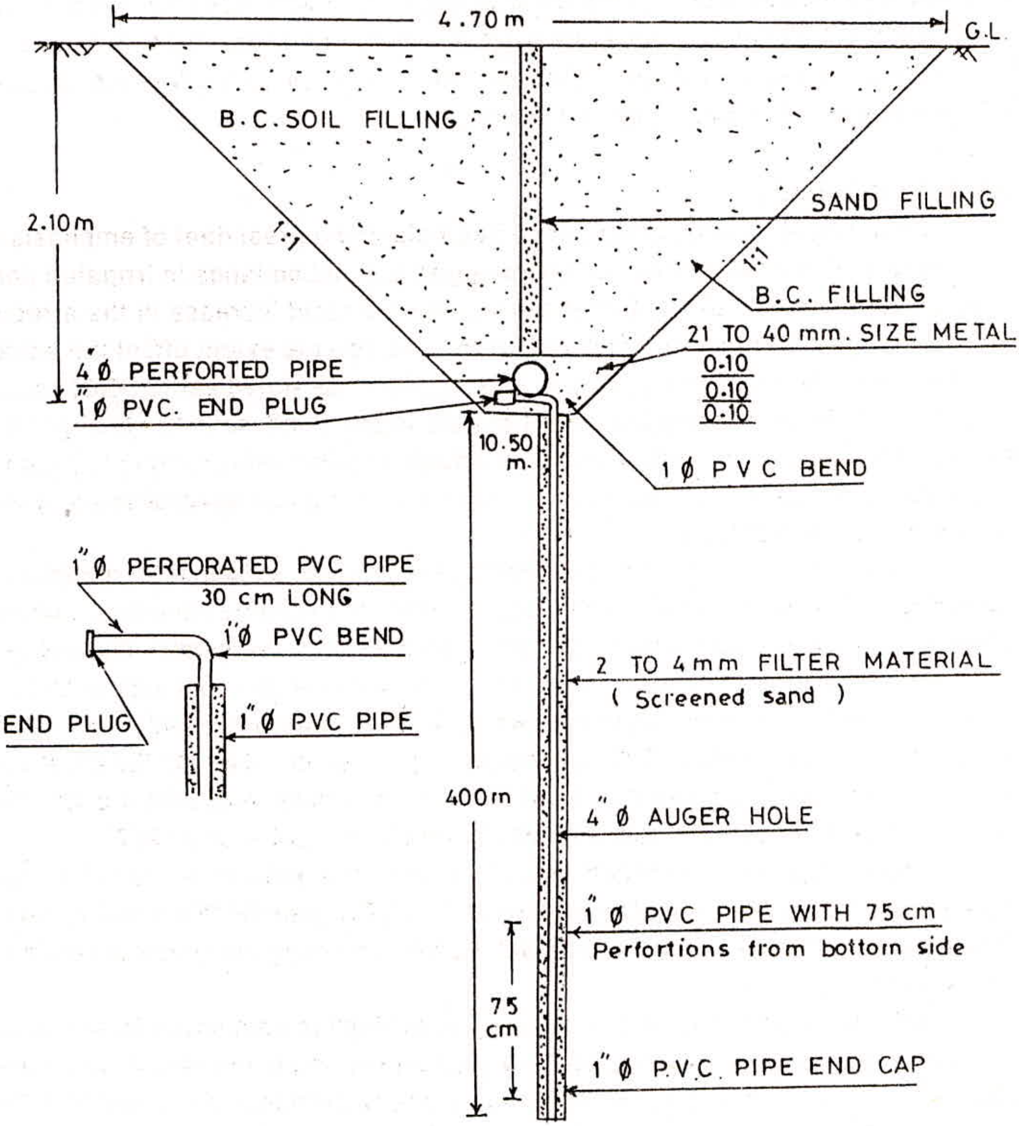


FIG. 4 : DETAILS OF CHIMNEY DRAIN SYSTEM.

However, plantation of such trees has to be planned carefully in conjunction with other methods of drainage because of their significant adverse effect on the growth of crops taken near them even up to a distance of 50 m. Such trees should, therefore, be planted only along the canal and channel sides to drain the seepage water and to lower the water table in the area.

CAD, MOWR Initiatives

Government of India oflate, have been placing a great deal of emphasis on activities related to reclamation of waterlogged and saline lands in irrigated commands. The reason for this is that there has been a rapid increase in the affected area in the project commands which has to be considerable extent offset the advantage of irrigation in increasing agricultural production. As stated earlier, GOI setup a Working Group for estimating the extent of waterlogging and salinity which gave its report in 1991 according to which the area affected by this twin problem in irrigated commands was nearly 5.76 million ha at that time. In the last several years, it may have increased considerably.

Ministry of Water Resources (MOWR) had prepared a manual for reclamation of waterlogged areas in collaboration with Central Soil Salinity Research Institute (CSSRI), Karnal which has been separated to all State Governments. Thereafter, a National Conference of the issues related to the twin problem was held in Delhi in December 1996 followed by another at Kota, Rajasthan in April 1997. The recommendations of the December 1996 Conference have been circulated to the Chief Secretaries of all states alongwith a request for detailed survey to update the statistics on extent of waterlogged and saline lands (CADNEWS, April - June 1997).

A new component of reclamation of waterlogged and saline areas has been included under Command Area Development (CAD) Programme in which assistance to the extent of 50% would be given by GOI for implementing the schemes related to these aspects.

GOI have also constituted a standing co-ordination committee for the implementation of the Centrally sponsored CAD programme and management and waterlogged and saline lands in the commands under the Chairmanship of Additional Secretary, MOWR with representatives of ICAR, Ministry of Agriculture and Co-operation, Central Water Commission, Planning Commission, Central Ground Water Board and Joint Secretary (CAD) as its members.(CAD notification No: 7-3/97-CAD dated 28th April 1997).

PARTICIPATORY IRRIGATION MANAGEMENT

THE NEED FOR PIM

The present irrigation management approach is top down wherein the prescriptions are handed down from the top and irrigation is managed more according to standard administrative procedures than by local variable needs. The cognitive distance between the water users and the agency is so much that their objectives do not match which is one of the major reasons responsible for poor performance of most irrigation projects. Farmers' participation in irrigation management has now become increasingly appreciated as a means of improving the performance of costly irrigation investments. When properly carried out, the participatory irrigation management (PIM) provide benefits not only to the farmers but also to the government agency through equity in distribution, reduced costs and improved agricultural production and producivity. More specifically stated the objectives of PIM are to:

- Improve service deliveries through better operation and maintenance which in turn will result in improved efficiency and equity as well as improved reliability essential for production of high value crops.

- Ensure the physical sustainability of irrigation infrastructure. As water users associations (WUAs) assume management of the lower levels of the system (e.g. a minor), the irrigation agency can focus its limited resources on the main system.

- Promote a sense of partnership (ownership) between the farmers and the irrigation agency which will ensure better communication and co-operation leading to mutual benefits.

The operational objective of PIM is to transfer the management of irrigation facilities at appropriate level from government to user associations. In most cases, management transfer will focus at the level of a minor or distributary for large systems or the entire system in case of small schemes.

FUNCTIONS OF WUAs

The essential functions of WUAs would be:

- Management of allotted water to WUA among the members and non members on principles of equity to be decided by WUA.

- Repairs and maintenance of the system within their jurisdiction.
- Assessment and collection of water charges from farmers and remittance to the Irrigation Agency (IA) at rates fixed in the memorandum of understanding be tween WUA and IA.
- To ensure measured quantity of water supply trom the IA.

DEVELOPMENT AND EXAMPLES OF PIM IN INDIA

Upto nineteenth century all the irrigation schemes, mostly small in size were managed by farmers themselves. Some of the examples are as follows (Datye and Patil, 1987; Maloney and Raju, 1994; Joshi, 1997):

In Vijayanagar Empire (13th - 16th Centuary AD) which is now part of Karnataka State, a series of diversion weirs and canals were built by rulers in which farmers participated voluntarily. Resolution of conflicts and routine maintenance were achieved by farmers themselves.

In Tamil Nadu, the Chola King Karikala built an anicut on river Cauvery. Certain parts of the irrigation system known as 'Sarkari' were maintained by the government and the lower parts known as 'Kudimarammat' (maintenance by donated labour) were maintained by the farmers.

Himachal Pradesh had an ancient system called 'Kuhl' in which irrigation was managed by the community. Similarly in the hilly regions of Uttar Pradesh there was a tradition of farmers managing very small diversion schemes.

In Maharashtra, the 'Phad' system of irrigation evolved in Nashik and Dhule in the seventeenth century is a small scale community irrigation which is entirely managed by irrigators.

Thus, the concept of PIM is not alien to India and has been practiced in this country for a long time in some form or the other. However, the PIM in its present context and scope of modern irrigation systems is quite recent in the country.

Since the last quarter of the nineteenth century a number of modern irrigation projects have been constructed through Departmental agencies. Management of these schemes was totally taken over by the irrigation agency without any involvement of the farmers.

In 1938, the then Government of Bombay (now Maharashtra) appointed Irrigation Inquiry Committee under the chairmanship of Sir Visvesvaraya to investgate the causes of under utilisation of irrigation in the State. One of the recommendations of the Committee was to entrust irrigation to a village or group of villages if the farmers were willing to take up co-operative irrigation. In 1947, the Government set up Canal Advisory Committees and Water Panchayats to facilitate farmers' participation. The role of the Committees was to advise the Department of Irrigation on scheduling of water. In 1960, the Government of Maharashtra appointed an Irrigation Commission (Barve Commission) which also recommended participation of farmers in irrigation management (Lele and Patil, 1994).

In Madras (now Tamil Nadu), the PWD tried to introduce Kudimarmmat by enacting laws to make it mandatory for the farmers to maintain the tanks. Similarly in 1920, under the Madras Panchayat Act, tank irrigation was handed over to village Panchayats which had the right to enforce Kudimarammat. These experiments did not succeed in enlisting farmers participation because the Government kept asserting its powers to enforce their participation without caring for their rights (Maloney and Raju, 1994).

The planned and systematic effort by the government on PIM started for the first time in India under the centrally sponsored Command Area Development Programme in 1985. The CAD programme was started in 1974 in the backdrop of the concern expressed by the Irrigation Commission in 1972 about under utilisation of the potential created in irrigation commands in order to ensure that water below the outlet should reach all the fields in the command area and to have more efficient management of available water. PIM was not a component of this programme at that time. On 16th October 1985, Ministry of Water Resources (MOWR), Government of India wrote to state governments participating in the CAD Programme to take up farmers participation on pilot basis on at least one minor (comprising about 1000 - 2000 ha. area) in each CAD Project to involve farmers in water management and maintenance of water courses/field channels with the objective that eventually the minor level system could be handed over to WUAs.

The need for PIM was also emphasised by the National Water Policy adopted in 1987 which states that "efforts should be made to involve farmers progressively in various aspects of management of irrigation systems, particularly in water distribution and collection of water rates".

In 1987, the CAD wing of MOWR issued guidelines for farmers' participation which were sent to state government who in turn have to formulate plan for implementation of these guidelines. In order to provide incentive for promotion of PIM, the MOWR under this centrally sponsored CAD Programme made a provision of 50% of the cost of management subsidy on matching basis (by Central and State governments) at the rate of Rs.100 per hectare during the first two years and Rs.75 per ha.of CCA for the third year by way of reimbursement for farmers associations formed at the minor level for taking over the management of distribution below the minor level. In the Ninth Five Year Plan now it is proposed to give Rs.500/ha of CCA as lump sum amount to the WUAs formed under CAD Programme at the start - Rs.250/ha each by Central and State government and Rs.50/ha to be contributed by WUA. This amount is to be invested in a Bank in the form of a long term deposit and the yearly interest accrued therefrom is to be used by the WUA for meeting the management cost. However, very few states have adopted this new model and are continuing with the earlier subsidy scheme.

In Maharashtra, sugar factories acted as catalysts in formation of some farmers' associations such as Samvatsar Society in Ahmadnagar district, Shambhagi Warna Co-operative Farming Distributary Society, Kadloi, and Malinagar Irrigators' Water Co-operative Society in Solapur district (Lele and Patil 1994; Patte, 1995).

In some cases the WUAs were formed as a result of initiative of officers of irrigation departments especially those who had seen the formation and working of similar organisations elsewhere in India and abroad. WUAs in Hadshi and Parunde Minor Irrigation Projects in Minor 10 at Shevare in Bhima Project, in 28 L and 29 R outlets of Mettupalayam Distributary in Lower Bhawani Project are some such examples (Patole, 1995a; Patole, 1995b; Parode, 1995; Sureshsuvaram; 1995).

Some Non-governmental Organisations (NGOs) have also made significant efforts in formation of WUAs in the country. Prominent among them are: Agha Khan Rural support Programme, Society for People's Participation in Ecosystem Management (SOPPECOM) in Pune, Samaj Parivartan Kendra in Nashik, Professional Assistance for Development Action (PRADAN) - a national level NGO worked in Tamiln Nadu and Bihar, Centre for Applied System Analysis Development (CASAD), Pune, Development Support Centre, Ahmedabad, and Institute of Resource Development and Social Management (IRDAS).

Efforts have also been made for formation of WUAs, as a part of the conditions under externally aided projects such as Water Resources Management and Training Project (WRMTP) of US AID and National Water Management Project (NWMP) and Water Resources Consolidation Project (WRCP) of World Bank. WUAs currently being set up under WRCP in three states viz; Tamil Nadu, Orissa and Haryana.

Efforts made by various Water and Land Management Institutes (WALMIs) and other State Training Institutes (STIs) in Water Management under the Action Research Programme undertaken by them have also been instrumental in formation of some WUAs in various states such as WUA in Anklav subminor of Mahi Kadana Project in Gujarat, WUA at Saliperi in the Mahitaneheri Channel command in Cauvery - Valappar Project in Tamil Nadu, Paliganj Distributary Farmers Committee in Sone Command Bihar.

STRUCTURE OF WUAs

Hydraulic unit has been accepted as the basis for formation of WUAs. At the outlet level, the WUA is considered too small to be effective. But WUAs at minor level having CCA of 500 to 750 hectare are considered to be ideal as basic unit. Small irrigation schemes having CCA upto 1000 ha can have a single tier. But for medium and major projects multi-tiered WUA and a federation of WUAs at Distributary / Branch Canal level has been proposed which will be responsible for co-ordination between lower (minor) and higher level WUAs and finally, WUAs at project level will have the advisory functions.

MOTIVATION FOR WUAs

The successful formation of WUA and its sustainability depends largely on the motivation both on the part of the farmers and the irrigation bureaucracy. This motivation can largely come from the understanding of how they stand to gain from such an organisation some of the advantages to the farmers are (Joshi, 1997):

- WUAs get explicit water right
- Assured delivery of water on volumetric basis as scheduled to WUAs according to the agreement with irrigation agency
- Freedom of cropping pattern and conjunctive use
- The WUA could levy water rates higher than the rates charged by the irrigation agency and keep the excess amount for the use of WUA.
- Right to information about the availability of water before begining of the season.
- Rehabilitation and physical improvement of the system which is pre-requisite to transfer of management to WUA is a major gain.

- Farmers do not have to depend on O & M of the system on an outside agency since it is taken over by WUA.
- With de facto ownership of the system below minor once turned over to WUA, unauthorised water use and interference of vested interests in irrigation supply is greatly reduced.
- Resolution of conflicts, if any, is quicker
- Staff of WUA is locally based and hence more readily available than the staff of irrigation agency.

Similarly, the advantages of WUA to the staff of irrigation agency are:

- The cost of O & M of the system is reduced
- The staff is relieved of the responsibility of supplying water to individual farmers fields and can concentrate more on the improvement of the main canal system.
- A lot of office work and contacting individual farmers for collecting revenue is eliminated
- The agency does not have to involve itself in resolving conflict among irrigators.

CURRENT STATUS AND STRATEGY FOR PIM

The progress in transferring O & M to under associations has been slow. The major constraints identified are: lack of awareness among farmers and officials, resistance of the staff, attitudes of big farmers, need for suitable modifications in irrigation and other relevants acts, lack of State level comprehensive policy on PIM and cumbersome registration and legal procedures. In order to create mass awareness, a National Conference on PIM sponsored by EDI of World Bank was held at Aurangabad in 1994 for representatives of state governments, NGOs, IIMI and World Bank. This was followed by participation of a delegation from India in an international conference on PIM in February 1995. Another National Conference was held at New Delhi in June 1995 followed by a number of State/Regional and Project level conferences during 1995-98. The state levels and project level conferences on PIM conducted during 1997-98 are given in Table 8. Actions on other aspects are being taken at the Central and State Government levels with a view to accelerate implementation of PIM in the irrigation commands.

Table 8: State / Project level conferences on PIM held during 1997-98

Sr.No.	State	Number of conferences	
		State Level	Project Level
1)	Andhra Pradesh	2	21
2)	Bihar	-	4
3)	Gujarat	-	8
4)	Haryana	1	-
5)	Jammu & Kashmir	-	1
6)	Karnataka	1	1
7)	Maharashtra	1	-
8)	Rajasthan	1	4
9)	Tamilnadu	-	2
10)	Uttar Pradesh	1	-
	Total	7	41

COMMAND AREA DEVELOPMENT APPROACH FOR INTERDISCIPLINARY WATER MANAGEMENT

EVOLUTION AND OBJECTIVES OF CAD CONCEPTS

Evaluations of surface irrigation projects particularly major and medium irrigatilon works have identified the following reasons mainly responsible for under utilisation of their potential :

- lack of reliability and dependability due to deficiencies in planning,
- design, construction, operation and maintenance of the projects;
- lack of on - farm development works,
- unrealistic assumptions about the 'duty', losses in transit and seepage;
- lack of agricultural support services such as credit and extension;
- lack of farmers involvement in system operation and maintenance; and
- lack of coordination between various agencies involved in the development of irrigation command.

The concern at the above finding of a series of appraisal reports led GOI, on the recommendations of the Irrigation Commission and National Commission on Agriculture, to formulate a Command Area Development Authority (CADA) model in December 1974 for adoption by the state governments with the overall objective of increasing productivity, maximising total production, efficient use of water with equitable distribution at minimum administrative cost and with beneficiary participation. The model would set up a CADA with a full time administrator of the rank equal to Secretary to the State Government, with control over the heads of all concerned departments such as Irrigation, Agriculture, and Cooperation.

The CADAs established in 1974-75 were formed through the following procedures :

1) executive order of the state government,
2) assumption of special functions by an existing department such as Irrigation or Agriculture,
3) statutes passed by the state legislature.

While the CADAs in Gujarat, Maharashtra, Andhra Pradesh and Rajasthan were established through procedure (1) and (2), in Utter Pradesh a special legal status was acquired by CADA through procedure (3).

The functional responsibilities assigned to the Command Area Development Authorities were as follows :

- Modernisation, maintenance and efficient operation of the irrigation system upto the outlet of one cusec capacity.
- Maintenance of main and intermediate drainage system.
- Development of field channels and field drains within the command of each outlet.
- Land leveling on outlet command basis wherever necessary according to the crops to be grower and the method of irrigation.
- Consolidation of holdings and redrawing of field boundaries on an outlet command basis, where necessary.
- Implemntation of rotation/warabandi and fair distribution of water to individual fields.
- Development of ground water to supplement surface irrigation.
- Selection and introduction of suitable cropping practices.
- Strengthening of extension and input supply services and credit facilities.
- Development of marketing, processing and communication facilities.
- Preparing individual programmes of activities for small farmers, marginal agricul ture labour.
- Diversification of agriculture and development of allied activities like animal husbandary, farm-forestry and poultry.

The CADA programme with the above objectives was launched initially with 60 major and medium projects with a CCA of 13 million ha in 1974-75. It was extended to 76 major and medium projects with a CCA of 15 million ha in 16 states and one union territory at the beginning of the sixth plan (1980-85). As of September 1997 the CADA activities extend to a cultivable command area (CCA) of about 21.78 million ha covering 217 irrigation projects in different states (CAD NEWS, 1998)

ORGANISATIONAL MODELS, THEIR MERITS AND CONSTRAINS.

The responsibilities assigned to CADAs, as discussed earlier, are enormous dealing with the complete gamut of irrigated agriculture, equity and social justice to farmers of all categories. To implement these functions, financial resources were not a constraint because finances are provided by GOI to the States/Union Territories under the centrally sponsored CAD programme on matching basis for selected items of activitiy

The organisational model for the CAD adopted varies from state to state. However, two distinct approaches are : (a) the CAD being a coordinating agency, as in most of the states or (b) its being a controlling authority for all the concerned departments as in the case of Rajasthan and Madhya Pradesh. In their preoccupation with OFD works, most of the state governments placed only the agricultural staff and the budget for OFD works under the CADA which did not have any administrative control over the irrigation personnel (Jayaraman et al, 1982). The adequate administrative coordination with Irrigation Department personnel could be achieved only when CADA happened to be placed under the direct control of the state Irrigation Department itself, as in the state of Maharashtra. In states like Gujarat and Maharashtra, where decentralised democratic administrative system has been operating, the CADAs receive agricultural extension assistance from the local self government institutions.

According to Singh (1978), among all the state CADAs in India, the Rajasthan State model seems to have a more self contained and unified chain of command. The CADA personnel are drawn from the Irrigation, Agriculture, Cooperatives, and Revenue Department. Citing the examples of Tamil Nadu, Punjab and Haryana where the production achievements are among the best inspite of these states not having CAD authorities, Kathpalia (1990) argues that it would be better to have a good coordinating agency for each project rather than a CAD authority. He suggests that "A multidisciplinary team be located in the WALMI/IMTI of a state ... (who) should carry out the diagnostic analysis, prepare the project, get it approved and later monitor the progress." The author of this Report does not subscribe to this view for, while the WALMIs or other state training institutes can and some do undertake studeis on somewhat similar lines in one or two selected irrigation commands under the Action Research programme, transferring the above responsibility on regular basis which is part of CAD programme to WALMIs would imply their stretching out too far beyond their capacities and outside their mandate. The state training institutes were established to provide in- servie training in land and water management . Their Action Research Programmes are geared to apply the land and water management concepts and methodologies on selected live irrigation projects and at the same time enable their trainers, as a learning process, to develop case studies and to continually update their training modules on the basis of the experience so gained.

Indian Institute of Management, Ahemadabad (1988) in their study on evaluation of CAD programme have observed that the desired integration between the various component functions in the CADA particularly between irrigation and agriculture has not been achieved. Such integration cannot be achieved by simply bringing together persons on deputation from other departments. With staff from different disciplines within CADA, and in the absence of a genuine willingness and commitment to function as on interdisciplinary team, personnel often have to pull in opposite directions. The essential pre-requisites for a multidisciplinary team to function as an effective and sustainable interdisciplinary team are the three C's : commitment , co-operation and communication. In the absence of these pre- requisites, personnel overtime become frustrated and attempt to leave CADA and join their respective parent departments. It is, therefore, not surprising that the IIM study has found the implementation of CAD programme in most states to be slow.

It has also been commented in the above referred report that the present organisational structure top heavy, bottom thin, and linkages at various levels weak. It has suggested that all irrigation related functions should be directly under CADA and emphasised the urgent need to professionalise management, sufficient number of specialists be included for the core functions and their responsibilities be clearly defined for which they should be accountable.

The report further mentions that appreciable contribution been made by OFD works in terms of bringing larger area under irrigation and making water available to more number of farmers thereby improving the cropping pattern, intensity and yields; however, the implementation of OFD works has been slow, their maintenance poor the targeted productivity and cropping patterns neither realistic nor implementable in many cases due to unreliable irrigation supply resulting in only limited increase in the farm income as consequences of CAD programme. The uncertainty of irrigation supplies have been found to be mainly due to deficiencies in design, lack of control structures and measuring devices, faulty demand estimation, absence of water distribution network within outlet commands and lack of proper maintenance of the structures.

Since the constructions of OFD works has been done by the Government agency without farmer's participation or consent - in most of the cases heretofore - the farmers have often been reluctant to take up the maintenance of the field channels and they rather expect the government to do it. On the other hand, high administrative cost procedures government agency to supervise and maintain the FCs. In the light of such difficulties, the need for motivating and organising farmers to form water users' associations or societies at the outlet level and a federation of such societies at the minor level is being increasingly felt with a view to turn over the full responsibility of water distribution and O & M below the outset/ minor level to the beneficiaries. Experiments on these lines have recently been carried out in some irrigation commands and useful lessons drawn from such case studies, which present stories of both success and failure, can be used for formulating modalities for replicable success stories elsewhere. The various issues concerning formation of farmers' organisations for better water use management are already discussed separately in section VII of this Report.

RECENT DEVELOPMENT :

In order to give philip to the wider implementation of the Centrally Sponsored CAD programme in various states in the Country, the following important positive steps have been taken by the Ministry of Water Resources.

State Level Interaction Meetings :

There had been a persistent feeling in the past that there was a lack of dialogue between the Union Ministry of Water Resources and Department of CAD in the State Governments. There is a lot to be learnt by such interactions. On the one hand mutual problems in the implementation of the CAD programme can be discussed and on the other hand best practices of one state can be disseminated among other states leading to cross fertilisation of ideas. With this objective in mind that the idea of holding state level interaction meetings has recently emerged.

Such interaction meetings were held at Bangalore in Karnataka, Panji in Goa and Pune in Maharashtra in the month of January 1998 and Bhubaneshwar in Orissa and Bankura in West Bengal in March 1998 (CADNEWS, 1998)

Inter-Ministerial Coordination Committee :

As mentioned in an earlier section, the Government of India constituted through its Notification No. 7-3/97-CAD dated 28th April 1997 an Inter-ministerial Coordination Committee for the implementation of the Centrally Sponsored CAD programme and Management of Waterlogged, Saline and Alkaline land in the commands of irrigation projects under the Chairmanship of Additional Secretary, Ministry of Water Resources. The terms of references of this Co-ordination Committee are as follows :

i) To coordinate different activities of CAD Programme.
ii) To suggest steps for effective implementation of CAD programme.
iii) To examine the problems of waterlogging, salinisation, etc. under commands. measures for the same covered under the CAD programme and suggest remedial preventive and
iv) To examine projects received from the states for reclamation of waterlogged. areas and taking steps to give suggestions and sanction them

v) To monitor the progress of reclamation of such areas alongwith other CAD activtieis.

This Co-ordination Committee is to meet at least once in 3 months (CADNEWS, 1997).

Central assistance amounting to Rs. 12648 lakhs for implementation of CAD Programme was released for the year 1997-98 on the basis of proposals received from 17 states (Table 9). An agreement has been signed between Mani Media, New Delhi and Ministry of Water Resources in March 1998 for production of two documentary films, one each on Command Area Development Programme and Participatory Irrigation Management covering identified projects in the states of Andhra Pradesh, Assam, Gujarat, Haryana, Kerala, Maharashtra, Orissa Rajasthan and Uttar Pradesh (CADNEWS, 1998).

Table : 9 Central assistance to States (1997-98) for implementing CAD Programme

Sr.No.	State	Amount of Grant (Rs.in lakhs)
1)	Andhra Pradesh	3839.57
2)	Assam	124.00
3)	Goa	20.00
4)	Gujarat	97.11
5)	Haryana	1116.85
6)	Himachal Pradesh	73.07
7)	Jammu & Kashmir	189.00
8)	Karnataka	437.87
9)	Kerala	200.00
10)	Madhya Pradesh	6.25
11)	Maharashtra	298.30
12)	Manipur	86.91
13)	Orissa	231.47
14)	Rajasthan	2226.65
15)	Tamilnadu	552.46
16)	Uttar Pradesh	3057.83
17)	West Bengal	90.00
	Total	**12648.24**

EPILOGUE

As we step in the new millennium, it is important to take an analytic review of the water management practices in command areas in view of progressively growing demand to increase food production while at the same time availability of water, the most important resource input for agriculture, diminishing with time.

Effective water management needs to be measured in terms of sustained production of irrigated crops can be more specifically reflected in terms of total production per unit water per unit land area. Along with maximising crop production, water management has to also focus on the equity of the benefits of irrigation among farmers of all classes and in different parts of (locational equity) of the irrigation command. Conservation of scarce soil and water resources and mitigation of negative environmental impacts is also of concern to appropriate water management command areas.

Efforts to improve utilisation of irrigation potential created and the efficiency level of various projects need to be intensified. Providing adequate micro distribution network, evolving appropriate design of cropping pattern, irrigation scheduling based on actual crop water requirement using soil- water-crop relationships instead of adhoc norms of duty (AI/DC), adopting suitable model of rotational water supply considering local conditions, land leveling and efficient water application methods, taking suitable preventive measures to control water logging and soil salinity problems, effective implementation of conjunctive use of surface and ground water and participatory irrigation management are key to improving utilisation of the irrigation potential and overall efficiency of the projects and sustained agricultural development in the command areas.

Water management in areas encompasses various inter-related and interactive disciplines and hence Command Area Development Programme of the Ministry of Water Resources, GOI which is based on the interdisciplinary approach, can effectively address the above mentioned facets of water management. Effective implementation of the centrally sponsored activities of CAD programme in the projects presently covered under the programme needs to be ensured and gradual extension of the programme to other projects in various states is very much needed. Recent initiatives of MOWR in organising State Level and interstate meetings and establishing Inter-ministerial Coordination Committee are positive steps in this direction. Some state governments are already taking advantage of central assistance provided under

CAD programme for implementing various schemes related to reclamation of water-logged and saline lands and PIM. Similar efforts should also be made by other states by submitting proposals to MOWR for such schemes in their project commands.

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