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Development and application of a software, EQUITA for equitable water distribution in canal command areas

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ABSTRACT

The principle of equitable water distribution is to supply predetermined quantity of water at scheduled time. The equity may be on the basis of distribution of operating time of outlets and volume of water in proportion to the size of holding, or in proportion to the requirements of beneficiaries. Software EQUITA was developed to prepare rosters for equitable water distribution in outlet command areas, within the overall framework of rotational water distribution system. Different levels of equity require different amount of data regarding beneficiaries, their land holdings, watercourses, conveyance losses and the crops grown. The developed software EQUITA can be used to prepare rosters for water distribution for beneficiaries of outlet command areas to achieve desired equity, based on the availability of data.

National Water Policy, 1987 states "Water distribution in irrigation commands should be done with due regards to equity and social justice. Disparities in availability of water between head reach and tail reach farmers and between large and small farmers should be obviated by adoption of a rotational and equitable water distribution". Several water distribution methods are followed in different canal commands in the country, some of these are *warabandi, shejpali*, block system, localised system and zonal system. Excepting *warabandi,* that attempts to achieve time equity, all other methods need major modifications to achieve different levels of equity in water distribution (Rajput and Michael, 1986).

Efficient utilization of canal water requires that the beneficiaries are apprised in advance their entitlements of water and the date, time and duration when they are expected to receive it. But, excepting *warabandi* and to some extent *shejpali*, no other water distribution system clearly spells out the policy of water distribution indicating the amount and time of availability of water to the beneficiaries

Equity in water distribution has been loosely referred to and is considered at par with equality, equitability, fairness, evenhanded dealing and adherence to principle of justice. Equity needs to be built in to the system of water distribution devoid of any interference from human control, government agency or a system plays a vital role and is proper functioning is crucial to satisfactory distribution of water. The factor of equity, therefore should be an integral component of the water distribution schedule of the outlet (Rajput, 1992).

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Preparation of the rosters for water distribution among a large number of beneficiaries is a time consuming process. Considerations of additional parameters for achieving different levels of equity makes the task more cumbersome, rendering it to be an appropriate case for use of computers (Palmer, 1986). Keeping the basic structure of *warabandi* same for its known merits, a user friendly and interactive software EQUITA was developed in C++ computer language to prepare the rosters for equitable water distribution in outlet command areas.

METHODOLOGY

The software EQUITA was developed to prepare rosters for water distribution to different beneficiaries to achieve 1. Proportional equity, 2. Time equity, 3. Volumetric equity, 4. Requirement equity and 5. Social equity. Water distribution schedules are planned to start from Sunday 0000 h and to continue till the following Saturday 2400 h i.e. for 168 hours in a weekly rotation of on and off irrigation cycles as in regular *warabandi.* Irrigation schedule continues round the clock. The water distribution starts with the water course at the highest reach and proceeds to water courses at successively lower reaches. The sequence of water distribution to different fields served by a particular water course is also in the similar order i.e. the field situated at the head reach of a watercourse gets irrigation supply first and then those situated at its successively lower reaches.

Proportional equity

Having fixed the sequence of turns of different beneficiaries (i = 1,2,3,.....,n), as discussed above, time allotments of each beneficiary (It_i) out of total operation time of 168 hours of an outlet (OT) were estimated in proportion to the sizes of his land holding (A_i) to the total command area (TA) to achieve proportional equity as follows:

$$It_1 = OT \times (A_t / TA) \qquad \ldots (1)$$

Time equity

Present day *warabandi* incorporates the watercourse filling time allowance (f_i) as well as the watercourse draining time allowance (d_i) in addition to the proportionality of the size of land holdings of different beneficiaries. Thus, it is the net operation time (NOT), rather than the operation time (OT) which is allotted to the beneficiaries in proportion to their size of holding, irrespective of the location of their holdings in the command area. According to this procedure, the various parameters are calculated as follows:

$$NOT = \left\{ OT - \left(\sum_{i=1}^{n} f_i - \sum_{i=1}^{n} d_i \right) \right\} \qquad \ldots(2)$$

$$NAT_1 = \frac{NOT}{\sum_{i=1}^{n} A_i} \times A_i \qquad \ldots(3)$$

$$It_i = NAT_1 + f_i - d_i \qquad \ldots (4)$$

Volumetric equity

Equitable distribution of outlet's flow time (Eq. 4) does not result in equitable water distribution in terms of volume of water, owing to the seepage losses in the watercourses. Therefore, in EQUITA conveyance losses were also considered to achieve volumetric equity. The ratio of the outlets discharge (Q_0) and the flow

rates reaching different fields (Q_i) was considered as their respective seepage factors (SF_i) to account for the conveyance losses. Allotted time of different beneficiaries were then multiplied by their respective seepage factor to obtain revised allotted time (RT_i). Revised allotted times were then multiplied by the correction factor (CF) to adjust the shares of all the beneficiaries within the operation time of the outlet (Eq. 7). Distribution of irrigation water on the basis of these rosters (Eq. 9) will ensure delivery of volume of water in proportion to the size of different holdings and will thus achieve volumetric equity.

$$SF_i = \frac{Q_o}{Q_i} \quad \ldots (5)$$

$$RT_i = NAT_i \times SF_i \quad \ldots (6)$$

$$CF = \frac{\Sigma\, NAT_i}{\Sigma\, RT_i} \quad \ldots (7)$$

$$CT_i = RT_i \times CF \quad \ldots (8)$$

$$It_i = CT_i + f_i - d_i \quad \ldots (9)$$

Requirement equity

In general, the farm holdings are small in India. Yet traditionally the farmers grow many crops of their choice and also leave some part of the land fallow in each season. In such a multi land use system, distribution of water equitably in terms of volume of water per unit area may not serve well from the point of view of maximizing the productivity of the available water. Estimation of water requirements of each beneficiary (WR_i) in a multi land use system was made on the basis of depths of irrigation (d_j) needed and cultivated area (A_j) of different crops (j = 1, 2, ...,m) in different holdings (Rajput and Michael, 1990). Time allotments for each beneficiary to achieve requirement equity were then estimated in proportion to the water requirement of each beneficiary in total water requirement of the command (TWR) as follows:

$$WR_i = \sum_{j=1}^{m} d_j \times A_j \quad \ldots (10)$$

$$It_i = \left(\frac{WR_i}{TWR} \times NOT \right) + f_i - d_i \quad \ldots (11)$$

Social equity

For achieving social equity (i.e. to distribute available water equally among all the beneficiaries), available volume of water was divided equally among different beneficiaries irrespective of their size of holding or magnitude of water requirement. Time allotments to different beneficiaries were estimated as follows:

$$It_i = \frac{CT_i}{n} + f_i - d_i \quad \ldots (12)$$

Development of the Software EQUITA

The developed software EQUITA is user friendly and interactive. It was written in C++ computer language to prepare the rosters for water distribution to achieve proportional equity, time equity, volumetric equity, requirement equity and social equity. EQUITA adjusts the schedules developed on any criteria within the normal operation duration of an outlet i. e. 168 hours of a week.

EQUITA seeks data, one by one, in the form of the responses to the queries made by it based on the level of equity desired by the user. Rosters for water distribution on proportional equity need the data about the sizes of different land holdings. For achieving time equity, data on the length of watercourses is also needed. If the volumetric equity is to be achieved additional information about the conveyance losses is also needed. In case of requirement equity, data about the crops grown and their corresponding cultivated areas are needed. A complete sequence of requirements of data input, computations and output from EQUITA are presented through a flowchart in Fig 1. The data can be provided through the computer keyboard but the output from EQUITA can be seen on the computer screen as well as can be taken as a print out from the output file.

Application of Software EQUITA

EQUITA was used to prepare the water distribution schedule for achieving different levels of equity in water distribution in an outlet command having only six beneficiaries and with the other input data as listed in Table 1.

Output of the Software EQUITA

The software EQUITA was run using the input data as listed in Table 1. The output resulting from its use is presented in Table 2. The resulting schedules are in calendar days and time and hence may be readily understood by the users. It may be noted from Table 2 that in all the cases the total schedule is adjusted within 168 hour so as to match with the overall functioning of the rotational water distribution system. Weekly on and off rotation is also very helpful for the beneficiaries to remember their scheduled time. It may be difficult to introduce the rosters prepared using the EQUITA software where night irrigation and rotational water distribution are not followed. But in areas where rotational water distribution is followed, it is quite possible to use the developed software to achieve higher levels of equity in water distribution. For example, achieving volumetric equity where warabandi is

Table 1 Sample input data

Sl. No.	Survey No.	Area, ha	Length of watercourse, m			Cultivated area, ha		
			Total	Net	Drain	Crop 1	Crop 2	Crop 3
1	101	1.50	0	0	0	0.50	0.25	0.25
2	102	1.75	175	175	0	0.75	0.20	0.20
3	103	0.75	250	75	0	0.25	0.25	0.25
4	104	1.00	350	100	0	0.50	0.30	0.20
5	105	0.55	400	50	0	0.20	0.05	0.35
6	106	1.25	525	125	525	0.45	0.30	0.50

Operation duration of the outlet = 168.00 h Watercourse filling time constant = 0.24
Discharge rate of the outlet = 30 lps Conveyance constant = 7.50
Water requirements of Crop 1 = 8.5 cm, Crop 2 = 5.5 cm and Crop 3 = 7.0 cm

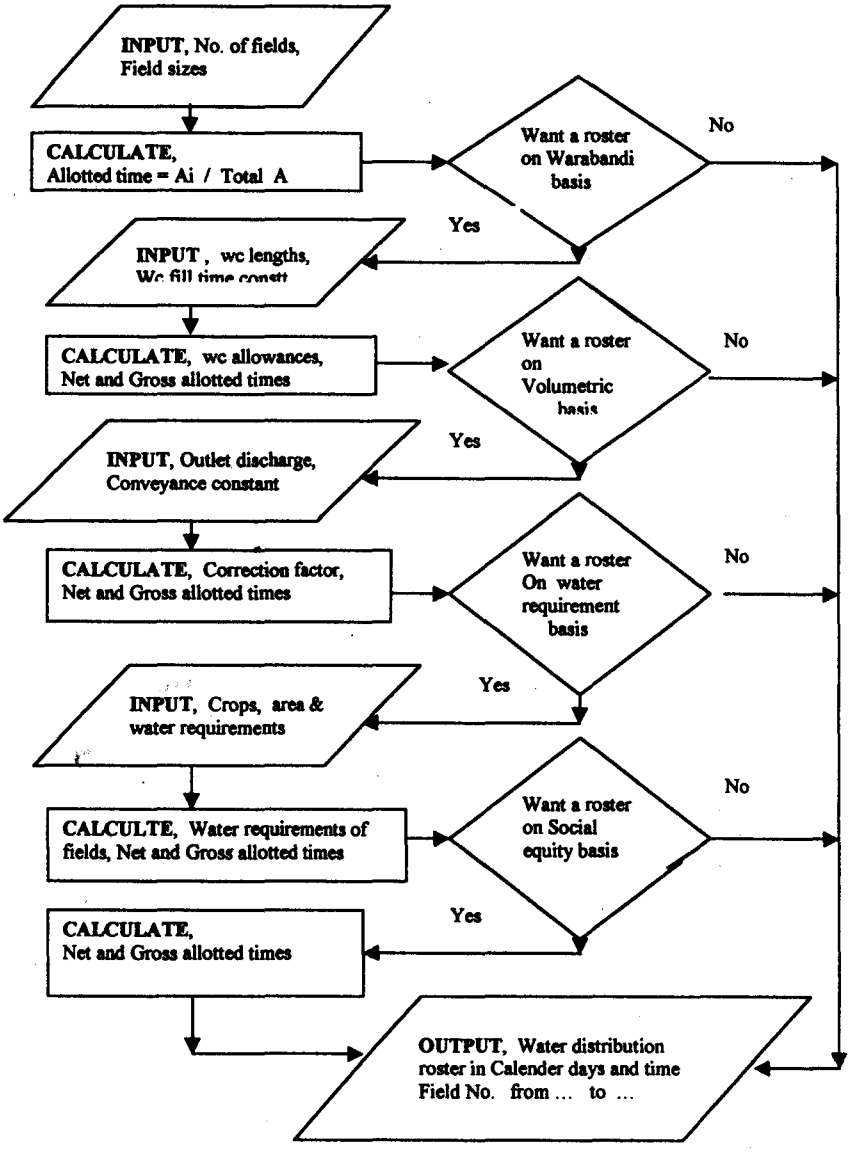

Fig. 1 Computation sequence of equitable water distribution software EQUITA

Table 2 Output of software EQUITA

WATER DISTRIBUTION SCHEDULE on Proportional Equity basis								
Survey no. 101	□	Sunday	0 h	0 min	to	Monday	13 h	3 min
Survey no. 102	□	Monday	13 h	3 min	to	Wednesday	8 h	17 min
Survey no. 103	□	Wednesday	8 h	17 min	to	Thursday	2 h	49 min
Survey no. 104	□	Thursday	2 h	49 min	to	Friday	3 h	31 min
Survey no. 105	□	Friday	3 h	31 min	to	Friday	17 h	7 min
Survey no. 106	□	Friday	17 h	7 min	to	Saturday	24 h	0 min
WATER DISTRIBUTION SCHEDULE On Time Equity Basis								
Survey no. 101	□	Sunday	0 h	0 min	to	Monday	12 h	55 min
Survey no. 102	□	Monday	12 h	55 min	to	Wednesday	8 h	24 min
Survey no. 103	□	Wednesday	8 h	24 min	to	Thursday	3 h	3 min
Survey no. 104	□	Thursday	3 h	3 min	to	Friday	3 h	54 min
Survey no. 105	□	Friday	3 h	54 min	to	Friday	17 h	33 min
Survey no. 106	□	Friday	17 h	33 min	to	Saturday	23 h	59 min
WATER DISTRIBUTION SCHEDULE On Volumetric Equity Basis								
Survey no. 101	□	Sunday	0 h	0 min	to	Monday	6 h	0 min
Survey no. 102	□	Monday	6 h	0 min	to	Tuesday	22 h	34 min
Survey no. 103	□	Tuesday	22 h	34 min	to	Wednesday	16 h	59 min
Survey no. 104	□	Wednesday	16 h	59 min	to	Thursday	19 h	30 min
Survey no. 105	□	Thursday	19 h	30 min	to	Friday	10 h	40 min
Survey no. 106	□	Friday	10 h	40 min	to	Saturday	24 h	0 min
WATER DISTRIBUTION SCHEDULE on Requirement Equity Basis								
Survey no. 101	□	Sunday	0 h	0 min	to	Sunday	23 h	15 min
Survey no. 102	□	Sunday	23 h	15 min	to	Tuesday	7 h	45 min
Survey no. 103	□	Tuesday	7 h	45 min	to	Wednesday	4 h	3 min
Survey no. 104	□	Wednesday	4 h	3 min	to	Thursday	10 h	32 min
Survey no. 105	□	Thursday	10 h	32 min	to	Friday	5 h	42 min
Survey no. 106	□	Friday	5 h	42 min	to	Saturday	24 h	0 min
WATER DISTRIBUTION SCHEDULE On the basis of Social Equity								
Survey no. 101	□	Sunday	0 h	0 min	to	Sunday	22 h	10 min
Survey no. 102	□	Sunday	22 h	10 min	to	Tuesday	0 h	1 min
Survey no. 103	□	Tuesday	0 h	1 min	to	Wednesday	3 h	8 min
Survey no. 104	□	Wednesday	3 h	8 min	to	Thursday	8 h	31 min
Survey no. 105	□	Thursday	8 h	31 min	to	Friday	14 h	56 min
Survey no. 106	□	Friday	14 h	56 min	to	Saturday	23 h	59 min

THANKS FOR USING SOFTWARE *** EQUITA ***

followed requires only additional information about the conveyance losses in the water-courses.

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