28th WEDC Conference Kolkata (Calcutta), India, 2002

SUSTAINABLE ENVIRONMENTAL SANITATION AND WATER SERVICES

Irrigation depths for heterogeneous irrigation schemes

Ian Smout and S. D. Gorantiwar, WEDC

THE WATER AVAILABLE for irrigation in the irrigation schemes of semi arid regions is limited. These irrigation schemes are further characterised by heterogeneity in soils, crops to be irrigated and weather parameters influencing water demand and supply and large number of users. Therefore the optimum allocation of water resources and their distribution to different crops and to different users in the command area, and scheduling the irrigation water deliveries on scientific basis and according to the pre-decided strategy are important aspects of irrigation water management in these irrigation schemes.

The distribution of water in the irrigation schemes in South Asia is based on either of two methods: demand and supply. In demand method, the users or farmers decide upon his/her demand and in the supply method, irrigation scheme authorities decide upon the supply of water to the users or farmers. The Warabandhi system of water distribution practised in the Northern India and Pakistan is supply based where in the users adjust their demand according to the supply. The Shejpali system of water distribution practised in Central and South India is demand based wherein irrigation authorities in the irrigation scheme take care of supplying the demand of each user. In the state of Maharashtra, the Shejpali system is followed (Mandavi, 1998). In this system the irrigation authorities estimate the water available for irrigation before the beginning of the irrigation year. The users in the command area submit their applications for supply of water indicating the crops they wish to grow and the areas under those crops. The irrigation authorities allocate water to different farmers on the basis of the crops and the overall demand. The demands are estimated based on either a "fixed interval-fixed depth" or "duty" (duty is the area irrigated by unit flow of water over the crop growing season and mostly computed on the basis of full irrigation) approach and considering uniform characteristics of the command. Irrigation authorities make proportionate reductions in the irrigated area proposed by the farmers if the total demand is higher than the water available for irrigation, which is usually the case. As the water is allocated on the basis of fixed depth or duty without taking into consideration the soil types, appropriate losses in application, distribution and conveyance processes, the capacity of water distribution system etc., the allocation and schedules are not appropriate and optimum. Hence users have a feeling that they are not getting their due share of water. This causes the users to develop the tendency to apply as much water as possible, as and when they get the supply. This disturbs the allocation and schedules.

It is possible to optimally allocate water to different crops and schedule the irrigation water deliveries, considering the complex climate-crop-soil relationship with the recent advances in irrigation modelling (Gorantiwar and Smout, 1996). In this paper the irrigation simulation-optimisation model (AWAM-Area and Water Allocation Model) developed by the authors (Gorantiwar and Smout, 1995 and Gorantiwar and Smout, 2002) was used to estimate the optimum depth of irrigation for allocating water according to the objectives (achieving maximum productivity with area proportionate water allocation) and developing the water delivery schedules considering the complexities in the irrigation scheme necessary

Area and water allocation model (AWAM)

The Area and Water Allocation Model, AWAM (Gorantiwar and Smout, 1995; and Gorantiwar and Smout 2002) was used for estimating the optimum depth of irrigation. The part of the model used for estimating the optimum depth of irrigation is described briefly below:

The model has the following four phases and is executed for each set of irrigation intervals over the irrigation season.

1. Generation of irrigation strategies
2. Preparation of irrigation programmes
3. Selection of irrigation programmes
4. Optimum allocation of resources

However, in the present study only two stages viz. preparation of irrigation programmes and optimum allocation of resources were used for deciding the optimum depth of irrigation.

1. Preparation of irrigation programme

The unit with similar climate (Region), soil (Soil group) and crop is termed as Crop-Soil-Region (CSR) unit, which is not a physical division of the irrigation scheme. The irrigation programmes, which consist of information on yield/benefits, are prepared for each CSR unit for different sets of irrigation depth per irrigation with the following two submodels. Different sets are obtained by varying irrigation depths from minimum and maximum permissible irrigation depth for each irrigation at some prescribed interval of irrigation depth. The irrigation depths are constant for all irrigations for particular set of irrigation depth.

- SWAB: This submodel simulates soil moisture in the soil root zone and estimates the actual crop evapotranspiration and the other related parameters in

response to the irrigation depth applied at each irrigation.
- CRYB: This submodel estimates crop yield and net benefits.

2. Optimum allocation of resources:
The entire irrigation scheme is physically divided into a number of smaller units called "Allocation Units" (AU) over which land and water resources are allocated. The climate is assumed to be uniform over the AU, but the AU may include different soils and crops. The climatic conditions may be different for different AUs. The need to divide the irrigation scheme into several allocation units arises due to the heterogeneous nature and large extent of the irrigation scheme and in order to make allocation of resources, water delivery schedules and management of the irrigation scheme efficient. The largest possible size of the AU is equivalent to the size of the irrigation scheme itself. The smallest size of the AU is the individual farm. The intermediate sizes are the command area of the secondary, tertiary and quaternary canals or their groups. This phase allocates land and water resources optimally to different crops grown on different soils in different allocation units, with the help of irrigation programmes obtained for different CSR units from Phases 1 through following three stages.

- Preparation of irrigation programmes for each CS unit of AU by modifying the irrigation programmes of the corresponding CSR unit considering the distribution and conveyance efficiencies.
- Allocation of the resources to each CS unit of AU with chosen objective(s) and constraints with the Resource Allocation (RA) submodel.
- The preparation of water release schedule for the canal system for the selected allocation plan

The irrigation scheme
The "Nazare Medium Irrigation Scheme" in a semi-arid region Maharashtra State of India was selected for the purpose of case study. The irrigation season of this irrigation scheme starts from the 15th October and ends on 14th October of next year. There are three distinct crop seasons within the irrigation season. These are Rabi, summer and Kharif. As little rainfall is received in Rabi season, the crops grown in this season are supplied with irrigation water for their growth. In summer season no rainfall is received but it is characterized with high evapotranspiration. The irrigations are given to a limited extent in the summer season. Most of the rainfall is received in Kharif (monsoon) season. Therefore crops grown in this season need one or two irrigations (protective irrigations) only. The irrigations during Kharif season are of little interest in this study as the reservoir fills during the Kharif season. Therefore for this scheme in this study, the irrigation season was considered to spread over Rabi and summer crop seasons.

The gross reservoir capacity and dead storage capacity of the reservoir are 22.313 and 5.684 Mm3, respectively. One main canal originates from the headworks. The full supply discharge and length of the main canal are 1.528 m3/s and 3.05 km, respectively. One distributory canal emerges from the main canal, the length of which is 11.75 km. The carrying capacity of the distributory canal is 1.528 m3/s. The cultural command area (CCA) of the irrigation scheme effectively 3539 ha. There are 28 direct outlets (4 on main canal and 24 on distributory canal) and four minors (all on distributory canal). There are 9 outlets on the minor. The details of the outlets on the minors could not be obtained. Therefore CCA of all 28 outlets and 4 minors were considered as allocation units, resulting in 32 AUs. The data related to allocation units in terms of different efficiencies (application, distribution and conveyance), soil types etc were obtained from different sources (Stofkoper and Tilak, 1992 and IRD, 1992). The climatological data was collected from the daily records of the Meteorological Observatory of the nearest agricultural university (Mahatma Phule Agricultural University, Rahuri). The same data series was used for the reservoir (for estimating the water evaporation) and command area (for estimating the reference crop evapotranspiration and bare soil evaporation). The climate over the entire command area was assumed as uniform. Thus there was only one 'Region'. The command area is characterized with four different types of soils. In the present study as two crop seasons formed the irrigation season, gram, sorghum, onion, wheat (Rabi crops), groundnut and sunflower (summer crops) were considered in the analysis. The fixed cropping distribution (gram-36%, sorghum-29%, onion-14% and wheat-21% in Rabi; and Sunflower–33 % and groundnut-66% in summer season) was considered. It was estimated that 55% of water is utilised in Rabi and 45% water is utilised in summer season on the basis of general cropping pattern in the irrigation scheme.

Results
The allocation plans were obtained for seven sets of irrigation interval. These are:

- 14 days in both Rabi and summer seasons (I-14),
- 21 days in Rabi season and 14 days in summer season (I-21-14),
- 21 days in both Rabi and summer seasons (I-21),
- 28 days in Rabi season and 21 days in summer season (I-28-21),
- 28 days in both Rabi and summer seasons, (I-28),
- 35 days in Rabi season and 28 days in summer season (I-35-28) and
- 35 days in both Rabi and summer seasons (I-35)

The values of productivity, which is the ratio of the estimated total net benefits in monetary units of the alloca-

Table 1. The productivity and estimated optimum depth of irrigation for different sets of irrigation interval

Irrigation interval set no.	Irrigation interval (days)		Productivity	Optimum irrigation depth per irrigation (mm)	
	Rabi	Summer		Rabi	Summer
I-14	14	14	1.00	50	110
I-21-14	21	14	0.96	70	110
I-21	21	21	0.93	70	140
I-28-21	28	21	0.87	80	140
I-28	28	28	0.74	80	140
I-35-28	35	28	0.62	90	140
I-35	35	35	0.61	90	-

tion plan to the estimated maximum total net benefits, are obtained for different allocation plans. The productivity and estimated optimum depth of irrigation for different sets of irrigation interval are presented in Table 1.

The maximum total net benefits were obtained for the allocation plan for the irrigation interval of 14 days in Rabi and summer seasons (I-14). Therefore the productivity of the allocation plan for I-14 is 1.00. The irrigation interval of 35 days in summer season was not suitable for the crops in summer season. Table 1 shows the values of the optimum irrigation depth for different sets of irrigation interval. The optimum irrigation depth is less in Rabi season and more in summer season. The optimum irrigation depth increases with the irrigation interval. The productivity is highest for the irrigation interval of 14 days in both Rabi and summer seasons and decreases with the irrigation interval.

The irrigation depth of 70 mm per irrigation at an interval of 21 days during Rabi season is proposed for the Nazare Irrigation Scheme (Stofkoper and Tilak, 1992). During summer season same irrigation depth (70 mm) at reduced interval of 14 days was considered. The optimised irrigation depths for the irrigation interval of 21 days in Rabi and 14 days in summer seasons obtained from the model for the cropping distribution followed in the irrigation scheme, were 70 mm per irrigation in Rabi season and 110 mm per irrigation in summer season. Coincidentally the irrigation depth estimated by the model for Rabi season matched with the depth adopted for this irrigation scheme. However in summer season though the irrigation interval is reduced, 70 mm depth is not optimum. It is estimated from the model that the water allocation based on optimum irrigation depth of 110 mm could give about 40% more total net benefits in summer season. Thus it is possible with AWAM model to estimate the optimised depth of irrigation for particular set of irrigation interval and also select the set of irrigation interval, which provides maximum productivity.

References

GORANTIWAR, S.D. and I.K. SMOUT, (1995). Water resources management of irrigation schemes in semi-arid and arid regions. Proceedings of the Regional Conference on Water Resources Management held at Isfahan University of Technology, Isfahan, Iran during 28-30 Aug., 1995:413-422.

GORANTIWAR,S.D. and I.K. SMOUT, (1996). Land and water allocation models: Concept and review. Proceedings of the International Agricultural Engineering Conference held in Pune, India during 9-12 Dec., 1996, Vol.II:1135-1143.

GORANTIWAR, S.D. and I.K.SMOUT, (2002). The optimum irrigation water allocation for the heterogeneous irrigation schemes with limited water supply. Proceedings of the Third International Conference on Water Resources and Environmental Research held at Dresden University of Technology, Dresden, Germany during 22-25 July, 2002, Vol.I: 392-396.

MANDAVIA, A.B., (1998). Modernization of irrigation system operational management by way of canal automation in India. Modernisation of irrigation system operations: proceedings of the 5th ITIS network international meeting, Aurangabad, 28-30 October 1998 the Food and Agriculture Organisation of the United Nations, Regional Office for Asia and the Pacific, Maliwan Mansion, 39 Phra Athit Road Bangkok 10200, Thailand.

STOFKOPER, J. and TILAK, M.B.G., (1992). "A Report on Action Research Programme in Nazare Medium Irrigation Project, Maharashtra State." Pune Irrigation Division, Pune, Maharashtra State, India.

IAN SMOUT, WEDC.
S.D.GORANTIWAR, WEDC.