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Design and evaluation of check basin irrigation system using SURDEV software model

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■ **ABSTRACT :** For efficient and judicious use of water resources, an accurate design and high quality optimization of the check basin irrigation system is necessary. BASDEV of SURDEV model was used to evaluate the check basin irrigation system of size 30 m × 45 m for medium soils in Bapatla, Guntur District, Andhra Pradesh, India, for an irrigation application depth of 75 mm with a stream size of 10, 20, 30, 40, 50, 60, 70, 80 and 90 lps. To optimize the efficiency of the design, the model was run varying the basin design dimensions and cutoff times. The outputs of BASDEV, is intended to improve the overall efficiency of basin irrigation system, provided optimum field dimensions for border irrigation in medium textured soils.

■ **KEY WORDS :** Application efficiency, BASDEV, Basin irrigation, Surface irrigation, Water Management, SURDEV

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Recognizing the fast decline of irrigation water resources for agriculture and increasing demand for water from different sectors, it is important to save water and increase the existing water use efficiency in Indian agriculture. India has an average annual rainfall of 1083 mm. The ultimate irrigation potential of the country has been estimated to be 139.5 mha. Merriam (1977) and Kay (1990**)** stated that low efficiencies in surface irrigation are not inherent to the method but are due to poor design and management. Poor designs and management are generally responsible for inefficient irrigation, leading to wastage of water, water logging, salinization and pollution of surface and ground water resources. The poor design, implementation and management are generally responsible for in sufficient irrigation, leading to the wastage of water, water logging, salinisation and pollution of surface water and groundwater resources (Hassan *et al.*, 2010 and Hamed *et al.*, 2011*)*. Surface irrigation that covers about 90 per cent of the total irrigated land in India. An accurate and suitable design of the surface irrigation systems can save more water and increase the irrigated land area.

A number of surface irrigation based computer software to mimic the complexity in designing have been developed in the past. Some of the early developed software in the field of surface irrigation include: BASCAD (Boonstra and Jurriens, 1988*)*, BICADM (Maheshwari and McMahon, 1991), FISDEV (Zerihun and Feyen, 1992), BASIN (Clemmens *et al.*, 1995), BORDER (Strelkoff *et al.*, 1998) and SURDEV (Jurriens *et al.*, 2001). All the above software has been developed only to design any one of the three surface irrigation systems (furrow or border or basin). However, SIRMOD (Walker, 2003) and SRFR/WinSRFR (Bautista *et al.*, 2009) are the most comprehensive software developed so far to design three types of surface irrigation systems (furrow, border and basin). This software are good for research and design but are still lacking in the step wise design process which are very essential for student learning. Software for the design and evaluation of surface irrigation systems (furrow, border and basin) along with the design of water conveyance systems (open channel and pipe line) is developed to assist users in educational and research organizations. The software named as 'SIDES' is developed using Visual Basic 6 programming language. The developed software for the design of surface irrigation systems is based on the volume balance approach and is tested using the available published datasets. Results obtained using the SIDES matched well with the published datasets for all the designs. Besides the design parameters at maximum application efficiency, SIDES also provides detailed tabular and step wise design results. (Sirisha *et al.,* 2014). SIDES uses two point method *(*Elliott and Walker, 1982) for evaluation of Kostiakov–Lewis infiltration parameters (k and a). In SIDES, windows for the evaluation of the Kostiakov–Lewis infiltration model parameters for furrow, border and basin irrigation systems were developed.

The design and evaluation of basin irrigation system under different conditions: soil type -light, medium and heavy; stream size- 10, 20, 30 and 60 Ips; length - 60,120, 150 and 240 m. The outputs of BASDEV provided optimum field dimensions for irrigating the small-drilled grain crops. Rectangular basins of 60 m length and 5-8 m width should be preferred for different flow rates in light soils. In medium soils, basin lengths of 90 m at lower flow rates and 120 m for higher flow rates should be selected. Maximum water application efficiency can be achieved in heavy soils. Square basins should be preferred only in heavy soils (Kaur and Gulati, 2005). Border irrigation method is used to irrigate most ofthe field crops. Accurate design and high quality optimization of the border irrigation system is necessary for efficient and judicious use of water resources (Rajan *et al.*, 2007).

Field trials in India have shown that basin irrigation is practicing and suitable in most areas of the country. Water is retained in the basin until it soaks into the soil. The size, shape and width of basins is mainly determined by the land slope, soil type, available discharge, required depth of irrigation application and farming practices (Brouwer *et al.,* 1988).

In farmer's fields, by and large surface irrigation is practiced where efficiency seldom exceeds 50 per cent. The design of surface irrigation systems requires many input parameters and needs intensive engineering calculations (Khanjani and Barani, 1999). Success of the techniques depends on a proper design and operation of surface irrigation systems at field level, to help farmers achieve good crop yields, use precious water resources more efficiently and limit water logging and salinization. A great potential for better utilization of basin irrigation system is possible by adopting accurate design that can result in higher efficiency. Through the advanced irrigation systems like micro, central pivot irrigation systems provide the highest efficiency in developing nations, majority of agricultural land area is still cultivated under surface irrigation methods only. Paddy is grown under check basin irrigations systems which consume more water. Any measure contributing slight saving in paddy will yield in large saving of water in any country. The present study is taken up to design and evaluate the basin irrigation system for sandy loam soils of Bapatla and cross verify with the BASDEV module of SURDEV model.

■ METHODOLOGY

Already existing basin irrigation plots with medium soil (sandy loam) available in Agricultural College Farm, Bapatla, Guntur district, Andhra Pradesh were selected for the present study. The check basin irrigation system fields were of size 30 m × 45 m, for an irrigation application depth of 75 mm with a stream size of 10, 20, 30, 40, 50, 60, 70, 80 and 90 lps.

SURDEV software :

SURDEV (Jurriens *et al.*, 2001) is a computer package for the design, operation and evaluation of surface irrigation system. The SURDEV computer package was developed by the International Institute for Land Reclamation and Improvement (ILRI), presently Alterra, Wageningen. The package enables the user to simulate many of the problems involved in the practice of all the three surface irrigation methods. In addition to simulations, SURDEV performs calculations of the optimal flow rates, field lengths, cut-off times, minimum and maximum depth of irrigation necessary in surface-irrigation situations.

The SURDEV programme package that accompanies three programmes BASDEV (for level basins), BORDEV (for sloping borders) and FURDEV (for graded furrows). Together, they enable the user to design, operate and evaluate surface irrigation systems. The present study is mainly focused on BASDEV module.

BASDEV module:

BASDEV (Jurriens *et al.,* 2001) package enables the user to simulate many of the problems involved in the practice of basin irrigation.

When a calculation module is selected, BASDEV displays two windows namely Field Parameters and Input Decision Variables (Fig A).Field parameters include the infiltration characteristics, the surface roughness or flow resistance and the required irrigation depth. A final choice may be restricted by the cost of land grading or the orientation of the fields, for instance. The value of Manning's roughness co-efficient, n, can be specified in the *Field Parameters* window. Accepted values range between 0.01 and 0.50. The required depth to be infiltrated at the end of the basin is given as the last input in the *Field Parameters* window. This target is determined outside BASDEV, as indicated in the accepted range is between 40 and 500 mm.

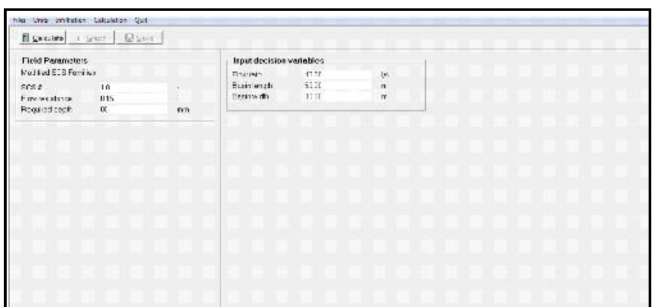

Fig. A : Various main options BASDEV module

The decision variables in surface irrigation are normally the field dimensions (length and width), flow rate and cut-off time. Each of these parameters appear under the heading *Input Decision Variables* depends on the selected calculation mode.

Calculation modes :

BASDEV can be run in four modes namely Flow rate, Dimensions, Cut-off time and minimum depth. Calculation Mode 1 is primarily for design purposes when the dimensions of the basin are known and want to know the approximate flow rate that is needed to achieve a reasonable performance. The programme will also give the required cut-off time and the primary performance indicators as well as various depth and time parameters.

Calculation Mode 2 is to know the approximate basin dimensions that are needed to achieve a reasonable performance when flow rate is already known. The program will also give the required cut-off time, together with the primary performance indicators and infiltrated depths.

Calculation Mode 3 is one of the two main modes of BASDEV. It will be the most frequently used and is the starting mode for the experienced user. Here, both the flow rate and basin dimensions are input. The required cut-off time is the resulting decision variable, while also the primary performance indicators and depth and time parameters are given.

In Calculation Mode 4, the cut-off time is specified as input in addition to the basin dimensions and the flow rate. The main indicator is the minimum infiltrated depth, occurring at the far end of the field. This mode is most suitable for a performance evaluation of an existing level basin irrigation system and for testing the performance sensitivity to a change in the field parameters. Together, Modes 3 and 4 constitute the core of BASDEV.

Output window :

Once all input is entered, pressing F2 will perform the calculations and output. The screen again shows the two input windows, but a third window will be added showing the results (Fig. B). The graph window of output gives graphical representation of output (Fig. C).

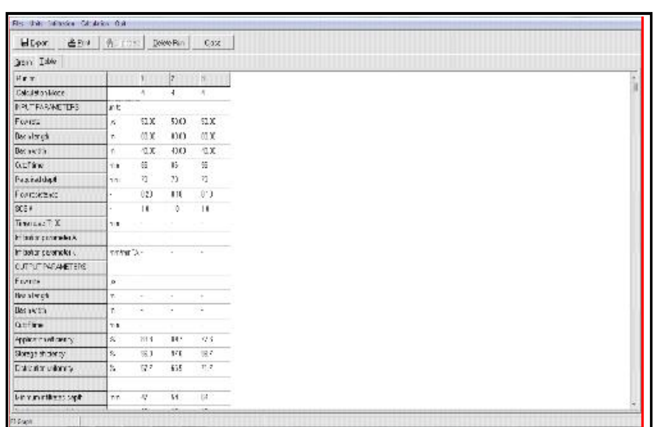

Fig. B : View/ print out put window of BASDEV model

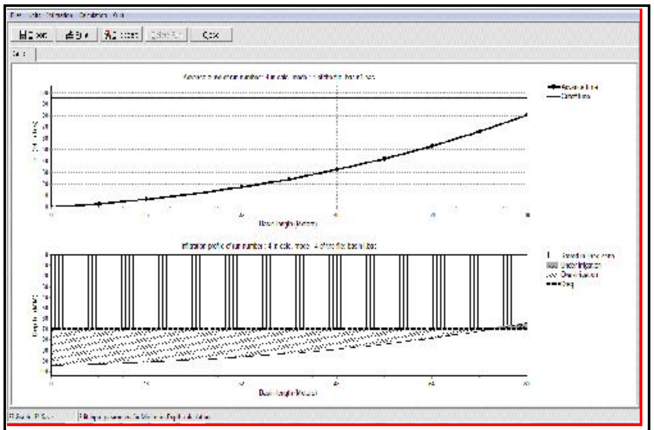

Fig. C : Graphical representation of BASDEV output

Steps by step procedure of programme usage :

SURDEV package is to be selected first. BASDEV module is to be selected from the main menu of SURDEV. If existing file is to be used, it can be retrieved with the load command under the files menu. If a completely new file is to be made, by passing the files menu, calculation menu is to be selected. If other units are to be used, unit settings option will be availed otherwise default settings may be retained. The type of infiltration characteristics inputting in the infiltration menu may be chosen as modified SCS family's infiltration type. From calculation menu, a mode to work in is to be selected. Most of the work will be done in Modes 3 and/or 4. Less experienced users can start in Mode1 or 2 to get a first estimate of flow rate or field dimensions, respectively. Mode 4 can be used to evaluate an existing situation or to do sensitivity analyses.

In the input window, specify field parameters can be specified and decision variables, after which the program is to be run with [F2]. The results of each run are given in tabular form in the output window or in graphical form with [F3]. The results of one simulation run (output and input in one file) can be saved in a separate file or can be appended to earlier runs in an existing file with [F4]. 'Files and view /print' option is to be selected from the main menu to see what has been done and/or to print a file directly, or convert it to a print file for a word-process programme where further analyses are carried out and own graphs are to be prepared.

RESULTS AND DISCUSSION

By providing basin width as variable input, the cut off time, application efficiency (%) maximum depth of irrigation (mm), average depth of irrigation (mm), advance time (min) and recession time (min) were obtained as outputs of using BASDEV in the very first run. The following input parameters (field parameters) were selected which could be most practical and suitable to local conditions of Bapatla.

Soil type :

The soil type was sandy loam was considered in this study for which intake family and flow resistance has been considered 1.0and 0.15, respectively.

Basin length:

There is basin length 30,45m have been considered in this study (Fig. 1).

Basin width:

There is basin width 30 m have been considered in this study (Fig. 1).

Flow rate:

Flow rate *i.e.* 10, 20, 30, 40, 50, 60, 70, 80 and 90 l/s have been use for applying 75 mm of net irrigation.

Initially an evaluation was made for an existing check basin of 45 × 30 m and for the sandy loam soil that can be classified by the SCS family # 1.0. The flow resistance (broadcast small grains) can be taken as 0.15. The net irrigation requirement is 75 mm the above shows that this occurs at a flow rate-value of 70l/s. Under all trails, there is no under irrigation observed (Fig 2 and 3). Table 1 shows that there was no optimum solution were reached in all runs. As the flow rate increases, the

Fig. 1 : Check basin chosen for the present study

application efficiency also increased. If the farmer can supply a flow rate of 90 l/s. The relation between application efficiency and flow rate is shown in Fig 4. With the increase in flow rate the application efficiency

Fig. 2 : The outlet stream for the check basin

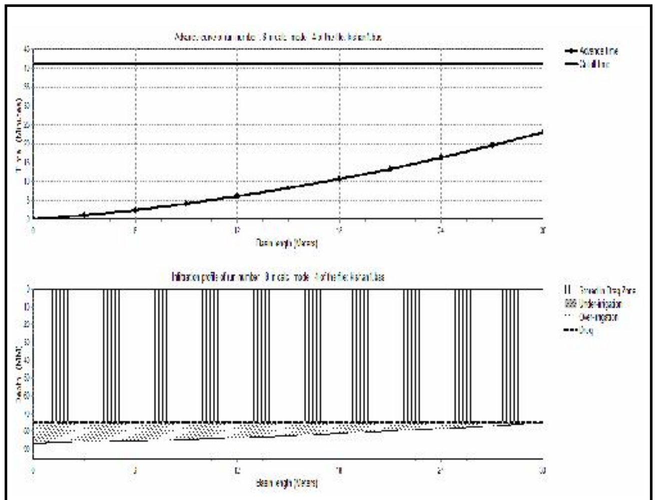

Fig. 3 : Graphical output of BASDEV model for 30 × 45 m basin

Table 1 : Results of the trial runs for improving efficiencies

Run no.		1	2	3	4	5	6	7	8	9
Calculation mode		3	3	3	3	3	3	3	3	3
Input parameters	units									
Flow rate	l/s	10	20	30	40	50	60	70	80	90
Basin length	m	45	45	45	45	45	45	45	45	45
Basin width	m	30	30	30	30	30	30	30	30	30
Cutoff time	min	-	-	-	-	-	-	-	-	-
Required depth	mm	75	75	75	75	75	75	75	75	75
Flow resistance	-	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
SCS #	-	1	1	1	1	1	1	1	1	1
Time rated T100	min	-	-	-	-	-	-	-	-	-
Infiltration parameter A	-	-	-	-	-	-	-	-	-	-
Infiltration parameter k	mm/min^A	-	-	-	-	-	-	-	-	-
Output Parameters										
Flow rate	l/s	-	-	-	-	-	-	-	-	-
Basin length	m	-	-	-	-	-	-	-	-	-
Basin width	m	-	-	-	-	-	-	-	-	-
Cutoff time	min	402	111	66	48	37	31	26	23	20
Application efficiency	%	42	76.2	85	88.6	90.6	91.8	92.7	93.3	93.9
Storage efficiency	%	-	-	-	-	-	-	-	-	-
Distribution uniformity	%	-	-	-	-	-	-	-	-	-
Minimum infiltrated depth	mm	-	-	-	-	-	-	-	-	-
Maximum infiltrated depth	mm	213	111	96	91	88	86	85	84	84
Average applied depth	mm	178	98	88	85	83	82	81	80	80
Over irrigation depth	mm	-	-	-	-	-	-	-	-	-
Under irrigation depth	mm	-	-	-	-	-	-	-	-	-
Over irrigation length	m	-	-	-	-	-	-	-	-	-
Under irrigation length	m	-	-	-	-	-	-	-	-	-
Advance time	min	350	76	44	33	27	23	20	18	17
Recession time	min	453	179	147	136	130	126	124	122	120

also increased and reached a constant value of 93 per cent. For the existing design, the application efficiency is 93.9 per cent, the cut-off time (T_{co}) 20 minutes and the advance time (T_a) 17 minutes. This is the best result possible, provided the minimum infiltrated depth at the downstream end of the basin is equal to the required depth.

To improve the efficiency, a new a design exercise with the software was made with available flow rate is fixed at 30l/s. The value of the flow resistance can be taken as 0.20as the crops are grown in rows in the direction of flow. In initial assignment, the dimensions

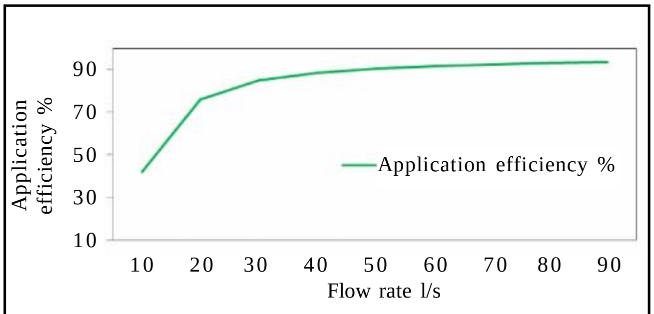

Fig. 4 : Relationship of flow rate Q l/s to application efficiency (%)

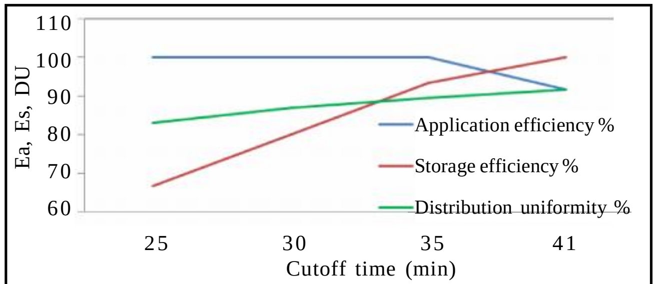

Fig. 5 : Relationships of cut-off time to application efficiency Ea storage efficiency Es and distribution uniformity DU (%)

Table 2 : Results of the trial runs for improvement from present situation

Run no.		1	2	3	4	5	6
Calculation mode		2	3	4	4	4	4
Input parameters	Units						
Flow rate	l/s	30	30	30	30	30	30
Basin length	m	-	30	30	30	30	30
Basin width	m	-	30	30	30	30	30
Cutoff time	min	-		41	35	30	25
Required depth	mm	75	75	75	75	75	75
Flow resistance	-	0.15	0.15	0.15	0.15	0.15	0.15
SCS #	-	1	1	1	1	1	1
Time rated T100	min	-	-	-	-	-	-
Infiltration parameter k	mm/min^A	-	-	-	-	-	-
Flow rate	l/s	-	-	-	-	-	-
Basin length	m	28	-	-	-	-	-
Basin width	m	28	-	-	-	-	-
Cut-off time	min	36	41	-	-	-	-
Application efficiency	%	92.7	91.6	91.6	100	100	100
Storage efficiency	%	-	-	100	93.3	80	66.7
Distribution uniformity	%	-	-	91.6	89.5	86.9	83
Minimum infiltrated depth	mm	-	-	75	63	52	41
Maximum infiltrated depth	mm	85	86	86	75	65	56
Average applied depth	mm	81	82	82	70	60	50
Over irrigation depth	mm	-	-	7	0	0	0
Under irrigation depth	mm	-	-	0	5	15	25
Over irrigation length	m	-	-	30	0	0	0
Under irrigation length	m	-	-	0	30	30	30
Advance time	min	20	23	23	23	23	23
Recession time	min	123	126	126	103	85	68

are reduced and assumed as L = W = 28 m; resulted in application efficiency Ea = 93; Tco= 36 minutes; and Ta =20 minutes. In the next step, the basin dimensions have been changed to 30 by 30m in Mode 3, resulted in advance time 23 min, the cutoff time 41 min and the application efficiency 92 per cent. Similarly, consecutive runs were made with decreasing Tco values till the cutoff time approximately equals the advance time.

Runs 3 to 6 of Table 2 showed that the application efficiency increased from 89 to 100 per cent, whereas the storage efficiency and distribution uniformity decreased owing to increasing under-irrigation. To increase the distribution efficiency, certain level of under irrigation is allowed in design. From the runs 4 to 6, average under-irrigation depths increased at the rate 10 per cent. From the results it has been concluded that in medium soils *i.e.* Sandy loam soils of Bapatla, basin length upto 30 m and width ranging from 5 – 30m at cutoff time between 41 – 35 min were found suitable. For the relation between efficiencies with cutoff time is shown in Fig 5. From Table it could be seen that for various flow rate of 30 l ps and 30m × 30 m with 35 min cutoff time resulted in highest application efficiency of 100 per cent and 93.3 per cent storage efficiency, 89.5 per cent distribution uniformity.

Conclusion :

Accurate design and high quality optimization of the basin irrigation system is necessary for efficient and judicious use of water resources. An attempt was made to evaluate a check basin practiced in agricultural college form Bapatla using BASDEV of SURDEV model. The basin dimension standarzation in Indian conditions is very difficult hence the design could be improved by improving the condition of flow rate and cutoff time. With the existing situations under sandy loam conditions, the basin dimensions were arrived as 30× 30m and the advance time as 23 min, with the cutoff time as 35 min and the application efficiency 100 per cent. This type of location specific designs by BASDEV software is highly essential on policy issue in improving overall project efficiency.

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