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RESEARCH ARTICLE

OPTIMAL IRRIGATION MANAGEMENTATMUNDOGHATCANAL COMMAND AREA OFHIRAKUDCANALSYSTEM USING GENETIC ALGORITHM

Ashutosh Rath, *Samantaray Prakash and Chandra Swain

Department of Civil Engineering, VSS UniversityofTechnology, Burla, Odisha, India

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ABSTRACT

Optimization methods are designed to provide the 'best' values of system designand operating policy variables – values that will lead to the highest levels of system performance. These methods, combined with more detailed and accurate simulation methods, are the primary ways we have, short of actually building physical models, of estimating the likely impacts of particular water resources system designs and operating policies. Many of the optimization methods used in practice incorporates concepts from engineering economics. Hirakud command area is served by three canal systemsnamely Sambalpur distribrutary, Bargarh Main canal, and Sason main canal. The study highlights the advantages of using ADV flow tracker for accurate measurement of discharge,along the use of CROPWAT software to find out the crops water requirements of different crops.Genetic Algorithmoptimizationis used to select a suitable cropping pattern. It is found that as per the present practice of cultivation the farmers are getting a net benefit of Rs.320lakhsonly over the command area that can be enhanced to Rs 537.5.0 lakhs in Indian currency by adopting thecropping pattern suggested in this study.

INTRODUCTION

Water is always treated as the biggest resource without which the humanity cannot be survived. Apart from the other uses of water, the water plays an important role in Irrigation. The basic principle of the irrigation projects to maximize yields. The new operational rule for the water management is based on maximizingthe net benefits rather than yields. If the water is not available to the plants as per the requirement it results in famines and disasters. In the recent past due to less rainfall and non-viability of adequate water for irrigation, the farmers of this area faced huge financial losses as the result of which some of the farmers also committed suicide.The objective of this study is tomake a case study to evaluate the performance of Mundoghat canalsystem and to develop an optimal irrigation model. Due to different constraints of the Hirakud irrigation system,it resulted in heavy loss of canal water due to water-logging and thus decreases in productivity rate in the command area.The major portion of water is also lost during transportation and distribution. The problems related to water release, allocation, distribution and utilization as obtained after survey and close interaction with water users and canal managers can be broadly categorized as -Technical, Social, Managerial and Hydraulic, Institutional& Financial, and administrative, which led to wide gap in canal water availability and crop water requirement.A lot of studies have already been made on this subject.

Corresponding author: Samantaray Sandeep
Department of Civil Engineering, VSS UniversityofTechnology, Burla, Odisha, India

Blaney *et al*., (1950) determined the way to find water requirements in irrigated areas by utilizing the climatologically data and irrigation data. Ahmed*et al* (1976) studied the methods for optimization of the irrigation strategy under a stochastic weather regime condition. Scherer (1977) developed the methods for the water allocation and pricing to control of irrigation-related salinity in a river basin. Anwar *et al* (2001) investigated the mixed-integer linear programming for the Irrigation scheduling. Royce*et al* (2001) developed Model based optimization of crop management for climate forecast Applications Gupta *et al* (2004) made a study on the availability of water for India in 2050: the first-order assessment of the options available in water resources. Raju *et al* (2004) studied Irrigation planning using Genetic Algorithm".Wardlaw (2004) made a study based on comparison of the methods bases on genetic algorithm and linear programming for lateral canal scheduling. Kumar*et al* (2007) studied the multipurpose reservoir operation using particle swarm optimization. Spiliotis *et al* (2007) made a study on the methods to minimize cost irrigation network design with the help of interactive fuzzy integer programming. Ostadrahimi et.al(2012). Work based on Multi-reservoir operation rules: multi swarm pso-based optimization approach Rao (2012) studied the methods to Manage irrigation Canal Systems with Optimum Irrigation Scheduling for Irrigation Scheme of North Gujarat, India. Mishra.*et al*. (2013) made a study on methods to evaluate the Performance of a Rehabilitated Minor Irrigation Project and steps to augment its water resources through secondary storage. Banik *et al.* (2014) used the methods of CROPWAT, to find crop water assessment of Plain and hilly region. Garg *et al* (2014) studied about integrated nonlinear Model for Optimal cropping pattern and Irrigation scheduling under deficit Irrigation. The Mudoghatcanal ofDhankauda block, Sambalpur District, Odisha has a large crop area but till date no study of this kind is done. The report not only highlights the process of canal automation but also it shows the advantages of using ADV flow tracker for accurate velocity measurement. Along with that the use of CROPWAT software is also shown in the study, which has helped in finding different crop details and finally the crop pattern. This study also highlights the needs of the local farmers and also recommends the ways which will help the farmers for better cultivation and to earn an overall annual income much more than what they earn today.

MATERIALS AND METHODS

Different people judge the Performance of airrigation system with various parameters. The irrigationengineers judge a good system performance by its efficiency in delivering of water from head works to outlet. The important performance parameters are productivity, equity, and stability, where productivity is considered as agricultural output, equity is taken as fairness in distribution of resources and benefits, stability is considered as performance over time. An appropriate incentive and reward system will encourage managers to improve their current level of performance to desirable level.

Benchmarking

Benchmarking described as a management tool: for the Systematic and continuous improvement in a system by taking the reference of the previous performances Benchmarking useful in taking a system from one position to a better position. The bench marking can be applied in the irrigation sector to enhance the performance of a system in terms of increase in yield of crops, minimizing in wastage of water, and proper allocation of water as per need.

Cropwat

CROPWAT 8.0 software (FAO, 2006) Food and Agriculture Organization of the United Nations", Rome, Italy can be utilized to calculate the crop water requirements for the various crops basing on climatic data, soil data and crop data. It also helps in development of irrigation schedules basing on the different management conditions and also suggests the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 for Windows includes a host of updated and new features. The CROPWATprogramme is consist of 8 different modules, out of which 5 are data input modules and 3 are calculation modules.

The data input modules of CROPWAT are:

- **Climate/ETo:** input of measured ETo data *or* of climatic data by using Penman-Monteith equation.
- **Rain:** Effective rainfall can be calculated from the input rainfall data.
- Crop (dry crop or rice Helpful for the input of crop data such as the planting date;
- **Soil:** Describe the soil properties such as field capacity, wilting point etc.
- **Crop pattern:** input to find pattern and the scheme supply of water.
- **CWR –** to calculate the crop water requirements for the various crops.
- **Schedules (dry crop or rice) –** It is helpful to find irrigation schedules
- **Scheme –** It depends on the cropping pattern.

The calculation modules of CROPWAT are:

Flow monitoring with flow tracker

The velocity measurements were made with SonTek/YSI Flow Tracker Handheld Acoustic Doppler Velocimeter (ADV) (2006). Flow Trackers have many unique data-processing needs because of their method of operation and some of the inherent limitations of the acoustic Doppler measurement technique. The Flow Tracker cannot measure the velocity of the water. The Flow Tracker measures the velocity of particles sediment, small organisms, and bubbles, suspended in the flow, assuming that these particles travel at the same velocity as the water. Therefore, the quality of the measurement is dependent on the presence of particles within the sampling volume that reflect a transmitted signal. The Flow Tracker records the signal-to-noise ratio SNR, standard error of velocity based on 1 s data, angle of the measured flow relative to the *x*-axis of the Flow Tracker probe number of filtered velocity spikes, and a boundary quality-control flag. These velocity and quality-assurance data may be used to evaluate the measurement conditions.

Fig.1. FlowTracker with 2D Probe

Principles of Operation

The Flow Tracker ADV operates at an acoustic frequency of 10 Mhz and measures the phase change caused by the Doppler shift in acoustic frequency that occurs when a transmitted acoustic signal reflects off particles in the flow. The magnitude of the phase change is proportional to the flow velocity. The phase difference can be positive or negative, allowing ADVs to measure positive and negative velocities. The Flow Tracker measures the velocity at a rate of approximately 10 Hz, averages the data, and records 1 s velocity-vector data. According to the manufacturer, the Flow Tracker can be used in water depths as shallow as 3 cm and in velocities in the range of 0.1 to 450 cm/ s with an accuracy of ±1% of measured velocity.

Genetic Algorithm

The Genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm selects individuals at random from the current population to be parents and uses them to produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. It can be applied to solve a variety of optimization problems that are not well suited for standard optimization algorithms, including problems in which the objective function is discontinuous, non-differentiable, stochastic, or highly nonlinear. The genetic algorithm can address problems of mixed integer programming, where some components are restricted to be integer-valued.

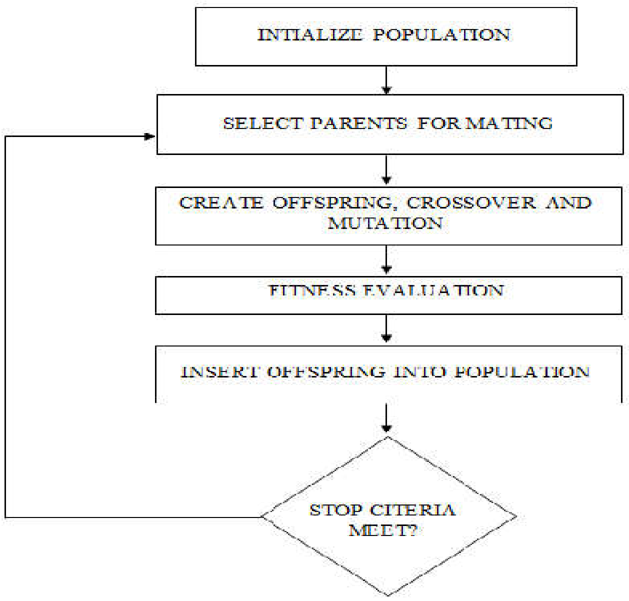

Fig. 2. Flow chart for Operation Scheme of Standard GA

Study area

The present study is carried on Mundoghat area of Sambalpur district. This area is situated at the western part of the Orissa. Also it is financially backward and is mostly populated with tribal people. The literacy rate is 67.25%.

Agricultural practices: Paddy is the dominant crop in both Rabi and Kharif season. Nearly 95% of the CCA is under paddy Cultivation. The agriculture year of the command begins from July and ends in next June. Cropping seasons Rabi and Kharif are prevailed in most of the command. Rabi crops also known as winter crops are grown from December to May. Kharif crops also known as summer crops are grown from July to December

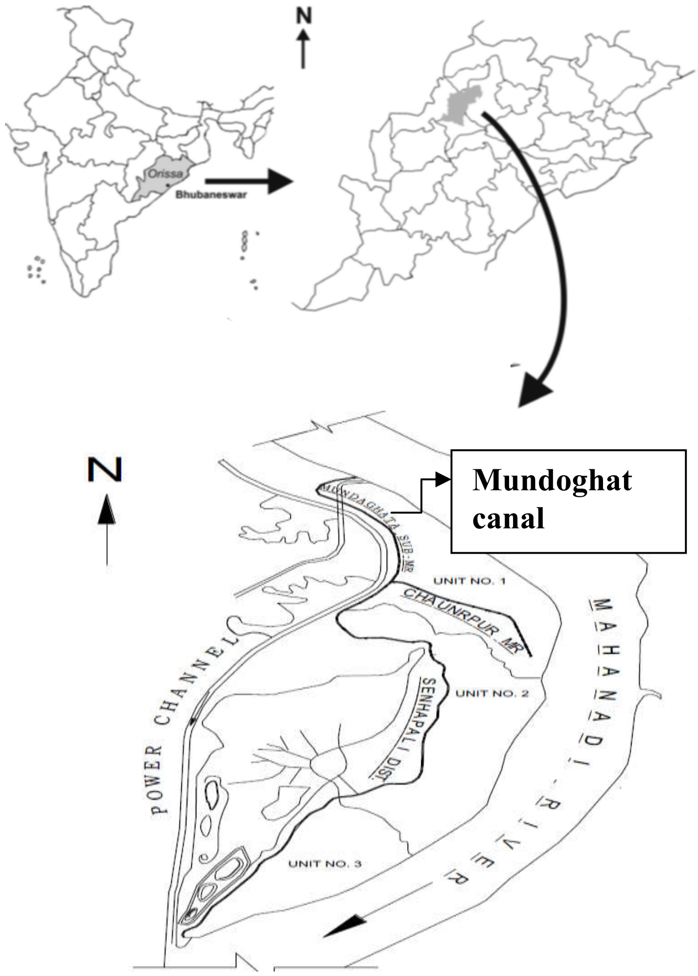

Fig.3. Study Area Mundoghat canal

Table 1. Details of Main Canals of Hirakud Command Area

Name of Canal	Length of canal (Km.)	Full supply discharge (Cusec)	Bed width of Canal (m.)	Full Supply Depth of canal (m.)
Bargarh Main Canal	84.28	107.60	45.7	2.68
Sason Main Canal	21.79	17.80	16.67	1.49
SambalpurDistributary	18.08	3.40	4.57	1.06

The study area is a part of the Hirakud canal command which lies in the western part of Odisha on the eastern coast of India. It extends from 21°05'N to 21°55'N latitude and from 83°55'E to 84°05'Elongitude. The climate of the command area is tropical monsoon with four distinct seasons: (a) Summer- March to May, (b) Monsoon- June to September, (c) Post-monsoon- October to November, and (d) winter- December to February. The area gets rain by the south-west monsoon.The soil type is a mixture of sand and gravel as well as of clay. The surface texture varies from loamy sand to sandy loam abruptly underlined by heavy surface and in some parts it varies from sandy clay to clay loam and the clay content increases with depth.

The distributaries under study get water from Sason main canal. The Sason Main canal is fed from Hirakudreservoir.

Data collection and interpretation

The process of data collection and its interpretation play a vital role to make the study fruitful. The collection of data such as velocity, discharge, the data of various crops of Rabi and Kharif as per the interview of the local people as well as the Department. Of the Agriculture Government .of Odisha.The list of various crops and their minimum support Paddy in Sambalpur district for Kharifcrops as collected from the Department Agricultural.

Calculation of optimized crop pattern

The crop water requirement of different crops under the command area were found using CROPWAT. The study shows that the maximum water requirement of crops is during flowering season. Also it is revealed that sugarcane and rice required high amount of water i.e. 1123mm and 1005mmrespectively. The study of original project report field study and scan of official records of Agricultural Department for present cropping pattern and field interview with farmers related that there is a scope for improvement of cropping pattern. The farmers are eager to change their habit of growing rice as the only crop. They need strong technological back up and motivation.

Development of optimal crop pattern for Mundoghat

The following data of Mundoghat which are essential for the study of optimal irrigation management of the area are given below. As discussed with the local farmers of Dhankauda Block and the data of Agricultural Dept.the yieldof the various crops are as follows

Development of optimal crop pattern for Mundoghat

As discussed with the local farmers of Dhankauda block and the official of the Irrigation department the yield and the crops prices as a rate of Rs/ton.The net benefit after the deduction of the cost of labors and fertilizers and pesticides for the various crops are as follows

Table 2. Crop yield at in Mundoghat

Village	Types Of Crops	Yield in ton/Ha	Rs/ton
Mundoghat	Paddy	2.84ton/Ha	10800
	Maize	2.0ton/Ha	32000
	Pigeonpea(Harad)	0.99ton/Ha	27000
	Green gram	0.56ton/Ha	9850
	Black gram(Biri)	0.42ton/Ha	27000
	Kulthi	0.85ton/Ha	54000
	Others pulses	0.9ton/Ha	40000
	Ground nut	1.16ton/Ha	46000
	Til	0.4 ton/Ha	70269
	Mesta	0.69 ton/Ha	38000
	Sweet potato	10.8ton/Ha	13200
	Vegetables	4.1ton/Ha	10000
	Chilly	1.45ton/Ha	20000
	Sun flower	0.59ton/Ha	52051
	Sugarcane	2.12ton/Ha	29000

The crop water requirement for different crops has already been calculated from the CROPWAT 8.0.The cost of water for different crops is given below.Using the above data a linear programming model was developed. The problem was solved using Particle swarm optimization. Optimization problems are often classified as linear or nonlinear, depending on whether the relationships in the problem are linear with respect to the variables. In general, an optimization model will consist of the following three items the Objective Function, Variables and the Constraints. For this problem:

Objective Function

$MNB=\sum Y_C*P_C*A_C - \sum \{IN_{(c,m)}*A_C*IC\}$

Where MNB is maximum net benefit, Yc is yield for crop c (tones/ha), P_c is crop Paddy (Rs. /tones),A_c is the crop area for crop c (ha), IN (cm) is the irrigation water need for crop.IC is irrigation or water cost (Rs./cm/unit ha). The objective function is subject to the following physical and environmental constraints.

Table 3. Crop water requirement

Name of Crop	C.W.R (cm)	Water cost in Rs/cm*ha
Paddy	100.9	Rs 590/cm for all the crops
Maize	40.9	
Pigeonpea(Harad)	39.4	
Green gram	39.3	
Black gram(Biri)	39.2	
Kulthi	41.5	
Others pulses	39.4	
Ground nut	29.4	
Til	30.2	
Mesta	29.6	
Sweet potato	41.0	
Vegetables	35	
Chilly	33.4	
Sun flower	37.5	
Sugarcane	78.0	

Area Availability to Total Area

$\sum A_C \leq \sum TA$

The sum of all crop area is equal or less the total farm area, where TA is the total area.

Water Demand to Water Availability

$\sum IN_{(c,m)}*A_c \leq \sum WA$

The total water a viability can be ascertained from the flow measurement with the help of the flow tracker. The discharge data also available from the canal authority. In the development of model the data recorded with flow tracker have taken into consideration, which seems to be more accurate.

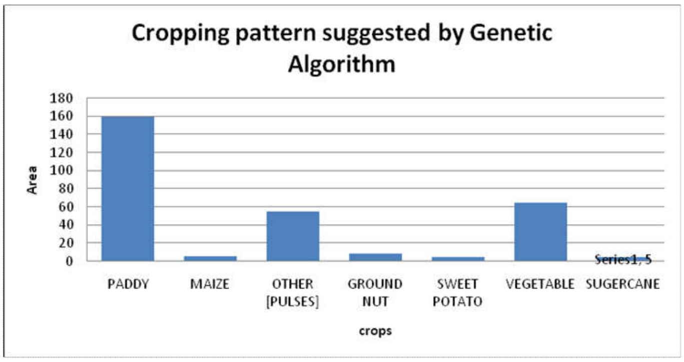

Fig. 5. Area suggested by GA

Development of models by adopting different cropping pattern

The models have been developed basing on the data proposed during the construction of Mundoghat canal. The constraints of land water availability etc. are put in the model as boundary conditions.During the execution paddy is denoted by P, groundnut by G, pulses by D, vegetable V, sugarcane S, sunflower F and maize M,Pigeon pea (Harad) H,Green gram MU, Black gram (Biri) B, Kulthi K, Others pulses PU, Ground nut G, Til T, Mesta ME, Sweet potato SP, Vegetables V, Chilly

C, Sun flower SF, Sugarcane S. The proposals have been framed basing on the water and availability, suitability and the views of the farmers and the Official of the Irrigation Department.

Table 4. Comparisons between the models

Name of model	Net benefit (Rs IN Lakhs	Remarks
Present habbit	320	As per present habits
BY GA	537.5	Best acceptable Model

Conclusions and Major findings of the study

A comparison of performance of different proposals is considered. From the above discussion it is revealed that there is a net benefit of Rs217.5LAKHS over the existing cropping pattern, which is a net additional profit of the farmers in the command area of Mundoghat Canal. Although the water is a natural resource but at present scenario the valueof water has been recognized both at administrative and farm levels as an essential commodity.To achieve the required goal of agriculture proper utilization of the irrigation water is highly desirable.As the available water resources, is limited it is important for the authorities to develop models for reducing the water losses at the time of operation and conveyance .Normally, the people at the tail-end unable to get their legitimate share of water to meet their demand. Furthermore, the farmers at upper end have a tendency to irrigate their farms with available water and as frequently as possible. Application of more water to crops does not necessarily mean better yields; it may lead to problems of water logging and thereby adversely affect crop yields. The major findings of this study are while conducting the field study on the Mudoghat.it is found that the farmers are interested in cultivating crops other than paddy but they need proper guidance and help from the administration. Optimal use of available water resourcescan be achieved when both surface water and ground water are to be used conjunctively to maximize agricultural production. Crop diversification needs to be implemented to improve the productivity of land. It requires suitable implementation of command area development works and improvement of the water delivery systems to minimize losses to ensure water availability to the tail end users.

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