Application of Genetic Algorithm to Derive an Optimal Cropping Pattern, in Part of Hirakud Command

Ashutosh Rath, Sandeep Samantaray, Sudarsan Biswal and Prakash Chandra Swain

Abstract Proper management with available limited water resources is to be given top priority to meet the threat of food security due to increase in population. Establishment of a new major irrigation project is a challenging task due to social, environmental and other multiple causes. The present study is conducted on Senhapali Canal, a distributary of Hirakud system in Sambalpur District of Odisha State, India, which is very close to Hirakud Dam over River Mahanadi. In the present work, experiments are conducted to develop a suitable cropping pattern through optimization techniques like LINDO and Genetic Algorithm. The developed cropping pattern gives net returns of Rs. 585 lakhs while using LINDO and Rs. 590.07 lakhs if GA is used. Hence, the cropping pattern obtained by using Genetic Algorithm may be adopted by the farmer to get more net returns than the existing one adopted by farmers.

Keywords Genetic Algorithm · Hirakud command area · Optimization CROPWAT · ADV Flow Tracker

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1 Introduction

There is a great necessity of irrigation in Indian tropical climate. Agriculture plays an important role in economical performance of the country. It contributes about 15 to 20% of the total GDP. More than 60% of population of the country depend directly or indirectly on agriculture. Due to rapid increase in population and stagnation in agricultural production there is an increase in food scarcity in Odisha. Hence an integrated planning of available land and water resources in the state is required to maximize the economic returns. Optimization techniques are used to find the best feasible solution and operating policy which can provide improvement in the system performance. Genetic Algorithm (GA) based on the concept of natural selection and process of evolution utilized largely for solving all types of optimization problems considering all the boundary conditions. The aim of this study is to develop a method to get maximum yield from a particular crop land and also by managing the irrigation water in that particular area. Frizzone et al. developed a separable linear programming model, considering a set of technical factors which might influence the profit of an irrigation project. Srivastava et al. [7] proposed an integrated Genetic Algorithm (GA) for development of watershed and NPS pollution model. Kumar et al. [4] described the application of Genetic Algorithm (GA) in water distribution to various crops from an irrigation reservoir. Azamathulla et al. [1] made a comparative study between the Genetic Algorithm and linear programming for high efficiency of reservoir operating system. Yang et al. [8] used Genetic Algorithm for multi-objective planning of both surface and subsurface water. Mehdipour et al. [5] described rule curve for reservoir operation. Singh [6] developed a optimization model to increase farm income. Banik et al. derived a comparative crop water assessment using CROPWAT. CROPWAT is used to develop a model for water assessment of using field data. The aim of the present work is to formulate a feasible and acceptable cropping pattern in the proposed study area for deriving optimal benefits.

2 Study Area

The Senhapali Distributary, given in Fig. 1, emerges out of the power channel of the Hirakud system to provide irrigation to villages Chaunrpur, Senhapali, Berhampura, Baguria, Bakbira, Jharpali, Tihikipali. The CCA of Senhapali Distributary is 871 ha. There are two cropping seasons, namely kharif from June to December and Rabi from January to May. The study area produces a large portion of food crops of the Odisha State. So this area is also known as the food bowls of the state of Odisha. At the present scenario, the farmers of the area are showing their disinterest in cultivation, because of huge financial loss they are facing for last few years due to uncertainty of rainfall and decrease in the water availability.

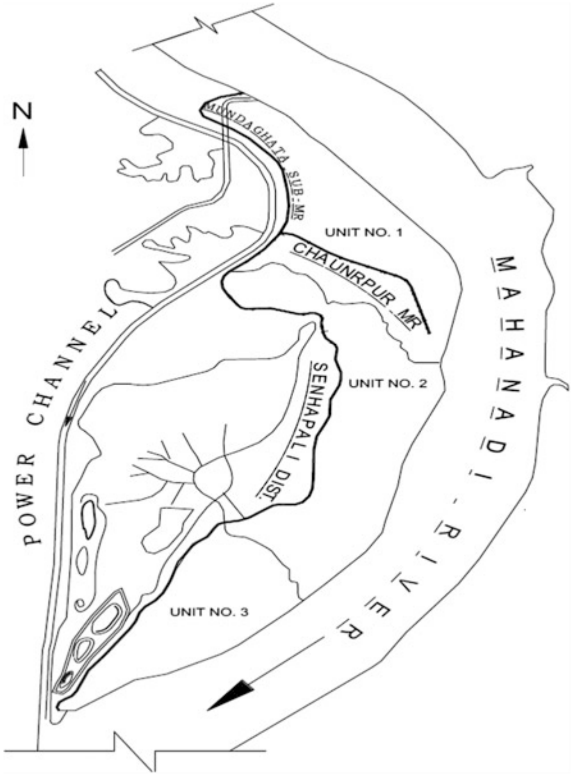

Fig. 1 Command area map of the Senhapali Distributary

3 Materials and Method

3.1 CROPWAT 8.0

The CROPWAT software which was developed by FAO, in the year 2006, applied to find the water needed for various crops. The software requires the data such as climate/ETo, rain, soil, types of crops.

3.2 Flow Monitoring with Flow Tracker

The Flow Tracker is described in Fig. 2. As per the specification, it can be operated with a frequency of magnitude 10 MHz. It is found that acoustic velocimeters can be applied for measuring both mean and turbulent velocities accurately and report estimates of the error based on velocity range settings. The Flow Tracker ADV measures the phase change caused by the Doppler shift in acoustic frequency that occurs when a transmitted acoustic signal reflects off the particles in the flow.

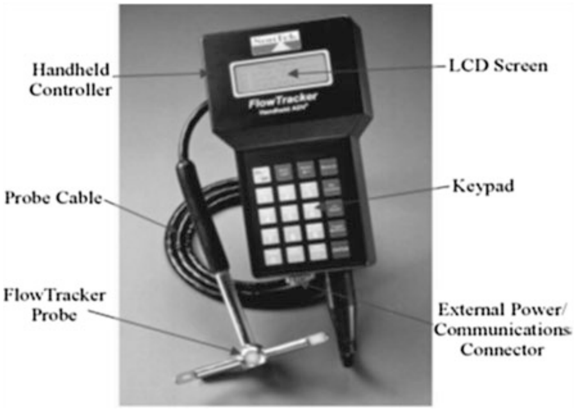

Fig. 2 Flow Tracker with 2D probe principle of operation

The magnitude of the phase change is proportional to the flow velocity. The flow velocity determines the phase change. It can measure the velocities of various sections even in shallow depth of about 3 cm with a velocity ranging from 0.1 to 450 cm/s. The various parts of the instruments are shown in the figure.

3.3 LINDO: Classical Optimization Techniques

LINDO: Optimization methods are designed to provide the 'best' values of system design and operating policy variables values that will lead to the highest levels of system performance.

3.4 Genetic Algorithm

3.4.1 Methods of Operation of GA

It is one of the popular methods used for optimization, which was put forth by John Holland (1960). But it became more popular in the 1980s. Its concept was based on biology. Darwin's principle: survival of the fittest. It is based on the bio-inspired operators like mutation, crossover and selection. In engineering, first the model was transformed to a function and solution is found and then the parameters are found which are to be optimized. Genetic Algorithm optimization tool always provides a potential solution. The Genetic Algorithm is expressed by encoding of the search space, represented by a chromosome. 1. It starts with a set of population. 2. Solution for each one is found and new population was found on the basis of data in which new population is better than the old one. 3. Then the Solution is done on the basis of more fitness value which will help for reproduction of next generation. 4. Process was continued till the termination criteria were satisfied GA.

3.4.2 Steps of Genetic Algorithm

1. Population initialization using random generation. 2. Fitness function evaluation for each individual. 3. Following steps are updated until the stopping criteria are reached. i. For reproduction best fit individual is selected. ii. Crossover and mutation processes are done to generate new offspring. iii. Again fitness of individual member is calculated. iv. Less fit individual is replaced with new one. 4. Best solution was found. 5. Process will be continued until reach the stopping criteria

4 Derivation of Optimized Crop Pattern

The objective function is determined by considering the net benefits that the farmers are expected to get after deducting all the expenditures given in Eq. (1). While (2), (3) and (4) present the cost of fertilizers, seeds and labour, the constraints are the available land and the water flow in the canals which is ascertained with the help of the Flow Tracker given by Eqs. (6), (7) and (8).

Objective function:

$$\mathrm{MAXP} = \sum_{i}^{n} [(\mathrm{P_i} * \mathrm{Y_i} * \mathrm{A_i}) - \mathrm{A_i}[(\text{Cost of Fertilizers})_i + (\text{Cost of Seed})_i + (\text{Cost of Labour})_i + (\text{Cost of water requirements})_i]] \tag{1}$$

where

P Profit,
$\mathrm{P_i}$ Price of each crop in market (Rs/qntl),
Y_i Yield of each crop (qntl/ha),
$\mathrm{A_i}$ Area of each crop (ha).

$$\text{Cost of Fertilizer} = [(U_i * U_c) + (D_i * D_c) + (M_i * M_c)] * \mathrm{A_i} \tag{2}$$

where

U_i Urea required for each crop (kg/ha),
U_c Cost of urea (Rs/kg),
D_i DAP required for each crop (kg/ha),
D_c Cost of DAP (Rs/kg),
M_i MOP required for each crop (kg/ha),
M_c Cost of MOP (Rs/kg).

$$\text{Cost of Seed} = [(S_i * S_c)] * \text{A}_\text{i}, \quad (3)$$

where S_i = Seed required for each crop (kg/ha),

S_c = Cost of seed (Rs/kg).

$$\text{Cost of Labour} = [(L_i * L_c)] * \text{A}_\text{i}, \quad (4)$$

where L_i = Labour required for each crop (person/ha),

L_c= Cost of labour (Rs/person).

$$\text{Cost of Water} = [(W_{ri} * W_c)] * \text{A}_\text{i}, \quad (5)$$

where W_{ri} = Water requirement for each crop (m),

W_c = Cost of water (Rs/ha * m), ha = hectare, m = Metre.

Water availability constraints:

$$\sum (W_{ri} * \text{A}_\text{i}) \leq W_t \quad (6)$$

where W_t = Total water available from canal.

Land area constraints in different seasons:

$$\sum \text{A}_\text{i} \leq A_t,\ A_t = \text{The Cultivation area in different Season (Kharif and Rabi)} \quad (7)$$

Crop area constraints:

$$L_{bi} \leq A_i \leq U_{bi},$$

where L_{bi} = Lower bound of each crop, U_{bi} = Upper bound of crop nonnegative constraints:

$$A_i \geq 0 \quad (8)$$

4.1 Crop Yield of the Study Area

In this study, the crop yield for the kharif season only for the study area is taken into consideration. The data are verified by comparing with the report collected from Irrigation Department, Government of Odisha. Then the Solution is done on the basis of more fitness value which will help for reproduction of next generation. The detail of which is described in Table 1.

4.2 Water Requirement of Crops Using CROPWAT

CROPWAT is applied to find out the crop water requirements of the crops of the study area by considering local climatic conditions, soil data and rainfall data, as given in Table 2.

4.3 Discharge Measurement

The canal is divided into various cross sections for the velocity measurement. The instrument is placed at various width and heights to calculate the velocity. The calculated discharge at various sections is given in Table 3.

5 Results and Discussions

With the present cropping pattern, the farmers are getting a net benefit of 0.6705 million USD. The LINDO optimization suggests a net benefit of 0.8775 million USD by adopting the cropping pattern proposed by the software. By using the maximization technique and putting that equation in the main function and taking

Table 1 Crops and yields data of the study area

Crop	Yield (quintal/ha)	Crop	Yield (quintal/ha)
Paddy	33	Til	5.5
Maize	22	Potato	110
Arhar	10	Vegetables	125
Green Gram	6	Chilly	15
Black gram	5	Ginger	160
Other pulses	5	Turmeric	40
Groundnut	13		

Table 2 Crop water requirement (CWR) value for each crop in study area

Types of crops	CWR (m)	Cost of crop (Rs/qntl)	Types of crops	CWR (m)	Cost of crop (Rs/qntl)
Paddy	0.7901	1900	Potato	0.3042	1100
Maize	0.322	4000	Vegetables	0.2892	1500
Green gram	0.308	7250	Chilly	0.2338	10000
Black gram	0.308	8500	Ginger	0.2338	8000
Other pulses	0.244	8000	Turmeric	0.2338	11000
Groundnut	0.1931	4900	Arhar	0.308	10950
Til	0.2088	14000	Potato	0.3042	1100

Table 3 Measured discharge data

Number	Mean velocity (m/s)	Area of section (m^2)	Discharge (m^3/s)
1	0.359	2.311	0.830
2	0.426	1.938	0.826
3	0.482	1.675	0.807
4.1	0.332	2.395	0.795
4.2	0.369	2.141	0.790
5.1	0.354	2.173	0.769
5.2	0.435	1.705	0.741
6.1	0.280	2.625	0.735
6.2	0.300	2.43	0.729
7	0.380	1.905	0.724
8	0.344	1.978	0.680
9	0.251	2.504	0.629
10	0.287	2.175	0.624
11	0.732	0.840	0.615
12.1	0.545	1.106	0.602
12.2	0.441	1.204	0.531
13.1	0.504	1.045	0.527
13.2	0.596	0.827	0.493
14	0.199	2.015	0.401
15	0.147	2.048	0.301
16	0.275	0.660	0.181

the fitness function and constraint function into consideration, the values are calculated in GA. The crossover value and population values are changed, and after various iterations, the best cropping pattern for kharif season is found out. The benefits suggested by GA are more as compared to the LINDO. The optimal cropping pattern suggested by the Genetic Algorithm is given in Table 4.

It gave the different area of crops which should be adopted to arrive at the maximum profit. The cropping pattern is shown below.

GA gave the best fitness value and mean fitness value at generation value indicated by Fig. 3. The figure clearly shows the best and mean fitness values. The area of allocation by GA for various crops is shown in the graphical form in Fig. 4.

6 Conclusions

In this study, a total of 13 different types of crops for kharif season have been taken into consideration for investigation. The total cultivable area considered for calculation is equal to the total cultivable area adopted by farmers for kharif.

Table 4 Proposed crop areas by GA

Crop	Notation	Area of crop (ha)
Paddy	P	460.21
Maize	M	34.61
Arhar	A	24.49
Green gram	O	34.94
Black gram	B	43.54
Other pulses	S	76.44
Groundnut	G	9.85
Til	T	19.74
Potato	U	18.00
Chilly	C	29.49
Ginger	I	9.97
Turmeric	W	9.91
Vegetables	V	99.76

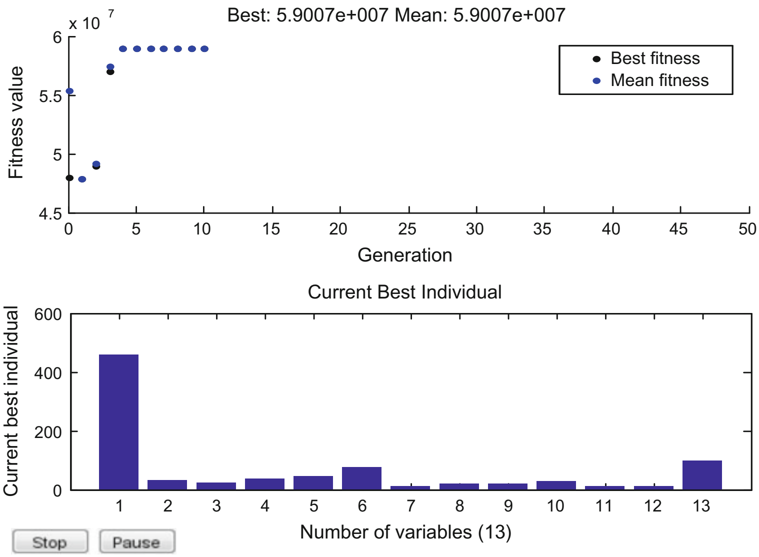

Fig. 3 Profit obtained and area of crop for maximum profit using GA for kharif season

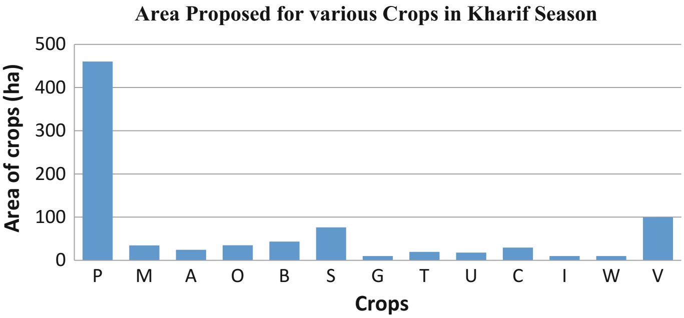

Fig. 4 Cropping pattern for kharif season obtained using GA

The major crop in the study area is paddy. The present benefits the farmers are getting are amount to 0.6705 million USD. The cropping pattern suggested by LINDO, the profit suggests a net benefit of 0.8775 million USD in kharif season. This is about 46% more as compared to the present habit. A net benefit of 0.885 million USD using Genetic Algorithm is obtained. This is about 48% more as compared to the present one. Hence GA is found to be an effective optimization tool for optimal crop planning and can be used for other command area. The study will help the farmers to improve their standard of living. The benefits can be further increased by adopting the principle of crop rotation and providing proper marking facilities.

References

1. Azamathulla, H. Md., Wu, Fu-C., Ghani, A.Ab., Narulkar, S.M.: Zakaria, N.A., and Chang, C.K.: Comparison between genetic algorithm and linear programming approach for real time operation. J. Hydro-environ. Res. (2008) 172–181.
2. Banik, P., Tiwari, N.K., and Ranjan, S.: Comparative crop water assessment using CROPWAT. International Journal of Sustainable Materials, Processes & ECO-Efficient – IJSMPE. (2014) Volume 1: Issue 3.
3. Frizzone, J.A., Coelho, R.D., Neto, D. Dourado., and Soliani, R.: Linear programming model to optimize the water resource use in irrigation projects: an application to the Senator Nilo Coelho Project. Sci.agric. (Piracicaba, Braz.). (1997) Vol. 54.
4. Kumar, D.N., Raju, K.S. and Ashok, B.: Optimal reservoir operation for Irrigation of Multiple Crops Using Genetic Algorithm. Journals of Irrigation and Drainage Engineering. (2006) Vol. 132, No. 2, April 1, 2006, ASCE, ISSN 0733-9437/2006/2-123-129.
5. Mehdipour, E. Fallah., Haddad, O. Bozorg., and Mariño, M.A.: Extraction of Multi-crop planning rules in a reservoir System: Application of Evolutionary Algorithms. Journal of Irrigation and Drainage Engineering. (2013) Vol. 139, No. 6.
6. Singh, A.: Optimizing the Use of Land and Water Resources for Maximizing Farm Income by Mitigating the Hydrological Imbalances. Journal of Hydrologic Engineering. (2014) Vol. 19, No. 7, July 1, 2014. © ASCE, ISSN 1084-0699/2014/7-1447-1451013. ASCE, ISSN 0733-9437/2013/6-490-498.

7. Srivastava, P., Hamlet, J.M., Robillard, P.D., and Day, R.L.: Watershed optimization of best management using AnnAGNPS and a genetic algorithm. Water Resour. Res. (2002) 38(3), https://doi.org/10.1029/2001wr000365.
8. Yang, C.-C., Chang, L.C., Chen, C.-S., and Yeh, M.-S.: Multi-objective planning for conjunctive use of surface and subsurface water using genetic algorithm and dynamics programming. Water Resour. Man. (2009).