DERIVATION OF OPTIMAL CROPPING PATTERN IN SAMBALPUR DISTRIBUTARY USING GENETIC ALGORITHM

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Abstract - The designs of Water distribution systems are based on certain objectives such as equity, adequacy to access its efficacy. The design of canal systems for distributing the water is based on the size of command areas. Duration of operation. It is a fact that Odisha is a predominantly agrarian state as more than 2/3rd of the state population depends on agriculture. Irrigation is the paramount importance for development of agriculture. The irrigation projects are built up to support crops with adequate water supply during the growing period. Dams are built to store water of monsoon water which was earlier being drained into rivers and sea. Hirakud dam over Mahanadi River in Odisha, India is one of such schemes which was built in the early days of Independence having live storage capacity of 5375 M Cum. After the compilation of all the data and analyzing them using GENETIC ALGORITHM, it is found that the present practice of cultivation, adopted by the farmers is neither sustainable nor a profitable cropping pattern because it yields a net benefit of 445.0 lakhs only over the whole command area. The farmers can earn much more money if they cultivate crops as recommended in this report. The net benefit of 590.70, which is more than the existing crop pattern.

Keyword - Command area, Discharge, Crop Optimization and GENETIC ALGORITHM

I. INTRODUCTION

Water management is essential for the irrigated crop production. An efficient irrigation systems with proper water management practices are the tools to maintain farm profitability in limited resources. Irrigation water is a tool to manage the conserve water supplies, and to reduce impacts of water-quality so to increase net returns. Water savings or the economical use of water at the farm level can restrict the rising water costs and controlled the water supplies on to increase the income. A well designed water management system may also minimize the use of chemical and labor inputs. It also help in enhancing revenues with higher crop yields and improved crop quality. A number of studies have been made such as Frizz one et al. (1997) developed a separable model based on linear programming by considering a set of technical parameters which may influence the benefit of an irrigation project. Brown (2007) developed an optimal stochastic multi-crop irrigation scheduling algorithm, to incorporate complex farm system models, by considering all constraints with the objective of maximizing farm profit. Srivastava. et. al. (2002) described a methodology which integrated a Genetic Algorithm (GA) with a continuous simulation, watershed scale NPS pollution model. Kumar. et. al (2006) proposed a Genetic Algorithm (GA) model for acquiring optimal crop water allocation and optimal operating policy from irrigation reservoir. Azamathulla et. al (2008) compared between the genetic algorithm and linear programming approach in real time approach for maximum efficiency of reservoir system. Yang et. al (2009) derived a multi objective planning for conjunctive use of surface and subsurface water using genetic algorithm and dynamics programming. Mehdipour et. al (2013) developed multi-crop planning rules in a reservoir system. Mishra et. al (2014) presented a multi-objective linear fractional programming (MOLFP) approach for multi-objective linear fuzzy goal programming (MOLFGP) problems. Singh (2014) optimized the use of land and water Resources for maximizing farm income by mitigating the Hydrological imbalances. Banik et.al (2014) derived about a comparative crop water assessment using CROPWAT.

II. METHODOLOGY

2.1 CROPWAT

The crop water requirements of the different crops can be found out with the help of CROPWAT 8.0. The requirement can be calculated by taking the existing climatic data of the locality such as the temperature, humidity, rainfall, duration of sun. With respect to different irrigation management conditions this programme can be applied to develop a proper the irrigation schedule by changing the various cropping pattern. The Evapotranspiration (ETO) losses which includes the losses due to evaporation and transpiration also can also be found out with the help of FAO Penman Monteith method. The other data like the rainfall which is effective can also be found out from the rainfall data by using USDA S.C. method. The objectives of CROPWAT is to find out the crop water requirements for the different crops and to develop irrigation schedules basing on data provided.

The CROPWAT programme consists 8 different modules, of which 5 are data input modules and 3 are calculation modules. The data input modules of CROPWAT are:
1. Climate/ET0: with the help of Penman-Monteith method.
2. Rain: to calculate - the effective rainfall;
3. Crop (dry crop or Paddy): to decide the planting date and crop scheduling;
4. Soil: to find out the field capacity and wilting point.
5. Crop pattern: to calculate the cropping pattern basing on available water.

The calculation modules of CROPWAT are:
1. CWR – to find the Crop Water Requirements of various crops.
2. Schedules (dry crop or Paddy) – to find of irrigation schedules basing on climatic and availability of water.
3. Scheme - for the calculation of scheme supply basing on a specific cropping pattern.

2.2 ACOUSTIC DOPPLER VELOCIMETER (ADV)
Acoustic Doppler Velocimeter (Flow Tracker) is the instrument mainly used to measure velocity in irrigation channels. It is based on the based on principle that it measures stream velocity by sensing the phase change caused by the Doppler shift in acoustic frequency. If a transmitted acoustic signal when reflects off by the sediment particles present in the flow. In a typical ADV system consists of N numbers of the receivers those records simultaneously. The velocity component, signal strength value, a signal-to-noise (SNR) and a correlation value for each receiver, The signal strength, SNR and correlation values are applied mainly to determine the quality and accuracy of the velocity data, although the signal strength.

2.3 GENETIC ALGORITHM:
The genetic algorithm (GA), established by John Holland basing on the principle of biological evolution based on Charles Darwin’s theory of natural selection. With the use of crossover and recombination, mutation, and selection. This genetic plays the essential part of the genetic algorithm in the problem-solving strategy. There are many positive aspects of genetic algorithms over traditional optimization algorithms, out of which most noticeable advantages are: its ability to deal with most critical problems and parallelism. It also can be applied to deal with various types of optimization. Having the objective (fitness) function is stationary or non-stationary (change with time), linear or nonlinear, continuous or discontinuous, or with random noise. As multiple off-springs belongs to a population behaves as an independent agents. Further the population (or any sub-group) can be explored the search space in many directions simultaneously.

2.4 METHODS OF OPERATION OF GA
GA works on mechanism of natural selection and genetics. They start with a set of random solutions called population. Each solution is called chromosome. Chromosome consists of string of symbols (usually a binary bit string) that represents a solution to a problem to be solved and discussed. The initial population has to be determined at the start. Chromosomes evolve from the successive iterations called generation. During each iteration, the chromosomes are evaluated using a fitness function basing on which it is eventually decided, if a chromosome capable to passes to the next or dies. After each iteration of algorithm, a new generation is formed with new chromosomes called offspring. They are formed by either by merging two chromosomes from the current generation using the crossover operation by by modifying a single chromosome using the mutation operation. The new generation is then formed by selecting some of the chromosomes according to their fitness value and by rejecting others that do not qualify as valuable individuals. Fitter chromosomes are more likely to live longer. After few generations the algorithm should converge to the best chromosome, which hopefully, represents the optimal solution to the problems. The similar technique is applied to solve this problem to get most feasible solution.

III. STUDY AREA
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’E longitude. Topography of the area varies from plain to undulating and comprises mostly terrace lands with average slopes between 1 and 6%. The elevation of the land surface varies from 120 to 180 m above the mean sea level. The general slope is toward south-east. The surface drainage of the command area is mainly controlled by the Mahanadi River and its tributaries. The soils of the study area have been developed mostly from granite rocks and are medium textured.
IV. DERIVATION OF OPTIMIZED CROP PATTERN

The farmers of the study area were consulting regarding their views towards cultivating various types of crops in Kharif and Rabi seasons. The yields of crops were verified from them along with the support price of the crops. The present crop pattern is unable to satisfy the farmers, as the return is less.

1. Objective function

\[ \text{MAX } P = \sum_{i=1}^{n} (P_i \cdot Y_i \cdot A_i) - A_i \left[ (\text{Cost of Fertilizers})_i + (\text{Cost of Seed})_i + (\text{Cost of Labour})_i + (\text{Cost of water requirements})_i \right] \]

Where

- \( P = \text{Profit} \)
- \( i = 1, 2, 3, ..., 20; \)
- \( n = \text{No. of Crops considered in the study area; } n = 13 \) (for kharif Season);
- \( P_i = \text{Price of each Crop in market (Rs/qntl);} \)
- \( Y_i = \text{Yield of each crop (qntl/ha);} \)
- \( A_i = \text{Area of each Crop (ha);} \)
- Cost of Fertilizer = \( [(U_i \cdot U_e) + (D_i \cdot D_e) + (M_i \cdot M_e)] \cdot A_i \)
- Cost of Seed = \( [(S_i \cdot S_e)] \cdot A_i \)
- Cost of Labour = \( [(L_i \cdot L_e)] \cdot A_i \)
- Cost of Water = \( [(W_i \cdot W_e)] \cdot A_i \)

2. Water availability constraints:

\[ \sum_{i=1}^{n} (W_i \cdot A_i) \leq W_t \]

Where

- \( W_i = \text{total water available from canal;} \)

3. Land area constraints in different Seasons:

\[ \sum A_i = \text{The Cultivation area in different Season (Kharif and Rabi)} \]

4. Crop area constraints:

\[ L_{bi} \leq A_i \leq U_{bi} \]

Where

- \( L_{bi} = \text{lower bound of each crop;} \)
- \( U_{bi} = \text{Upper bound of Crop;} \)

5. Non negative constraints:

\[ A_i \geq 0 \]

BY USING GENETIC ALGORITHM

In Genetic Algorithm optimization technique, attempt has been made to maximize the profit by changing the cropping pattern. The criteria have been selected as per the local demand and requirement of people that paddy is cultivated at least 50% of the total cultivated area. Further depending on the crops in Rabi and kharif, separate models have been developed for giving maximum benefits to the farmer. By using the maximization equation and putting that equation in the main function and taking the fitness function and constraint function into consideration the values are calculated. After that the crossover value and population values are changed and after various iterations the pattern which gives maximum profit is considered as the optimal cropping pattern for two seasons (Kharif and Rabi). The maximum profit and related cropping pattern are given in following paragraphs.

FOR KHARIF SEASON:

After various trail runs of the model ten iterations values are taken which have arrived at maximum profit. The profit values of ten iterations are given below and are shown in the form of line diagram.

<table>
<thead>
<tr>
<th>NO OF ITERATION</th>
<th>PROFIT(Lakh)</th>
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<tbody>
<tr>
<td>1</td>
<td>589.5483631</td>
</tr>
<tr>
<td>2</td>
<td>583.6872264</td>
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<tr>
<td>3</td>
<td>586.0553732</td>
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<td>4</td>
<td>586.9071022</td>
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<tr>
<td>5</td>
<td>590.098919</td>
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<td>6</td>
<td>587.9629419</td>
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<tr>
<td>7</td>
<td>578.9990756</td>
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<tr>
<td>8</td>
<td>563.8051457</td>
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<tr>
<td>9</td>
<td>572.0299364</td>
</tr>
<tr>
<td>10</td>
<td>578.2527016</td>
</tr>
</tbody>
</table>

According to the iteration values the graph is plotted. The graph shows that the maximum profit is obtained at iteration No. 5.

Fig. 2 Profit vs. Iteration values graph of Kharif using GA
The maximum profit arrived by running GA from the best ten iteration values is taken into consideration. The 5th iteration gave the maximum profit value of 590.0698919 lakhs. So the cropping pattern related to the 5th iteration value is taken as optimal cropping pattern.

CONCLUSION

The main objective of this study is to attain the optimal crop planning of the study area. The main objective the study is also to get maximization of returns/profits. Hence the solution will suit the farmers need and will improve the financial condition of farmers if they will adopt the optimal cropping pattern given by the programme. Literature were collected related optimal crop planning and the literature suggests the decision variables (area of different crop) as the statistical data which provides information on various heads.

REFERENCES


