Derivation of Optimal Cropping Pattern in Part of Hirakud Command using Cuckoo Search.

ASHUTOSH RATH, SUDARSAN BISWAL, SANDEEP SAMANTARAY, PROF. PRAKASH CHANDRA SWAIN

DEPARTMENT OF CIVIL ENGINEERING, VSS UNIVERSITY OF TECHNOLOGY, ODISHA, BURLA 768018, INDIA

Abstract

The economic growth of a Nation depends on agriculture which relies on the obtainable water resources, available land and crops. The contribution of water in an appropriate quantity at appropriate time plays a vital role to increase the agricultural production. Optimal utilization of available resources can be achieved by proper planning and management of water resources projects and adoption of appropriate technology. In the present work, the command area of Sambalpur distributary System is taken up for investigation. Further, adoption of a fixed cropping pattern causes the reduction of yield. The present study aims at developing different crop planning strategies to increase the net benefit from the command area with minimum investment. Optimization models are developed for Kharif season using LINDO and Cuckoo Search (CS) algorithm for maximization of the net benefits. In process of development of Optimization model the factors such as cultivable land, seeds, fertilizers, man power, water cost, etc. are taken as constraints. The irrigation water needs of major crops and the total available water through canals in the command of Sambalpur Distributary are estimated. LINDO and Cuckoo Search models are formulated and used to derive the optimal cropping pattern yielding maximum net benefits. The net benefits of Rs. 585.0 lakhs in Kharif Season are obtained by adopting LINGO and 596.07 lakhs from Cuckoo Search, respectively, whereas the net benefits of 447.0 lakhs is received by the farmers of the locality with the adopting present cropping pattern.

Key words- Command area, Discharge, Crop Optimization, Cuckoo Search

1. Introduction

Agriculture is the backbone of Odisha, state economy, employing over 65% of total work force. More than 80% total work force in Odisha is directly or indirectly dependent on agriculture. Due to rapid increase in population, demand on consumption of food is more. So the development of agriculture-based economy, needs an efficient planning of its land and water resources to get the maximum economic returns. In time water supply to crops as per the requirement is the prime factor of input for enhancing productivity. The scientific utilization of groundwater potential and adoption of crop rotation are also the key factors. Agriculture in Odisha is more a ‘way of life’ than a ‘mode of businesses’. In 2014, the National Crime Records Bureau of India reported 5,650 farmers had committed suicides. Such types of incidents are also reported in this study area. To overcome such situations it requires to adopt a scientific approach of water resources management and planning keeping in mind the available restricted resources (such as water, land, production cost, man power,
fertilizers, seeds, pesticides, etc.) with the help of optimization techniques. The farmer needs to understand the cropping pattern which will maximize their benefit and economic returns.

Different approaches of irrigation management based on the water and land availability in the schemes and the schedule of operation of the canal system are available. Category one (allocation model of area) this approach is adopted, if the water supply in the project is adequate, it is adopted on the principle of optimally allocating the area to various crops such that maximum yield per unit area can be obtained. The second category of approach is applicable, when the water availability and supply is restricted and the cropping pattern (areas of allocation) is pre decided. In such type of approach the available inadequate or restricted water requires to be circulated to different crops so that maximum production and benefits can be obtained from the entire scheme (Water allocation models). The third category when the water supply is restricted and the cropping patterns (areas) can be chosen freely as per the suitability. Both water and area to be allocated optimally to different crops to get maximum production and benefits in the scheme (Land and Water allocation model).

The present study indicated the land allocation to the various crops based on available water. Various studies have been conducted in this area area of optimization. Frizzone et al. (1997) developed a separable linear programming model, considering a set of technical factors which may influence the profit of an irrigation project. Royce et al. (2001) studied the development of a model based optimization of crop management for climate forecasting applications. Sethi et al. (2002) developed the optimal crop planning based on conjunctive use of water resources based on increasing trend of intensive rice cultivation in a coastal river basin. Raju and Kumar (2004) proposed the application of Genetic Algorithm (GA) for irrigation planning. Kumar et al. (2006) proposed a genetic algorithm (GA) model for acquiring optimal crop water allocation and optimal operating policy from irrigation reservoir. Yang et al. (2009) derived a multi objective planning for conjunctive use of surface and subsurface water using genetic algorithm and dynamics programming. Yang and Deb (2010) developed an optimization algorithm on Cuckoo Search (CS). Yang and Deb (2011) derived a multi-objective Cuckoo Search Algorithm for design optimization. Noory et al. (2012) optimized irrigation water allocation and multi-crop planning using discrete PSO algorithm. Valian et al. (2012) developed an improved Cuckoo Search for reliability optimization problems. According to them this is a developed meta-heuristic optimization algorithm which solves engineering optimization problems by keeping the parameters constant. Mehdipour et al. (2013) developed multi-crop planning rules in a reservoir system. Singh (2014) optimized the use of land and water resources for maximizing farm income by mitigating the hydrological imbalances. Banik et al. (2014) discussed about a comparative study area crop water assessment using CROPWAT.

The purpose of this study is to develop a feasible and acceptable cropping pattern in the study area that would help the farmers to get optimum benefits from their field, which would improve financial the condition of the farmers. It is worth mentioning that no significant research work related to optimal use of the irrigation water with the use of scientific water management practice was carried out in the proposed study area, though this area is called food bowl of the state of Odisha, India.

2. Materials and Method

2.1 Optimization techniques

The process of the Optimization are designed to find the ‘best’ values of system design and operating policy variables – values that will lead to the highest levels of system performance. A good numbers of optimization methods used in practice incorporates the concepts based on engineering economics. Engineering economic methods mostly identify a set of mutually exclusive alternatives out of which only one best alternative can be selected considering all constraints.

2.2 Classical Optimization Techniques

The classical optimization techniques are applied in finding the optimal solution or unconstrained maxima or minima of continuous and differentiable functions. In the present paper, linear programming with the help of LINDO software is used as the optimization technique for solving the problem of choosing optimal crop pattern.
2.3 Cuckoo search

The recently developed Cuckoo search (CS) technique is one of the latest nature-inspired metaheuristic algorithms, which was developed in the year 2009 by Xin-She Yang of Cambridge University and Suash Deb of C. V. Raman College of Engineering. Cuckoo search (CS) technique based on the brood parasitism of some cuckoo species. The recent studies reveal that CS is potentially far more efficient than PSO and genetic algorithms.

2.3.1 Cuckoo search rules

The Cuckoo Search can be described by following three idealized rules [I]-Each cuckoo lays one egg at a time, and dumps its egg in a randomly chosen nest; [ii]-The best nests with high-quality eggs will be carried over to the next generations [iii] The number of available host nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability $p_a$ [0; 1]. In such type of situation, the host bird takes a decision either to get rid of the egg, or simply abandon the nest and build a completely new nest. In the case of a maximization problem, the quality or fitness of a solution can simply be proportional to the value of the objective function. For the application point of view, we can follow the simple representations that each egg in a nest represents a solution, and each cuckoo can lay only one egg (thus representing one solution), the aim is to use the new and potentially better solutions (cuckoos) to replace a not-so-good solution in the nests. Obviously, this algorithm can be extended to the more complicated case where each nest has multiple eggs representing a set of solutions. For this present work, we will use the simplest approach where each nest has only a single egg. In this case, there is no distinction between eggs, nest or cuckoo, as each nest corresponds to one egg which also represents one cuckoo. One of the most important steps in the algorithm is the use of Levy’s flights for random searches. The Levy’s flight is a type of random walk and described by a sequence of jumps determined from a probability density function. The step size, which controls the random search process in Levy’s flight, is generally selected between the intervals 0 and 1. Setting $\lambda = 1$ may produce efficient results, especially for small-sized optimization problems. The vector of the new nest is generated from randomly selected $i$th nest by Levy flights using:

$$\text{New\_nest}_i^t = \text{nest}_i^t + \lambda (\text{nest}_i^t - \text{nest}_b^t)$$

Where $\text{New\_nest}_i^t$ is the new nest generated by Levy flights, $\text{nest}_i^t$ is a randomly selected nest from the population, $\text{nest}_b^t$ is the best nest obtained, $\lambda$ is step size, and $\lambda$ is the step length or Levy flights vector. After determining the new nest, the objective function values of two nests are calculated and the best nest is kept.

**Pseudo code of the Cuckoo Search (CS)**-Based on these three rules, the basic steps of the Cuckoo Search (CS) can be summarized as the pseudo code shown below.

Objective function $f(x), x = (x_1,x_2,....,x_d)^T$

Generate initial population of $n$ host nests $x_i$ (i-1, 2,3......n);

while($t<\text{Max Generation}$) or (stop criterion)

Get a cuckoo randomly/generate a solution by Levy flights and then evaluate its quality / fitness $F_i$

Choose a nest among $n$ (say, j) randomly

if($F_i>F_j$),

Replace j by the new solution.

End

A fraction (pa) of worse nests are abandoned and new ones/solutions are built/generated. Keep best solutions (or nests with quality solutions). Rank the solutions and find the current best
End while

In this work the number of host nests selected $n = 15, \quad = 1$ and $p_a = 0.25$.

2.3.2 Objective function:

The crop water requirement of different crops under the command area were found using CROPWAT. The field interview with farmers revealed that there is a scope for improvement of cropping pattern. The farmers are eager to change their habits of growing Paddy as the prime crop. They need strong technological back up and motivation. In this study Optimal Irrigation models have been developed with the help of Lingo software.

2.4 Cropwat

CROPWAT 8.0 software (FAO, 2006) has the capability to calculate the crop water requirements for the various crops based on climatic data, soil data and crop data. It helps helps in development of irrigation schedules based on the different management conditions and 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 CROPWAT programme consists of 8 different modules, out of which 5 are data input modules and 3 are calculation modules. The data input modules of CROPWAT are:

1. Climate/ETo: input of measured ETo data or of climatic data by using Penman-Monteith equation.
2. Rain: Effective rainfall can be calculated from the input rainfall data.
3. Crop: Helpful for the input of crop data.
4. Soil: Describe the soil properties such as field capacity, wilting point etc.
5. Crop pattern: input to find pattern and the scheme supply of water.

The calculation modules of CROPWAT are:

6. CWR- to calculate the crop water requirements for the various crops.
7. Schedules- It is helpful to find irrigation schedules.
8. Scheme- It depends on the cropping pattern.

2.5 Flow monitoring with flow tracker

The velocity measurement was made with SonTek/YSI Flow Tracker Handheld Acoustic Doppler Velocimeter (ADV) (2006). Flow Tracker consists of unique data-processing capability. The Flow Tracker ADV based on the measures the velocity of sediment particles, small organisms, and bubbles, suspended in the flow. It is assumed and treated that these particles travel at the same velocity as the water. It 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, etc. These velocity and quality-assurance data may be used to evaluate the measurement conditions.

![FlowTracker with 2D Probe](image)

**Fig. 1 FlowTracker with 2D Probe**

**Principle of Operation**

The acoustic frequency at which the Flow Tracker ADV acts is of 10 Mhz and it measures the phase change resulted due to 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.

3. STUDY AREA
The present work is carried out in the command area of Hirakud canal system, Sambalpur, Odisha, India. The present experiment is carried on one of the canals of the Hirakud canal system. This area is situated at the western part of the Odisha from 21°05’N to 21°55’N latitude and 83°55’E to 84°05’E longitude. Hirakud Reservoir is considered as a multipurpose Dam, used to control flood, and other purposes like the irrigation and power generation. The Dam is constructed across river Mahanadi, which is situated at about 15 km upstream of Sambalpur town in the state of Odisha. The Hirakud canal system consist of three canal system namely Bargarh Main canal, Sason main canal, Sambalpur distributary. The Sambalpur distributary emerges from the left dyke of the Hirakud Reservoir.

![Fig.2 Command area of Parmanpur distributary](image)

The average annual rainfall of the command area is found to be approximately 1,200 mm, out of which approximately 90% is received during monsoon season (mid-June to mid-October). The major crops are paddy, Wheat, Pulses like Arhar, Green gram and Black gram, Oilseeds like Groundnuts, Til and Mustard, and Sugarcane. Paddy is the most dominant crop.

4. DERIVATION OF OPTIMIZED CROP PATTERN
The farmers of the study area were consulting regarding their views towards cultivating various types of crops in Khariff 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. Hence the types of crops satisfy the farmers, as the return is less. Hence the types of crops were finalized after through discussion and acceptance by the farmers of the command area. LINGO is a simple tool for linear and nonlinear optimization to formulate large problems concisely, solve them, and analyze the solution. Optimization technique helps in finding the answer that yields the best result; attains the highest profit, output, or happiness; or achieves the lowest cost, waste, or discomfort. In general, an optimization model composed of the following three items: objective function, Variables and constraints.

**Objective Function**
\[ MNB = Y_C \times P_e \times A_C - \{IN_{(c,m)} \times A_C \times IC \} \]
Where MNB is maximum net benefit, \( Y_c \) is yield for crop \( c \) (tones/ha), \( P_c \) is crop price (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.

**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**

\[ \sum IN_{(cm)*A_c} \leq \sum WA \]

**Computation of crop yield in Hirakud canal catchment area**

The yield of the crops for Kharif Season as obtained from the official of the Irrigation department is given in the table below.

**Table 1 Existing cropping pattern & Yield of each crop in the Command area of Sambalpur distributary**

| Name of crop | Area of crop (ha) | Yield (qtl/ha) | Name of crop | Area of crop (ha) | Yield (qtl/ha) |
|--------------|-------------------|---------------|--------------|-------------------|---------------|
| Paddy        | 674               | 33            | Til          | 5                 | 5.5           |
| Maize        | 10                | 22            | Potato       | 1                 | 110           |
| Arhar        | 5                 | 10            | Vegetables   | 80                | 125           |
| Green gram   | 15                | 6             | Chilly       | 12                | 15            |
| Blackgram    | 10                | 5             | Ginger       | 5                 | 160           |
| Other pulses | 48                | 5             | Turmeric     | 5                 | 40            |
| Groundnut    | 1                 | 13            |              |                   |               |

4.1 **Water requirement of crops using CROPWAT:**

The crop water requirement for different crops are calculated by considering the climate data, soil data, temperature data and rainfall data etc with the help of Cropwat software. Cropwat gives the CWR value at different condition. The CWR value of crops cultivated in the study area are given in the table. As per the discussions with the farmers of the locality and the official of the Irrigation department the crops prices as a rate of Rs/ton are obtained after the deduction of the cost of labors and fertilizers, pesticides for the various crops.

**Table 2 CWR value of each crop in study area**

| CROP NAME  | CROP WATER REQUIREMENT (CWR) in (m) | Cost of crop (Rs/Qntl ) | CROP NAME  | CROP WATER REQUIREMENT (CWR) in (m) | Cost of crop (Rs/Qntl ) |
|------------|-------------------------------------|-------------------------|------------|-------------------------------------|-------------------------|
| PADDY      | 0.7901                              | 1900                    | MUSTARD    | 0.3897                              | 5500                    |
| WHEAT      | 0.4267                              | 2475                    | POTATO     | 0.3042                              | 1100                    |
| MAIZE      | 0.322                                | 4000                    | SWEET POTATO | 0.4116                              | 3500                    |
| GRAM       | 0.4431                              | 8500                    | ONION      | 0.4394                              | 1200                    |
4.2 Discharge data of Sambalpur distributary:

The canal has rectangular cross section with partially lined. The velocity of flow is measured at different locations such as 0.2B, 0.4B; 0.6B and 0.8B from left side of the bank where B indicates the width of the canal. The ADV was placed at different depths such as 0.2D, 0.4D and 0.8D, free from water surface. Where D indicates the depth of the water in the canal. The velocity at different sections are measured. Then the average velocity is taken for calculation at that section and the area of that section is also taken into consideration, for calculation of discharge in the canal

Table 3. Discharge data at Different Stations as obtained from ADV flow tracker

| Station No. | Average velocity (m/s) | Area($m^2$) | $Q (m^3/\text{s})$ | Station No. | Average velocity (m/s) | Area($m^2$) | $Q (m^3/\text{s})$ |
|-------------|-----------------------|-------------|-------------------|-------------|-----------------------|-------------|-------------------|
| 1           | 0.359                 | 2.311       | 0.830             | 9           | 0.251                 | 2.504       | 0.629             |
| 2           | 0.426                 | 1.938       | 0.826             | 10          | 0.287                 | 2.175       | 0.624             |
| 3           | 0.482                 | 1.675       | 0.807             | 11          | 0.732                 | 0.840       | 0.615             |
| 4.1         | 0.332                 | 2.395       | 0.795             | 12.1        | 0.545                 | 1.106       | 0.602             |
| 4.2         | 0.369                 | 2.141       | 0.790             | 12.2        | 0.441                 | 1.204       | 0.531             |
| 5.1         | 0.354                 | 2.173       | 0.769             | 13.1        | 0.504                 | 1.045       | 0.527             |
| 5.2         | 0.435                 | 1.705       | 0.741             | 13.2        | 0.596                 | 0.827       | 0.493             |
| 6.1         | 0.280                 | 2.625       | 0.735             | 14          | 0.199                 | 2.015       | 0.401             |
| 6.2         | 0.300                 | 2.43        | 0.729             | 15          | 0.147                 | 2.048       | 0.301             |
| 7           | 0.380                 | 1.905       | 0.724             | 16          | 0.275                 | 0.660       | 0.181             |
| 8           | 0.344                 | 1.978       | 0.680             |             |                       |             |                   |

5. Results and Discussions

5.1 Optimization by using LINGO

According to the Present cropping pattern adopted by farmers, the net profit obtained is Rs. 447.0 lakh. After much iteration with the help of lingo, the maximum profit found to be Rs. 585.0 lakh. The cropping pattern for the same is given in the table below.
Table 4. Cropping Pattern derived using Lindo for Kharif Season-

| Name of crop | Notation used for crop | Present cropping pattern adopted by farmers | Area of crops( ha) suggested by lindo | Name of crop | Notation used for crop | Present cropping pattern adopted by farmers | Area of crops( ha) suggested by lindo |
|--------------|------------------------|------------------------------------------|-------------------------------------|--------------|------------------------|------------------------------------------|-------------------------------------|
| PADDY        | P                      | 674                                      | 463.58                              | TIL          | T                      | 5                                        | 20                                  |
| MAIZE        | M                      | 10                                       | 25                                  | POTATO       | U                      | 1                                        | 20                                  |
| ARHAR        | A                      | 5                                        | 30                                  | CHILLY       | C                      | 80                                       | 30                                  |
| Green gram   | O                      | 15                                       | 30                                  | GINGER       | I                      | 12                                       | 8.71                                |
| BLACKGRAM    | B                      | 10                                       | 35                                  | TUMERIC      | W                      | 5                                        | 8.71                                |
| OTHER PULSES | S                      | 48                                       | 80                                  | VEGETABLES   | V                      | 5                                        | 110                                 |
| GROUNDNUT    | G                      | 1                                        | 10                                  |              |                        |                                          |                                     |

5.2 Use of cuckoo search technique

In CUCKOO SEARCH 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. By running the model for various iterations, many profit values and related cropping patterns are derived. From those iterations, ten best iterations and their profit values were taken into consideration and have shown in table and figure for Kharif season.

Fig.3 Profit Kharif season arrived at different iterations using Cuckoo Search

The no of iteration is in x-axis and the profit is in y-axis. The maximum value as indicated in the graph is taken into consideration as optimal profit and the related cropping pattern as the optimal cropping pattern. Maximum profit occurs at 5th iteration. Amounting to Rs.596.07000 lakh. Cuckoo Search gave the value of area of crop in the command window and the related profit value.
Table 5 Cropping Pattern obtained from Cuckoo Search for Kharif Season

| Name of crop     | Notation used for crop | Area of crop (ha) | Name of crop     | Notation used for crop | Area of crop (ha) |
|------------------|------------------------|-------------------|------------------|------------------------|-------------------|
| PADDY            | P                      | 474.69            | TIL              | T                      | 19.24             |
| MAIZE            | M                      | 28.98             | POTATO           | U                      | 18.40             |
| ARHAR            | A                      | 24.05             | CHILLY           | C                      | 29.83             |
| Green gram       | O                      | 34.20             | GINGER           | I                      | 9.73              |
| BLACK GRAM       | B                      | 31.02             | TUMERIC          | W                      | 9.38              |
| OTHER PULSES     | S                      | 73.71             | VEGETABLES       | V                      | 109.73            |
| GROUNDNUT        | G                      | 6.66              |                  |                        |                   |

The cropping pattern which considered as the optimal cropping pattern is shown below in graphical form

Fig. 4 Cropping Pattern using Cuckoo Search for Kharif Season

Discussions of results:

It is observed that the farmers of the locality cultivate paddy as the major crop. The profits obtained by them are not encouraging. It is mainly due to improper cropping pattern and the lack of crop rotation. At present, the farmers of the area are adopting 13 different crops in the Kharif Season. According to the cropping pattern adopted by farmers, the net profit obtained in the Kharif season is Rs. 447 lakh. Use of LINDO optimization technique yields a profit of Rs 585 lakh in kharif Season. Cuckoo search is the latest optimization technique which is adopted to derive the optimal cropping pattern. The maximum profit obtained by using the Cuckoo search for the kharif season is found to be Rs. 596.07 lakh.
From the above result, it is concluded that use of Cuckoo Search gave the higher profit with the optimal cropping pattern as mentioned in Table 7.

6. Conclusions:

The main objective of this study is to derive the optimal crop pattern in the study area and to get maximum of returns/profits. It will help the farmers to improve their financial conditions. Among the two optimization methods i.e., LINDO and Cuckoo Search, Cuckoo Search yields higher profits. The optimal cropping pattern derived by using the Cuckoo Search can be applied in the command area. Optimal use of available water resources can be achieved when both surface water and ground water will be used conjunctively to maximize agricultural production. It is essential to adopt Crop diversification to improve the productivity of land. Implementation of command area development works and improvement of the water delivery systems are required to reduce the losses and to ensure water availability to the farmers at the tail reach.

Reference

[1] Frizzone, J.A., Coelho, R.D., Neto, D. Dourado., and Soliani, R (1997) “Linear programming model to optimize the water resource use in irrigation projects: an application to the Senator Nilo Coelho Project” Sci.agric. (Piracicaba, Braz.) Vol.54 June 1997

[2] Royce, F.S., Jones, J.W., and Hansen, J.W., (2001) “Model based optimization of crop management for climate forecast Applications” ASAE Vol.44 (5): 1319-1327 (2001) (American Society of Agricultural Engineers

[3] Sethi, L.N., Kumar, D.N., Panda, S.N., and Mal, B.C., (2002) “Optimal Crop Planning and Conjunctive Use of Water Resources in a Coastal River Basin” Water Resources Management 16: 145–169, 2002

[4] Raju, K. Srinivasa, and Kumar, D. Nagesh (2004) “Irrigation planning using Genetic Algorithm”. Water Resource Management 18: 163-176, 2004.

[5] Kumar, D. Nagesh., Raju K.Srinivasa., and B, Ashok. (2006). “ Optimal reservoir operation for Irrigation of Multiple Crops Using Genetic Algorithm.” Journals of Irrigation and Drainage Engineering, Vol. 132, No. 2, April 1, 2006. @ASCE, ISSN 0733-9437/2006/2-123-129

[6] Yang, C.-C., Chang, L.-C., Chen, C.-S., and Yeh, M.-S. (2009). “Multi-objective planning for conjunctive use of surface and subsurface water using genetic algorithm and dynamics programming. "WaterResourManage.,23(3),417–437

[7] Yang, X.-S., and Deb, S. (2010), “Engineering Optimisation by Cuckoo Search”, Int. J. Mathematical Modelling and Numerical Optimisation, Vol. 1, No. 4, 330–343 (2010).

[8] Yang, X.-S., and Deb, S. (2011), “Multiobjective cuckoo search for design optimization
[9] Noory, H., Liaghat, A.M., Parsinejad, M., and Haddad, O.B., (2012) “Optimizing Irrigation Water Allocation and Multi-crop Planning Using Discrete PSO Algorithm” J.Irrig. DrainEng. 2012, 138(5): 437-444

[10] Mehdipour, E. Fallah., Haddad, O. Bozorg., and Mariño, M. A. (2013). “Extraction of Multi-crop planning rules in a reservoir System: Application of Evolutionary Algorithms.” Journal of Irrigation and Drainage Engineering, Vol. 139, No. 6, June 1, 2013. © ASCE, ISSN 0733-9437/2013/6-490-498.

[11] Singh, A., (2014) “Optimizing the Use of Land and Water Resources for Maximizing Farm Income by Mitigating the Hydrological Imbalances” Journal of Hydrologic Engineering, Vol. 19, No. 7, July 1, 2014. © ASCE, ISSN 1084-0699/2014/7-1447-1451.

[12] Banik, P., Tiwari, N.K., and Ranjan, S., (2014) “Comparative crop water assessment using CROPWAT” International Journal of Sustainable Materials, Processes & ECO-Efficient – IJSMPE, Volume1: Issue 3 [ISSN 2374 –1651]

[13] Valian, E., Tavakoli, S., Mohanna, S., and Haghi, A., (2012), “Improved Cuckoo Search for reliability optimization problems” 459-468

---

**FIRST AUTHOR-ASHUTOSH RATH**, working as Asst.professor at SIT, Sambalpur with Water Resource Engineering as Specialization. Currently pursuing PhD at VSSUT, BURLA. Two papers published in international journals.

**SECOND AUTHOR-SUDARSAN BISWAL**, M.tech at VSSUT working as Asst.professor at DREAMS College Sambalpur with Water Resource Engineering as Specialization.

**THIRD AUTHOR-SANDEEP SAMANTARAY**, M.tech working as Guest faculty at VSSUT, BURLA, Sambalpur with Water Resource Engineering as Specialization.

**FORTH AUTHOR-PROF. PRAKASH CHANDRA SWAIN** working as, Professor at VSSUT BURLA. Specialization Water Resources Engineering, Application of Artificial Intelligence Techniques to Water Resources Management. More than 30 International Publications.