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Simulation Optimization of Land and Water Resources

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Abstract

In hill plateau areas, Production of crops is dependent on seasonal rainfall. Using easy fit tool the rainfall is predicted for optimum planning of crops. The optimization problem is a multi-variable linear model and it is time consuming to simulate for optimal use of land and water resources. Gradient optimization is used to reduce the search time of variables. The finer step size updated the parameters to higher precision and increased accuracy of the parameters. The best optimized solution is then simulated using Monte-Carlo simulation method. A comparative analysis for different standard deviation ranges indicates larger the range of deviation of each variable improves the quality of solution.

Keywords: Mersenne Twister Algorithm, Tolerance Limit, Simulation Optimization, Monte-Carlo Simulation, Gradient Search Method

Introduction

The aim of present study is to plan for optimal use of water resources to reduce risk in agriculture and increase productivity. The area selected for the project is Kandhamal district located in North Eastern Ghat Agro Climatic Zone. The normal annual rainfall in the district is 1600 mm of which 80% is for monsoon period. The agricultural production is basically depending on seasonal rainfall. The optimization of crop land is associated with effective rainfall of the locality. Lack of rainfall forecasting is a root cause of drought, flood and resulting crop failure. Attempts are made to produce rainfall estimates for example (Hossein

Ansari [1]). He used non-linear model tools for rainfall forecasting. Local linear regression and neural network are also used for the said purpose. But uncertainty in prediction results high risk in decision making. Probabilistic forecasts have potential to provide more relevant information regarding future planning.

Materials and Methods: - The annual rainfall data from (1988 – 2004, 2007 – 2012) years is collected from Directorate of Agriculture, Govt. of Odisha[2]. A variety of approaches were available to determinate the appropriate distribution for the study but under a parametric approach a specific distribution was selected and parameters of the distribution was estimated from the observed data because large standard errors are mainly caused by the uncertainty in the shape parameters (T.A Buishan [3]) Easy- fit was used to determine the best probability distribution of the seasonal rainfall. Table shows the approximated random components that are best-fit for Johnson's SB distribution with positive skewness. In simulation modeling the computer generated random numbers are used for probabilistic forecasting of rainfall in a region. These random numbers are independent and uniform. The statistical test for uniformity is done using Anderson-Darling tests (Kelton [4]) because this test can detect the discrepancies in the tails and has higher power than Kolmogrove-Smirnov test. The random numbers are independent since they satisfied the auto-correlation test (Jerry Bank et al. [5]). The run length of simulation experiment is estimated using the following relation

$$N = \frac{\left(\Upsilon_{\left(1-\frac{\alpha}{2}\right)}\right)^2}{m_d^2} \cdot V_n^2 \quad \text{(Narsingh Deo [6])}$$

Where N is run length of Simulation,

$\Upsilon_{\left(1-\frac{\alpha}{2}\right)}$ is two tailed standardized normal static with probability (1-α), 'V_n' is variance of the observations and 'm_d' is mean deviation taken as 'tolerance limit' of the observations. The simulation output of statistically independent replications is generated using 'Meresenne Twister' algorithm as this algorithm passes through numerous tests for statistical randomness. The arithmetic mean of all replications are subjected to testing of hypothesis using two -sided students

t – distribution test, where $t_0 = \frac{\bar{x}_i - \mu_0}{\left(\frac{S_i}{n}\right)}$ is test statistics, 'μ_0' is the true specified value of the null hypothesis and 'S_i' is the standard deviation of sample size 'n'. The hypothesis is accepted because

$t_0 < \left(\frac{t}{\frac{\alpha}{2}}, n-1\right)$ with 'α' level of significance and 'n' sample size respectively. Prior to the formulation of the simulation model for rainfall estimation, several ancillary results are implemented through a series of model transformations to enhance the computational efficiency.

In the present model the Johnson's S_B variates has been implemented (Law,Kelton[4]).

Rainfall prediction analysis: -The annual rainfall of kandhamal district in mm from1988 to 2004are 1266.5, 1339.8 , 2220.7, 1718.6, 1552.5 ,1271, 2088, 1816.6, 1093.1, 1754.7, 1475.7, 1362.8, 1279,1965.5,1285.6,2096.1, 1545.2 also the annual rainfall from 2008-2012 are 1778.1,1700. 8,1729.7 ,1208.5 and 1597.8 mm respectively. The statistical parameters characterizes best-fit theoretical distributional information .Using easy-fit tool the obtained input parameters are given bellow.

<u>Table</u>

Mean	1599.2
Rank among all distributions	1
Variance	1.4363E+5
Test Statistic	0.22465
Skewness	1.3331
Kurtosis	2.6657

<u>Anderson – Darling level of fitness Test</u>: -

Level of Significance (α)	0.2	0.1	0.05	0.02	0 .01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9
Reject?	No	No	No	No	No

The simulation analysis of the data depends on four parameter for S_B distribution. But the accuracy of simulation is mainly caused by the uncertainty in the estimation of the parameter. So, the estimated components of SB distribution using easy- fit are shape parameters $\gamma = 0.41693$ and $\delta = 0.88473$, scale parameter $\lambda = 1438.7$ and location parameter $\xi = 1011.15$. The expected number of simulation runs estimated to be $5.82 \approx 6$. The generated simulation output are 1960.54, 1788.86, 2118.63, 1597.06, 1750.60 and 2298.96 mm .

The average simulated rainfall is 1919.1 mm. But, actual rainfall for 2013 is 1950.2 mm.In the present case hypothesis is accepted using two sided students t – distribution test with 5%

level of significance. Thus, estimated value and observed value of rainfall approach towards each other for pre-specified level of significance.

Simulation optimization model

Kharif is the main cropping season due to availability of water intake. The major crops grown during this period are Paddy, Maize, Vegetable, Turmeric, Mug, Ginger, Arhar and Fibers respectively. The net return from agriculture is computed by taking 2007-08 as base year of calculation. In the present paper the labor contribution has not been considered in obtaining the net return from different crops.

Crop Sequence	Cropping Area (Hector)	Net Return (Rs./Hector)
Paddy	x_1	6318.00
Maize	x_2	3961.00
Vegetable	x_3	10693
Turmeric	x_4	35446
Mug	x_5	3333
Ginger	x_6	53040
Arhar	x_7	12347
Fiber Crops	x_8	7759

The linear programming problem is

Maximize (y) = $6318\, x_1 + 3961\, x_2 + 10693\, x_3 + 35446\, x_4 + 3333\, x_5 + 53040\, x_6 + 12347\, x_7 + 7759\, x_8$

Subject
to
Constraints

$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8 \leq 128000$ (Cultivable area in Hectares)

$x_1 + x_2 + x_3 + x_5 \leq 117000$ (Up and Medium Land Constraint)

$x_2 + x_4 + x_5 + x_6 + x_7 \leq 96000$ (Upland Constraint)

$x_1 + x_2 + x_3 + x_5 + x_8 \leq 24170$ (Area under assured irrigation)

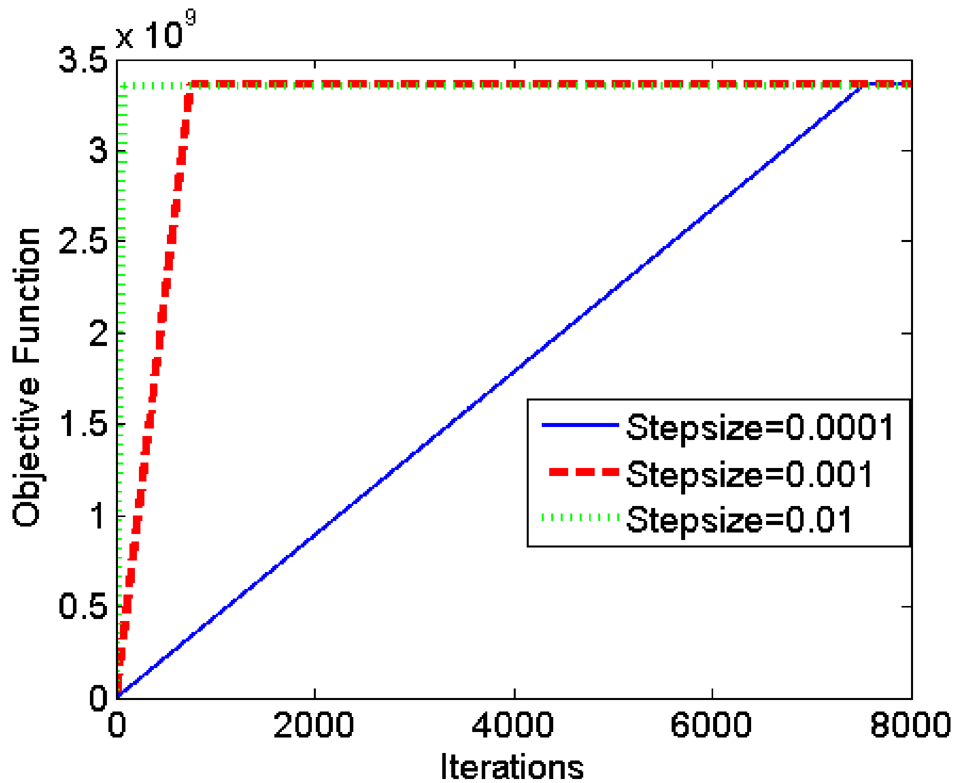
$x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, x_4 \geq 0, x_5 \geq 0, x_6 \geq 0, x_7 \geq 0, x_8 \geq 0$

The objective function is a multi-variable convex function, which is defined and differentiable in its neighborhood. Therefore every local maximum point is taken as a global maximum point with linear rate of convergence. The steepest descent method has been applied for solving the linear programming problem.The improved solution for the objective function is denoted by X which is equal to $x_i + \mu \,.\, \mathbf{C}_i$ for i = 1, 2 … 8.

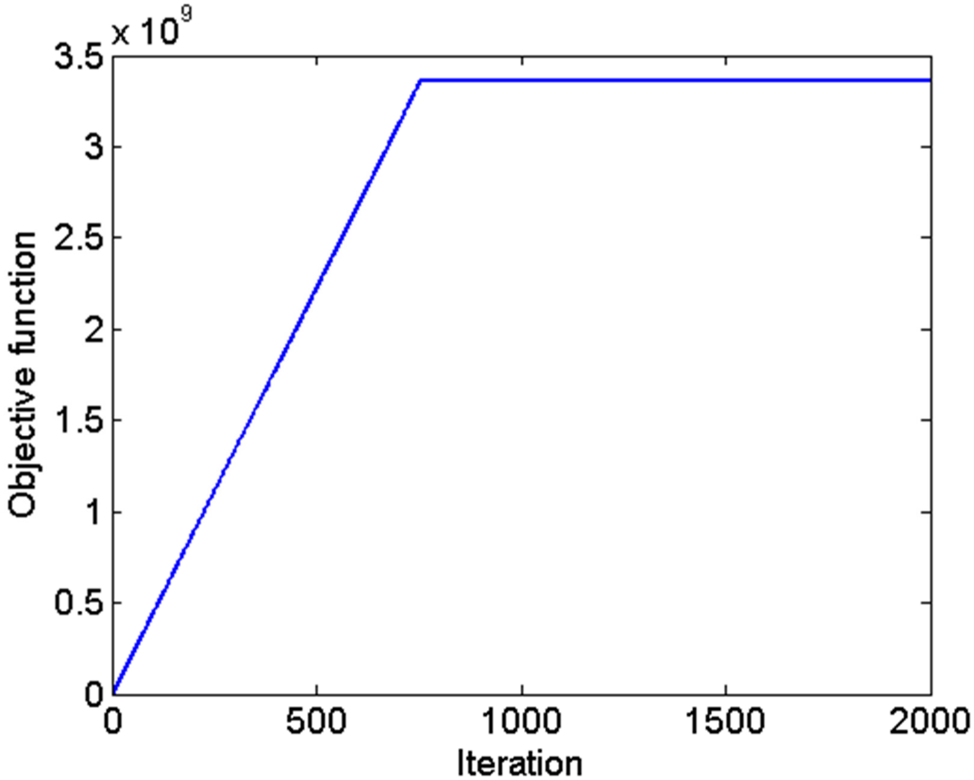
Where $\mathbf{C}_i$ is cost vector and $\mu = 0.001$ is step length. The finer step size can update each parameter to a higher precision. Therefore accuracy level of the parameter can be increased. Now optimized solution obtained in gradient optimization method has been simulated using Monte-Carlo Simulation. For simulating the optimized variables, Gaussian Probability distribution is chosen over ($m \pm 3\sigma$) range where 'm' is the mean and 'σ' is standard deviation of the distribution, since the range covers almost 98% area of the distribution. The Monte-Carlo simulation has been implemented on the model for 6000 iterations. A comparative study has been conducted by taking different standard deviations, which indicate more the deviation; more is the accuracy of the solution.

The comparative output analysis by Steepest-descent optimization method and the simulation optimization for different iterations are given bellow.

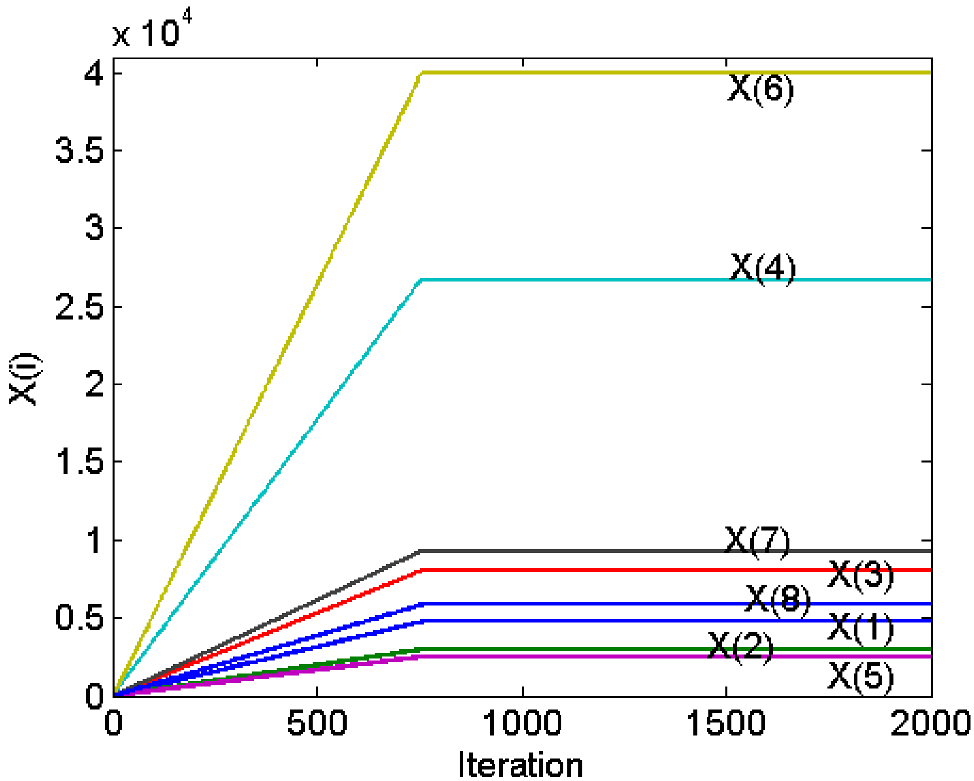
Variables(Area of crops in ha)	**Gradient Optimization 2000 (iterations)**	**Simulation Optimization (6000 iterations) & 200 Standard Deviations**
x_1	4763.772	4734.978
x_2	2986.594	2885.04
x_3	8062.522	8157.7
x_4	26726.283	27144.115
x_5	2513.082	2456.998
x_6	39992.16	40476.34
x_7	9309.63	9237.977
x_8	5850.28	5841.390
Y(Objective function)	3.5×10^9	3.48×10^9



(Optimization of LPP using steepest descent method for different finer step lengths)

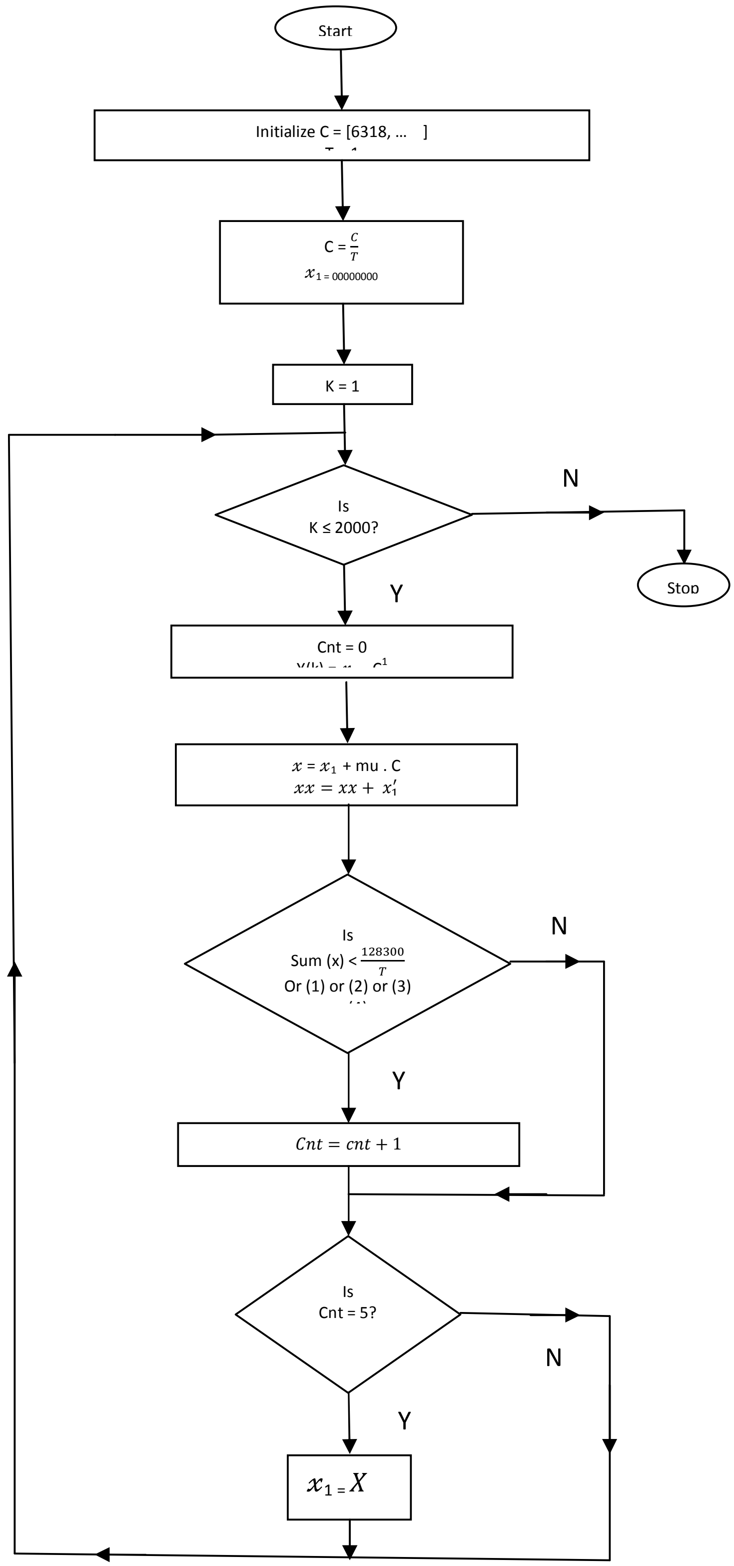


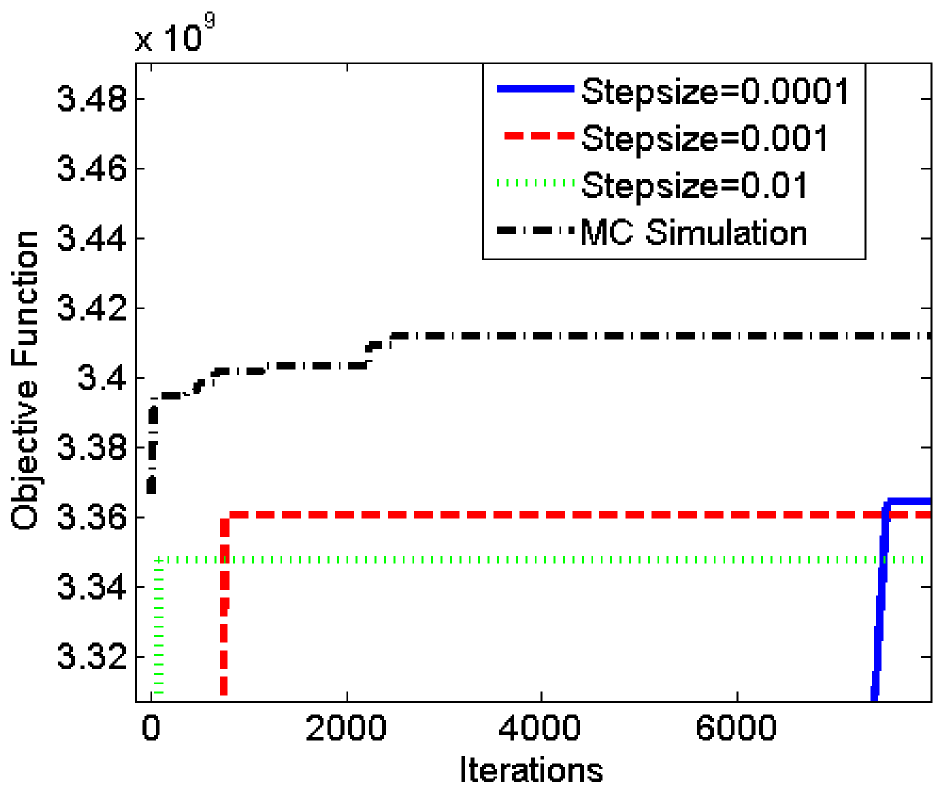
(Convergence of optimizing function using steepest –descent method for 2000 iterations)



(Values of variables in gradient optimization method for 2000 iterations)

FLOW CHART OF GRADIENT OPTIMIZATION





(Comparative analysis of gradient optimization and simulation optimization for 6000 iterations using finer step sizes)

Conclusion: The cropping pattern of hill plateau areas of Kandhamal district depends on rain water. Attempt is made to estimate the annual seasonal rainfall of the study area. The present problem is a constrained multi-variable linear model. To reduce the time consumption for searching optimal solution, steepest descent optimization method has been implemented. The best solution obtained in this process is then simulated using Mont-Carlo simulation. The graphical comparison indicates that for large deviation in case of the individual variables also give the convergent solutions. The expected solution range of variables is taken in comparison with standard agriculture practice of farmers.

References

1. Forecasting seasonal and annual rainfall based on non-linear modeling with gamma test in north of Iran. Author – Hossein Ansari. International Journal of Engineering Practical Research (IJEPR).
2. Handbook of Statistics. Directorate of Agriculture. Govt. of Odisha. (1988 - 2004, 2007 - 2012).
3. Extreme rainfall estimation by combing data from several sites by T.A.Buishan,1991
4. Simulation Modeling and analysis. (2003). 3rd Edition. Author – Averill M. Law, W. David Kelton
5. Discrete Event System Simulation. Author – JERRY BANKS, JOHNS CARSON – II, BARRY, L. NELSON, DAVD NICOL (2007).
6. System Simulation with digital computer. Author – Narsingh Deo (2000). Prentice Hall

Simulation optimization programme

```
clear
C=[6318 3961 10693 35446 3333 53040 12347
7759];
T=1;
C=C/T;
X1=zeros(1,8);
mu=0.001;
XX=[];
for k=1:2000
    cnt=0;
    y(k)=X1*C';
    X=X1+mu.*C;
XX=[XX X1'];

if sum(X)<=128300/T
    cnt=cnt+1
end
if X(1)+X(2)+X(3)+X(5)<= 117000/T
    cnt=cnt+1
end
if X(2)+X(4)+X(5)+X(6)+X(7)<=96000/T
    cnt=cnt+1
end
if X(1)+X(2)+X(3)+X(5)+X(8)<=24170/T
    cnt=cnt+1
end
if X(1)>=0 & X(2)>=0 & X(3)>=0 & X(4)>=0 &
X(5)>=0 & X(6)>=0 & X(7)>=0 & X(8)>=0
    cnt=cnt+1
end

if cnt==5
    X1=X;
end
end
plot(y)
```

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