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Computational Support to Optimum Cropping Pattern using MS-Excel

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ABSTRACT

The scientific planning for agricultural development has become a vital area of specialization in agriculture. The optimal cropping pattern that is allocation of land to various crops with maximum profits has become mandate, particularly for vegetable crops (cash crops) because their cultivation is cost expensive with high risk of profitability due to price fluctuations despite their enhanced profits over food crops. Usually, traditional cropping pattern varies from farmer to farmer depending on the available resources and perspective of land holding and failed to provide guaranteed returns due to uncertain prices (stochastic). To address this problem, several methodologies were developed and have been utilized meagerly due to great difficulty in getting solutions. Among them, one of the decision making model developed by Anjeli Garg, Shiva Raj Singh(2011) to provide the best returns under uncertainty using Fuzzy Multi objective Linear Programming (FMOLP) is quiet interesting and unique with its step-wise procedure. But it also involves tedious computations which may require more time and certain level of knowledge in mathematical concepts. In this juncture, authors have decided to provide a user-friendly procedure to solve MOLPP easily using MS-Excel instead of using high level software. To check efficacy of the developed user-friendlyprocedure the same problem mentioned by Anjeli Garg, Shiva Raj Singh(2011) was considered and obtained accurate results quickly. This procedure is also applicable for different combinations of multiple crops with different profit and resource coefficients.

Key words: Optimum Cropping pattern, MOLPP, User-friendly procedure, Solver in Excel.

1. Introduction

The quantity of yields produced from agriculture farms may influence the market prices significantly. Generally farmers follow a traditional method for a cropping pattern or allocation of land to different type of crops varies as per the available resources. Over the decade it has been observed that the net profit per acre is greater in vegetable crops (cash crops) than that of food crops. Thus for each cultivation pattern of vegetable crops, maximization of the profit will be the major objective of any farmer. These problems of allocation of land for different crops, maximization of production of crops, maximization of profit, minimization of cost of production are addressed in agricultural management system with the help of Operations Research approach particularly with Linear programming Problem (LPP), Integer Programming problem(IPP), Assignment problem(AP) and Transportation Problem (TP). Initially, these problems of agriculture sector were modeled as single objective linear programming problem by dealing with one objective at a time. But with changing scenario of multifaceted real time problems, several objectives need to be handled simultaneously subject to the same set of constraints. Thus, the situation demands for new methodologies which are capable in handling the complex problem of decision making, as the maximization of crop production can't guarantee the maximization of profit. In the agriculture sector, profit or loss also depend on fluctuating demand, supply and pricing of a particular crop with minimization of cost of cultivation needed for that crop. Thus the maximization of profit turns out to be a multiobjective decision making problem.

The success of aneconomic model depends on the fact that how effectively it can sustain for volatility of market prices. Thus, a good the model must accommodate the conditions of uncertainty and complexity, while handling imprecise information. In general food grains prices are not much volatile and give almost guaranteed return, as in many countries (India) food grains have government support prices, whereas vegetable prices are mostly random variables and its cropping is also highly cost effective. In fact the vegetable cropping needs to manage the several costs viz., capital investment in insecticides, pesticides, fertilizers, frequent irrigation, labours and transportation cost. Sometimes due to unexpected production of similar crops from local areas will also influence the market prices due lack of storagefacility. Surprisingly vegetable prices also vary on day to day basis even in the same season. By keeping in view of volatility ofvegetable prices,a proper land planning is initiated for optimal returns and computational difficulty is also taken care by user-friendly procedure developed using MS-Excel with the help of Solver tool.

2. Methodology

2.1 Problem description

Let us consider the problem [4] in which number of producible of crops are 'n' and respective profits for these crops are c_{i1}, c_{i2}, c_{i3}……. c_{in} per unit area along with respective probabilities p_i. The decision variable x_j, element $h_j$and $w_j$denote cultivation area for crop j and the work time in labour hours and required water units for growing crop j at the unit area respectively. As the land of a farm is limited$x_1+ x_2+ x_3+ x_4+\ldots\ldots x_n$ has to be less than or equal to 'L'acres and we call it as "land constraint". The total labour hours of working time is limited and thus $w_1x_1+ w_2x_2+ w_3x_3+ w_4x_4+\ldots\ldots+w_nx_n$has to be less than or equal to a certain 'W' and we call it as *"labour constraint"*. Under these constraints and discrete crisp and fuzzy random profit coefficients, we want to find the decision variables $x_j$so as to maximize the profit(R).

Maximize R
Subject to

$$\left.\begin{array}{ll} x_1 + x_2 + x_3 + \cdots \ldots \leq L & \text{(Land constraint)} \\ w_1x_1+w_2x_2 + w_3x_3 + \cdots \ldots + w_nx_n \leq W & \text{(Work time constraint)} \\ c_{11}x_1+ c_{12}x_2+ c_{13}x_3+ c_{14}x_4+\ldots\ldots+ c_{1n}x_n \geq R & \end{array}\right\} \quad (2.1.1)$$

$$c_{21}x_1+ c_{22}x_2+ c_{23}x_3+ c_{24}x_4+\ldots\ldots+ c_{2n}x_n \geq R$$
$$c_{31}x_1+ c_{32}x_2+ c_{33}x_3+ c_{34}x_4+\ldots\ldots+ c_{3n}x_n \geq R$$
$$\ldots\ldots\ldots\ldots$$
$$c_{m1}x_1+ c_{m2}x_2+ c_{m3}x_3+ c_{m4}x_4+\ldots\ldots+ c_{mn}x_n\geq R$$
$$x_1, x_2, x_3, x_4,\ldots\ldots x_n,\ R \geq 0$$

2.2 Computational algorithmto solve a Fuzzy MOLP

A computational algorithm for a scenario when profit coefficients are crisp discrete random variables by using fuzzy multiobjective linear programming approach is developed by Anjeli Garg, Shiva Raj Singh[2] is given below

Step-1: Solve each objective function with the same set of constraints providedin (2.1.1) separately.

Step-2: Using the solution obtained in step1, find the corresponding value of all the objective functions for each of solutions.

Step-3: From step 2, obtain the lower and upper bounds $z_k'$and $z_k^*$for each objective function and construct a table of Positive Ideal Solution (PIS).

Step-4: Consider a linear and non-decreasing membership function between $z_k'$and z_k^*, ∀k as

$$\mu_k(x) = \begin{cases} 1 & if\, z_k\,(x) = z_k' \\ \dfrac{[z_k\,(x) - z_k']}{[z_k \; - z_k']} & if\, z_k' \le z_k\,(x) \le z_k^* \\ 0 & if\, z_k\,(x) < z_k' \end{cases}$$

The above membership function is essentially based on the concept of preference/satisfaction.

Step-5: Transform multiobjective linear programming into LPP as

Max α
Subject to

$$\left.\begin{array}{l} x_1 + x_2 + x_3 + \cdots \ldots x_n \le L \quad \text{(Land constraint)} \\ w_1 x_{1+} w_2 x_2 + w_3 x_3 + \cdots \ldots . + w_n x_n \le W \text{(Work time)} \\ \mu_k(x) = \left\{ \dfrac{[z_k\,(x) - z_k']}{[z_k \; - z_k']} \right. \ge \alpha\,, x \in X \\ \text{where} z_k\,(x) = c_{k1}x_1 + c_{k2}x_2 + c_{k3}x_3 + \cdots \ldots + c_{kn}x_n \end{array}\right\} \qquad (2.2.1)$$

Further equation (2.2.1)can be written as

Max α
Subject to

$$\left.\begin{array}{l} x_1 + x_2 + x_3 + \cdots \ldots x_n \le L \quad \text{(Land constraint)} \\ w_1 x_{1+} w_2 x_2 + w_3 x_3 + \cdots \ldots . + w_n x_n \le W \text{(Work time)} \\ c_{11}x_1 + c_{12}x_2 + c_{13}x_3 + \cdots \ldots + c_{1n}x_n - \alpha(z_1^* - z_1') \ge z_1' \\ c_{21}x_1 + c_{22}x_2 + c_{23}x_3 + \cdots \ldots + c_{2n}x_n - \alpha(z_2^* - z_2') \ge z_2' \\ c_{31}x_1 + c_{32}x_2 + c_{33}x_3 + \cdots \ldots + c_{3n}x_n - \alpha(z_3^* - z_3') \ge z_3' \\ \ldots\ldots\ldots \\ c_{m1}x_1 + c_{m2}x_2 + c_{m3}x_3 + \cdots \ldots + c_{mn}x_n - \alpha(z_m^* - z_m') \ge z_m' \end{array}\right\} \qquad (2.2.2)$$

Step-6: Equation (2.2.2) can be solved easily using *Solver* module in MS-Excel and the procedureisprovided in next section.

Step-7: Finally, the guaranteed expected return can be calculated as $\sum_{i=1}^{k} z_i(x)p_i$,
Where$z_i(x)$ is the value of the ithobjective function at the values of decision variables obtained from the solution of equation (2.2.2).

2.3About *Solver* in MS Excel

Solver is a part of a suite of commands sometimes called **what-if analysis**. With *Solver*, one can find an optimal value for a formula in one cell called the *target cell* on a worksheet. Solver works with a group of cells that are related, either directly or indirectly, to the formula in the target cell. *Solver* adjusts the values in the *changing cells* specified, called the adjustable cells to produce the result specified from the target cell formula. One can apply constraints to restrict the values *Solver* can use in the model, and the constraints can refer to other cells that affect the target cell formula. Use *Solver* to determine the *maximum or minimum* value of one cell by changing other cells, for example, one can change the amount of your projected advertising budget and see the effect on your projected profit amount.

2.3.1 Supporting Terminology of *Solver*

What –if –analysis tools: A process of changing the values in cells to see how those changes affect the outcome of formulas on the worksheet.

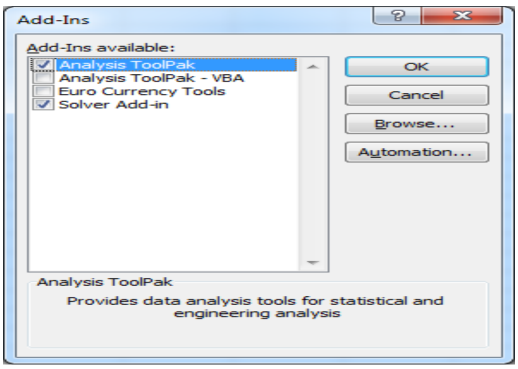
Formula: A sequence of values, cell references, names, functions, or operators in a cell that together produce a new value. A formula always begins with an equal sign (=).

Constraints: The limitations placed on a Solver problem. One can apply constraints to adjustable cells, the target cell, or other cells that are directly or indirectly
related to the target cell.

2.3.2 How to install *Solver* in Excel

Excel has a built-in statistical package for carrying out LPP.This feature is usually hiden and can be brought out to the menu by clicking the button sequencing.

Open Excelsheet →Office button/File → Excel options → Add- ins → analysis tool pack and solver add-in→ ok.(the process varies from version to version).



Automatically *solver* can be included in the menu of **data**.

3. Results and Discussion

3.1 Numerical illustration -Problem description

A farmer is to grow carrot, radish, cabbage and Chinese cabbage in a season in areas be x_1, x_2, x_3 and x_4 acres respectively.The farmer has a total land of 10 acres and a maximum labour work time available with him is 260 hours. The profit coefficients ('000 INR) and work time for the crops are given in the table-3.1. (Source: [2]).

Table-3.1: Profit coefficients, labour requiremententire duration of crop

	Carrot	Radish	Cabbage	Beetroot	Probability %
Profit coefficients (c_1)	29.8	10.4	13.8	19.8	10
Profit coefficients (c_2)	23.9	21.4	49.2	32.8	50
Profit coefficients (c_3)	37.0	16.0	3.6	9.7	10
Profit coefficients (c_4)	19.3	26.6	48.4	75.6	30
Work time	6.9	71	2	33	

Here, we illustrate solution of the problem by the working procedure provided in the section-2.2and the undertaken problem is to solve

$$\left.\begin{aligned}
&\text{Maximize } Z_1 = 29.8\, x_1 + 10.4\, x_2 + 13.8\, x_3 + 19.8\, x_4 \\
&\text{Maximize } Z_2 = 23.9\, x_1 + 21.4\, x_2 + 49.2\, x_3 + 32.8\, x_4 \\
&\text{Maximize } Z_3 = 37.0\, x_1 + 16.0\, x_2 + 3.60\, x_3 + 9.70\, x_4 \\
&\text{Maximize } Z_4 = 19.3\, x_1 + 26.6\, x_2 + 48.4\, x_3 + 75.6\, x_4
\end{aligned}\right\} \qquad (3.1.1)$$

Subject to constraints

$$\left.\begin{aligned}
&x_1 + x_2 + x_3 + x_4 \le 10 \quad \text{(Land constraint)} \\
&6.9\, x_1 + 71\, x_2 + 2\, x_3 + 33\, x_4 \le 260 \text{(Work time)} \\
&x_1 , x_2 , x_3 , x_4 \ge 0
\end{aligned}\right\} \qquad (3.1.2)$$

3.2 Working procedure of the methodology provided in section 2.3 using Solver:

Step-1 in section 2.2 can be achieved by the following way

a. Open Excel sheet and type the decision variables (X_1, X_2, X_3 and X_4) and names of the constraints (Land, work time) in the cells A4 to A7 and E4 to E5 asshown in Ms-Excel screen-2.

b. From B4 to B7 enter zeros and From F4 to F5 type the constraints given in (3.1.2) byusing respective cell addresses for decision variables starting with(equal to) "=" symbol.

c. For example: in cell F4 type “=B4+B5+B6+B7” (without quotes) and in cell F5 enter “=6.9*B4+71*B5+2*B6+33*B7” . Similarly in the cells B10 to B13 type Max Z_1 / $(Z_1)_1$, $(Z_2)_1$, $(Z_3)_1$, and $(Z_4)_1$respectivelyas shown in MS-Excel Screen-2. Further, enter equations of four objective functions fromC10 to C13 as

“=29.8*B4+10.4*B5+13.8*B6+19.8*B7”
“=23.9*B4+21.4*B5+49.2*B6+32.8*B7”
“=37.0*B4+16.0*B5+3.6*B6+9.7*B7” and
“=19.3*B4+26.6*B5+48.4*B6+75.6*B7” respectively.

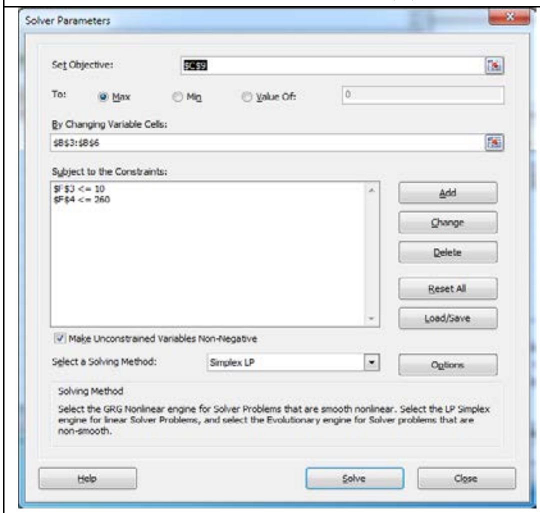
d. In main menu of Excel,Goto Data →Solver and *set objective function*, *by changing variable cells* as shown in MS-Excel Screen-1(a) by selecting respective cells. For *subject to the constraints* click on *Add* button and in the resultant window(MS Excelscreen-1(b)) select F3 and F4 cells and enter 10and 260 in the right side of the inequation. We can select the respective symbols ofinequations (<=, = ,>=) as per ourrequirements.

e. After entering all constraints, select *Make unconstrained variables Non-Negative* andSelect S*implex LP* and click on solve. Then window with the message *Solver found a solution* will be appeared as shown MS Excel screen-1(c) and click on Ok. Optimum solution withregard to the first objective funcation willl appear as shown in MS Excel Screen-2.

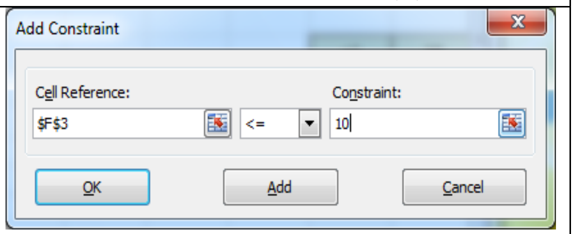
f. Copy the optimum solution and reset the decision variables values as zero in order to runthe same for the second objective function. Change the *set objective* cell as C11 and rerunthe *solver* and continue for the third and fourth objective functions also as C12 and C13.

Step-2 in section 2.2 can be achieved by copying Max Z_1 / $(Z_1)_1$, $(Z_2)_1$, $(Z_3)_1$, and $(Z_4)_1$ Valuesavailable in cells C10 to C13 immediately after running solver for each Objective function.

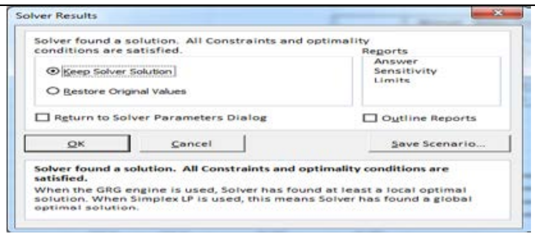
MS Excel screen-1(a)



MS Excel screen-1(b)



MS Excel screen-1(c)



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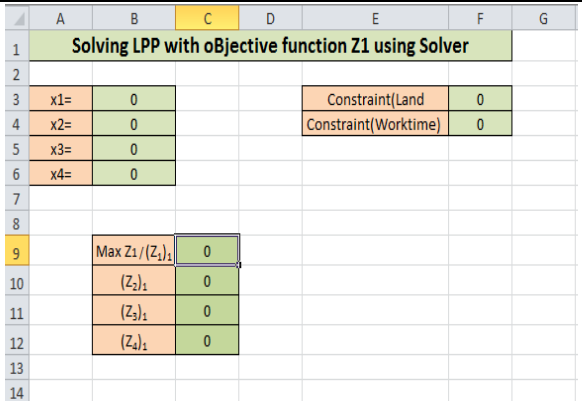
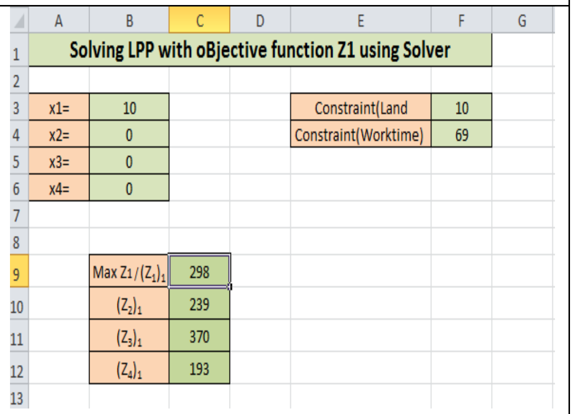
MS Excel Screen-2(a)



	A	B	C	D	E	F
1	Solving LPP with oBjective function Z1 using Solver					
3	x1=	0			Constraint(Land	0
4	x2=	0			Constraint(Worktime)	0
5	x3=	0				
6	x4=	0				
9		Max $Z_1/(Z_1)_1$	0			
10		$(Z_2)_1$	0			
11		$(Z_3)_1$	0			
12		$(Z_4)_1$	0			

MS Excel Screen-2(b)



	A	B	C	D	E	F
1	Solving LPP with oBjective function Z1 using Solver					
3	x1=	10			Constraint(Land	10
4	x2=	0			Constraint(Worktime)	69
5	x3=	0				
6	x4=	0				
9		Max $Z_1/(Z_1)_1$	298			
10		$(Z_2)_1$	239			
11		$(Z_3)_1$	370			
12		$(Z_4)_1$	193			

The Optimal solution to this crisp LP Problem for the first objective function with regard to constraints using (3.1.2) is $x_1 = 10$, $x_2 = 0$ $x_3 = 0$ $x_4 = 0$ $(Z_1)_1 = 11.4$. The four optimum solutions are summarized in table-3.2.

Table-3.2: Solutions at each objective function

	Max Z_1	Max Z_2	Max Z_3	Max Z_4
X_1	10	0	10	0
X_2	0	0	0	0
X_3	0	10	0	2
X_4	0	0	0	8

Step-3 in section 2.2 can be obtained by arranging solutions at each objective function solved with regard to constraints using (3.1.2)

Table-3.3: Positive Ideal Solutions

	Max Z_1	Max Z_2	Max Z_3	Max Z_4	*Max*	*Min*	(Max – Min)
Z_1	298	138	298	184.5	*298*	*138*	160
Z_2	239	492	239	365	*492*	*239*	253
Z_3	370	36	370	83.2	*370*	*36*	334
Z_4	193	484	193	694.6	*694.6*	*193*	501.6
	X_1	X_2	X_3	X_4			

Step-4and5 in section 2.2 will help to reformulate the problem, it reduces to a LPP as

Maximize α

Subject to

$$\left.\begin{array}{l} X_1 + X_2 + X_3 + X_4 \leq 10 \\ 6.9\, x_1 + 71\, x_2 + 2\, x_3 + 33\, x_4 \leq 260 \\ 29.8x_1 + 10.4\, x_2 + 13.8\, x_3 + 19.8\, x_4 - 160\, \alpha \geq 138 \\ 23.9x_1 + 21.4\, x_2 + 49.2\, x_3 + 32.8\, x_4 - 253\, \alpha \geq 239 \\ 37.0x_1 + 16.0\, x_2 + 3.60\, x_3 + 9.70\, x_4 - 334\, \alpha \geq 36 \\ 19.3x_1 + 26.6\, x_2 + 48.4\, x_3 + 75.6\, x_4 - 501.6\, \alpha \geq 193 \end{array}\right\} \quad (3.2.1)$$

Step-6 in section 2.2 can be working out with the help of step wise procedure given below.

1. Open a new Excel sheet and type the required entities as shown in MS Excel Screen-3(a) with red colored cells and also type the formulae mentioned in table-3.4 in respective cells which are kept in green colour for easy identification.

MS-Excel Screen -3(a)

	A	B	C	D	E	F	G	H	I
1	Solving MOLP provided in Equation (3.2.1) using Solver in MS-Excel								
2		Decision variables		Constraints					
3	x1=	0		Constraint1 =	0		Return calculations		
4	x2=	0		Constraint2 =	0				Probability
5	x3=	0		Constraint4 (Z1)=	0		Z1=	0	10
6	x4=	0		Constraint5 (Z2)=	0		Z2=	0	50
7	Alfa =	0		Constraint6 (Z3)=	0		Z3=	0	10
8				Constraint7 (Z4)=	0		Z4=	0	30
9							weighted returns		0
10									
11		Alfa (Objective Function) =	0						
12									
13									

Table-3.4: Required formulae to obtain the solution for MOLPP provided in equation (3.2.1)

Cell	Formulae to be entered	Cell	Formulae to be entered
E3	=B3+B4+B5+B6		
E4	=6.9*B3+71*B4+2*B5+33*B6		
E5	=29.8*B3+10.4*B4+13.8*B5+19.8*B6-160*B7	H5	=29.8*B3+10.4*B4+13.8*B5+19.8*B6
E6	=23.9*B3+21.4*B4+49.2*B5+32.8*B6-253*B7	H6	=23.9*B3+21.4*B4+49.2*B5+32.8*B6
E7	=37*B3+16*B4+3.6*B5+9.7*B6-334*B7	H7	=37*B3+16*B4+3.6*B5+9.7*B6
E8	=19.3*B3+26.6*B4+48.4*B5+75.6*B6-501.85*B7	H8	=19.3*B3+26.6*B4+48.4*B5+75.6*B6
C11	=B7	I9	=SUM(H5*I5/100 + H6*I6/100+H7*I7/100+H8*I8/100))

2. Open solver tool and fill up respective inputs appropriately as shown in MS Excel Screen-3(b) and click on solve which provides an optimum solution with message that solver found a solution.

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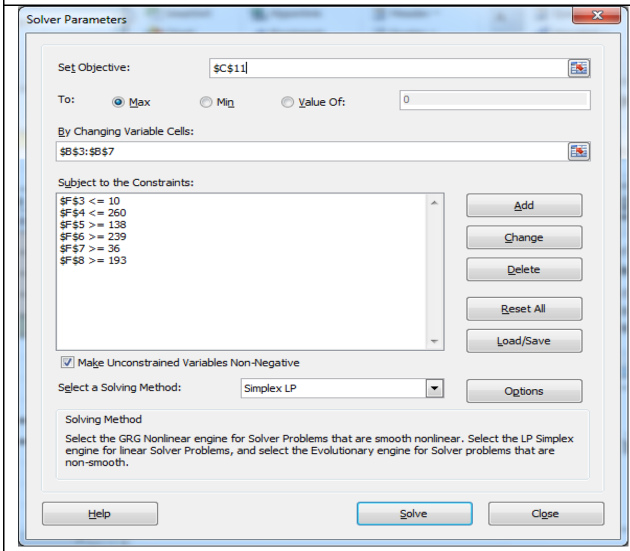
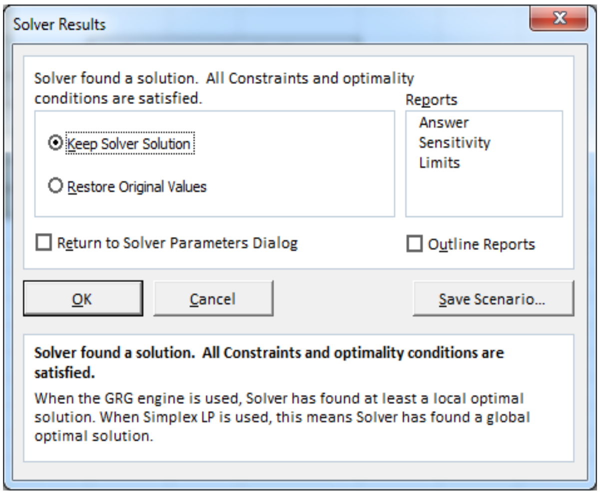
MS-Excel Screen -3(b)





3. Then we can observe the optimum solution provided by Solver in MS-Excel Screen-3(c) by omitting "Make unconstrained variables Non-negative" under Solver parameter.

4. Similarly if we select the option "Make unconstrained variables Non-negative", the optimum solution provided by Solver may be seen in MS-Excel Screen-3(d) .

MS-Excel Screen -3(c)

G17

	A	B	C	D	E	F	G	H	I	J
1	Solving MOLP provided in Equation (3.2.1) using Solver in MS-Excel									
2		Decision Variables								
3	x1=	3.78		Constraint1 =	10		Return calculations			
4	x2=	0.61		Constraint2 =	138.17				Probability	
5	x3=	3.75		Constraint4 (Z1)=	138		Z1=	207.54	10	
6	x4=	1.85		Constraint5 (Z2)=	239		Z2=	348.95	50	
7	Alfa	0.43		Constraint6 (Z3)=	36		Z3=	181.16	10	
8				Constraint7 (Z4)=	193		Z4=	411.11	30	
9							weighted returns		336.678	
10										
11		Alfa (Objective Function) =	0.4346							
12										
13										

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MS-Excel Screen -3(d)

	A	B	C	D	E	F	G	H	I	J
1	Solving MOLP provided in Equation (3.2.1) using Solver in MS-Excel									
2	Decision Variables									
3	x1=	4.14		Constraint1 =	10		Return calculations			
4	x2=	0.00		Constraint2 =	104.41				Probability	
5	x3=	3.79		Constraint4 (Z1)=	144.37		Z1=	216.66	10	
6	x4=	2.07		Constraint5 (Z2)=	239		Z2=	353.32	50	
7	Alfa	0.45		Constraint6 (Z3)=	36		Z3=	186.92	10	
8				Constraint7 (Z4)=	193		Z4=	419.76	30	
9							weighted returns		342.946	
10										
11		Alfa (Objective Function) =	0.4519							
12										
13										

5. The optimum solution which satisfies four objective functions simultaneously is x_1 =4, x_2=0, x_3=4 and x_4 =2which means that the farmer has to cultivate Carrot and Radish each at 4 acres of land and Beetrootin 2 acres in order to get guaranteed average returns of 342.95thousand rupees in spite of fluctuating prices. The maximum profit is identified at the fourth set of profit coefficients which may happen only at 30% of the time followed by second set of profit coefficients which likely to happen at 50% of chance.

6. Then theguaranteed weighted return can also be obtained in the cell I9automatically as shown in MS-Excel screen-3(c).

Conclusion

In the present scenario of agricultural production system certain goals are aimed notonly for maximal solution but also compromise solution.The optimum cropping pattern for higher profits is successfully tackled the problem of uncertainty in profits and cost of fertilizers with the help of fuzzy set based quantitative methodology. But there was a great scarcity in having computational support to solve the MOLP problemeasily. Hence, the developed user-friendly procedure is succeeded in providing optimum cropping patternwhichoffers a great vision to farmers regarding net guaranteed returns even in uncertain prices.

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