A Mathematical Programming Approach for Sugarcane Cultivation in the State of North India

Himanshu Pandey*[1] and Ashutosh Pandey[2]

ABSTRACT

In Indian economy sugarcane has great contribution to GDP. A large population of India depends on the agriculture sector for livelihood. At, the same time, due to expanding population , diminishing arable land and rising service industry, there is need to increase the production by utilizing the available agriculture resources. This paper represents a linear goal programming model for sugarcane to help farmers to allocate different resources available for sugarcane production in optimum manner.

Key words: *Agriculture, arable, fertilizers, cash, sugarcane, goal.*

1. INTRODUCTION

Agriculture planning problems cannot deal with a single goal of maximizing output or profits. These problems involve a number of goals such as maximizing total crop production and overall profit, minimizing expenditure on labour, water requirements and other cost related elements. These goals are conflicting in nature. It is difficult tasks to maximize ore minimize all goals simultaneously. Certain goals out of these can only be achieved at the expense of others, making it difficult for the decision maker to come up with an optimum plan. Goal programming (GP) is an effective and useful tool for dealing with problems having multiple and conflicting goals and for obtaining an optimum solution which comes closest to meeting the stated goals given the constraints of the problem. Goal programming is capable of handling effectively the problem involving multiple goals. It was developed by Charnes and Cooper (1961) has been refined and extended by Lee is senenties. Ijri (1965) has also done a lot of work in this area. Ignizio (1985) discussed the role of linear goal programming in solving multiple objective problems. In typical decision making situations, the goals set by a decision maker can be achieve aonly at the expense of other goals. It is necessary to make a hierarchy of importance among these goals so that lower priority goals are tackled only after higher priority ones are achieved. The application of Goal programming in the solution of problems affecting production management has been studied by different researchers. Habeed (1991) developed multi-criteria planning model for economy. Saliani (1996) discussed cultivation pattern design in water resources development. Sarker et al. (1995) developed a linear programming model to determine the areas to be allotted to different crops to maximize the total contributions from agriculture activities in Bangladesh. Sumpsi et al. (1996) created, applied and evaluated a multi objective model that aims at the simultaneous maximization of farmer's welfare and the minimization of the consequent environmental

1*. Himanshu Pandey, Associate Professor, Department of Mathematics and Statistics, D.D.U. Gorakhpur University Gorakhpur, UP, India, Email:himanshu_pandey62@yahoo.com
2. Ashutosh Pandey, Research Scholar (Statistics), Department of Mathematics and Statistics, D.D.U. Gorakhpur University Gorakhpur, UP, India, Email: ashutosh.srmcem@gmail.com

burden. Romero (2000) developed a risk programming model for agriculture resources allocation. Zander (2005) used multi objective model for the land use for sustainable development. Latinopoulos and Mylopoulos (2005) made use of goals programming for optimal allocation of land and water resources in irrigated agriculture. Sharma et al (2007) used fuzzy goal programming for agriculture land allocation problems. Nooripoor (2008) applied criteria decision making for horticulture sustainability. Nja and Udofia (2009) formulated Goal programming model for flour producing companies based on production time of three different products. Vivekanand et al (2009) used goal programming for the optimization of cropping pattern for a particular region, concentrating mainly on the factors like net return and proper utilization of surface and ground water in irrigated agriculture, Jafari et al (2008) formulated goal programming model for rice farm. In their study, the lexicographic goal programming model was considered to identify the optimal compound of agriculture product in the rice farm land of a village of Bebol country. Mohamad (2011) developed a mathematical programming model for crop mix problem.

The paper presented here deals with developing a linear goal programming model for areas of northern region of India involved in the production of sugarcane with the help of means of irrigation like canals and bore wells etc., not depending on rainfall.

2. DEVELOPMENT OF MODEL

Sugarcane is generally grown in Main season

- o Early: Dec - Jan
- o Mid: Feb - March
- o Late: April – May

Sugarcane is a sun shine loving plant. High humidity (80-85%) favors rapid cane elongation during grand growth period. A moderate value of 45-65% coupled with limited water supply is favorable during the ripening phase. Above 40% humidity coupled with warm weather favors vegetative growth of cane. As the northern plane is fertile and has proper irrigation facilities; it has all the favorable conditions required for Sugarcane.

3. ASSUMPTION OF THE MODEL

1. The total arable land available for cultivation is not being used for Sugarcane crop only.
2. Some portion of arable land is being used for growing veggies etc. for personal use.
3. The fertility of the land under study is same.
4. Some other crops are grown along with Sugarcane to save it from pests and diseases.
5. A number of verities of Sugarcane are grown simultaneously.
6. The crop is not depending on rainfall for water, means of irrigation like bore wells and canals are being used.
7. The budget available, water for irrigation, supply of labour and land are fixed.

Symbols and Notations to be used in Model Formulation

P: Expected net Profit from all crops in Rs.

N: Total number of crops cultivated.

E: Total area of land for cultivation in hectares.

I: Expected total ground water available for irrigation (cubic cm)

SC: Different varieties Sugar cane and SC =1,2,3…S.

d: Different other crops to be grown along with Sugarcane and d=1,2,3,…D

A_{sc} The area of land cultivation for Sugarcane in hectares.

L_d Land requires for other crops d in hectares.

R_{sc} Average production per unit area of Sugarcane(qtl/ha)

T_{sc} Total production target of Sugarcane (qtl).

S-JPSET : ISSN : 2229-7111, Vol. 4, Issue 2

O_{SC} Labour requirement per unit area for Sugarcane (man-day/ha)

EL Expected availability of labour (man-day)

B_{sc} Average investment per unit area for Sugarcane(Rs/ha/season)

B Total investment available in Rs.

M_{SC} Annual machine-hour per unit area for Sugarcane in hrs/ha.

HM Expected total machine-hours available in hrs.

P_{SC} Net profit for Sugarcane (Rs/qtl)

I_{SC} Amount of water required for Sugarcane(cubiccm/ha)

4. FORMULATION OF DIFFERENT GOALS

The goals for the LGP problem may be defined as follows:

4.1 Production Related Goals

The primary goals of farmers will be to get maximum output of Sugarcane. They will try to maximize expected sugarcane production, which is the product of the area under sugarcane cultivation with the average production per unit area in that season. The sum of the productions for all the varieties should be greater or equal to the total expected production target for that year. The corresponding goal equation is

$$\sum_{SC=1}^{S} R_{SC} A_{SC} \geq \sum_{SC=1}^{S} T_{SC}$$

or, $$\sum_{SC=1}^{S} R_{SC} A_{SC} + d_1^- - d_1^+ = \sum_{SC=1}^{S} T_{SC}$$

4.2 Net Profit Goal

The farmers will expect a specific amount of profit by producing the sugarcane crop. The goal corresponding to net profit on total production can be expressed as

$$\sum_{SC=1}^{S} P_{SC} A_{SC} \geq P$$

or, $$\sum_{SC=1}^{S} P_{SC} A_{SC} + d_2^- - d_2^+ = P$$

4.3 Availability of Labour

Production of sugarcane involves a number of process like tilling of land, planting, fertilizing, ploughing, irrigation etc. The people are involved in the process of developing, growing, transporting, millings and processing sugarcane. The farmer has to hire a number of agricultural laborers to accomplish all these processes. The corresponding goal equation is

$$\sum_{SC=1}^{S} O_{SC} A_{SC} \geq EL$$

or, $$\sum_{SC=1}^{S} O_{SC} A_{SC} + d_3^- - d_3^+ = EL$$

4.4 Availability of Water for Irrigation

For sugarcane cultivation it is necessary to ensure adequate supply of water. A total rainfall between 1100 and 1500 mm is adequate provided the distribution is being abundant in the months of vegetative growth followed by a dry period for ripening. It is also grown in the area where rainfall is low around 500 mm. Above 1500 mm rainfall would cause lodging of cane. Flood irrigation with canals and ground water through bore wells are main source of water. A minimum of three to four irrigations is necessary for optimum productivity. The water required for irrigation should not exceed the total amount available.The corresponding goal to availability of water is

$$\sum_{SC=1}^{S} I_{SC} A_{SC} \geq I$$

or, $$\sum_{SC=1}^{S} I_{SC} A_{SC} + d_4^- - d_4^+ = I$$

4.5 Availability of Machines

During sugarcane cultivation various processes like tilling of land, fertilizing, irrigation, harvesting and transporting to sugar mills etc. require availability of machine hours. The machine-hours required for sugarcane cultivation should not exceed the machine-hours available. The goal equation for machine-hour is

$$\sum_{SC=1}^{S} M_{SC} A_{SC} \geq HM$$

or, $$\sum_{SC=1}^{S} M_{SC} A_{SC} + d_5^- - d_5^+ = HM$$

4.6 Availability of Land for Sugarcane Crop

The portion of land under sugarcane cultivation should exceed the total land available for agriculture. The goal equation for cultivation land is given by

$$\sum_{SC=1}^{S} A_{SC} \geq E$$

or, $$\sum_{SC=1}^{S} A_{SC} + d_6^- - d_6^+ = E$$

4.7 Availability of Land for Food Crops and other Related Crops

As sugarcane is very high demanding crop it has to be grown in rotation by mixing with other crops. The total availability of land for sugarcane must not exceed total cultivation land available. Since sugarcane crop is yearly crop so that the farmer will not use the whole land for it. As the rotational crop such as wheat, rice, maize seeds, mustard seeds can be grown. Some portion of cultivable land will be used for growing crops for personal consumption. This land area should be less than the total land available for sugarcane production. The goal equation for land available for other crops can be written as

$$\sum_{d=1}^{D} L_d \geq E$$

or, $$\sum_{d=1}^{D} L_d + d_7^- - d_7^+ = E$$

4.8 Availability of Capital

A fix budget is required for arrange for fertilizers, seeds, machinery, maintenances and insectaries etc. The amount spent on these requirements should not exceed the budget allocated for sugarcane cultivation. The goal corresponding to working capital is given by

$$\sum_{SC=1}^{S} B_{SC} \geq B$$

or, $$\sum_{SC=1}^{S} B_{SC} + d_8^- - d_8^+ = B$$

4.9 Objective Function

Minimize $$C = P_1 d_1^- + P_2 d_2^- + P_3 d_3^+ + P_4 d_4^+ + P_5 d_5^+ + P_6 d_6^+ + P_7 d_7^+ + P_8 d_8^+$$

Where d_i^- and d_i^+ are non negative deviational variables denoting under achievement and over achievement of goals and all $A_{SC} \geq 0$. Moreover $P_1, P_2, P_3, P_4, P_5, P_6, P_7$ and P_8 are the priority factors and $P_1 > P_2 > P_3 > P_4 > P_5 > P_6 > P_7 > P_8$.

The model developed in this paper can be validated with the data available from the sugarcane producing areas of Uttar Pradesh, Punjab, Bihar, and Haryana. Moreover the manual calculation for the solution to the model will be cumbersome task so the software like MS Excel, Lingo, and MATLAB etc will be quite helpful.

5. CONCLUSION

The model derived in the current research here has taken consideration the environment conditions prevailing in north India. These priorities can be different depending on the objectives decided by different persons as per the resources available to them. A more improved solution of the problem can be obtained by including the constraints involving other related crops.

REFERENCES

[1] Biswas, A and Pal, B.B. (2005). *"Application of fuzzy goal programming tichnique to land use planning in agriculture system"*, Omega, 33:391-398.

[2] Habeed, Y.A., (1991). *"Adapting multi-criteria planning to the Nigerian economy"*. Journal of Operational Research Society, 42 (10):885-888.

[3] Ignizio, J.P. (1985), *"An algorithms for solving the linear goal programming Problem by solving its dual"*, J. Opl. Res. Soc., 36(6):507-515.

[4] Jafari, H.Koshteli, Q.R. and Khabri, B (2008), *"An optimal model using goal programming for rice farm"*, Applied Mathematical Sciences, 2(23):1131-1136.

[5] Lationpoulos, D and Mylopoulos, Y. (2005), *"Optimal allocation of land and water resources in irrigated agriculture by means of goal programming : application in Loudias river basin,"* Global Nest Journal 7(3): 364-273.

[6] Lee, S.M. (1972). *"Goal programming for Decision Analysis"*, Philadelphia, Auerbach Publishers.

[7] Mohamad, N and Said, Fatimah. (2011). *"A mathematical programnming approach to crop mix problem"*. African Journal of Agriculture Research 6(1): 191-197.

[8] Nja, M.E. and Udofia, G.A. (2009). *"Formulation of the mixed integer goal programming model for flour producing companies."* Asian Journal of Mathematics and Statistics, 2(3): 55-64.

[9] Noori poor, M, Shahvali. M and Zarafshani, K (2008), *"Itegration of communication media for horticulture sustainabilioty: The application of Multiple Criteria Decision Making (MCDM)."* American-Eurasian J. Agric. & Environ. Sci., 3(1): 137-147.

[10] Romero, C (2002), *"Risk programming for agriculture resource alloction : a multidimensional risk approach."* Annals of operations Research, 94: 57-68.

[11] Salaini, T (1996), *"Cultivation pattern design in watre resources development. Agriculture"*. Economy and Fourth Year Development Quarter, 15: 91-97.

[12] Sarker, R.A., Talukdar, S. and Anwarul, Haque. (1997). *"Determination of optimum crop mix for crop cultivation in Bangladesh."* Appl. Math. Sciences, 21(10):621-632.

[13] Sharma, D.K., Jana, R.K. and Gaur, Avinash. (2007). *"Fuzzy goal programming for agriculture land allocation problems"*. Yugoslav Journal of Operations Research 17(1): 31-42.

[14] Sumpsi, J.M., Amador, F., and Romero, C. (1996), *"On farmers ' objectives : A multi-criteria approach."* European Journal of Operational Research, 96: 64-71.

[15] Vivekanand, N., Vishwanath, K., and Gupta, S. (2009), *"Optimization of cropping pattern using goal programming approach."* OPSEARCH, 46(3): 259-274.

[16] Zander, P and Kachele, H. (2005), *"Modeling multiple objective of land use for sustainable development."* Agricultural Systems, 59(3): 311-325.

