CHAPTER – 2

REVIEW OF LITERATURE

A brief review of research work in the field of optimization techniques is presented in this chapter. The chapter is arranged with reviews of the applications of optimization models in agriculture. This chapter presents a review of the Linear and Non linear Fractional Programming Problems and Goal Programming Problems.

2.1 A REVIEW OF LITERATURE ON LINEAR PROGRAMMING

Singh (1972) made a feasibility study of crop insurance in U.P. using cross sectional data from Tarai farms for the year 1970-71, with the help of Linear Programming technique. He studied the crop variability in U.P. during 1951-70 and examined the feasibility of crop insurance programmes. He also evaluated two alternative causes, namely crop insurance and diversification, which will reduce income variance or minimize the probability of loss to achieve a more stable farm income. It was concluded that the fluctuating crop production is a chronic problem in U.P. and diversification stabilizes farm incomes at a higher level than the crop insurance programme.

Singh and Jha (1973) analysed the significance of the working capital constraints on the income possibilities of the farms of two villages belonging to Union Territory of Delhi, using Linear Programming. They concluded that the accurate scarcity of working capital appeared to be the most important factor responsible for low incomes per acre. Their study brings out crucial role of capital rationing, which permit farmers to get benefit from new technology.
Van de Paane and Stangeland (1974) used linear programming technique to study the optimum concentration of cattle feed supplements, which were prepared by feed mills and sold to cattle feeders. Two problems were studied, in the first problem the ratio in which supplement and main feed are utilized was considered as given, while in the second problem this ratio was optimally chosen. The relationships between these two problems as well as their dual problem were analyzed. It is concluded that feed milk profit margins for their supplements based on the quantity of the supplement and the inputs costs, generally lead to supplements which are too concentrated.

Singh and Sirohi (1977) attempted to determine the optimum allocation of water of Upper Ganga canal among various branches canals or crops in Western Uttar Pradesh. The main objective was to work out the economic optimum pattern of distribution of available water supplies of Upper Ganga Canal for maximizing returns to irrigation water in the command area. They used Linear Programming as the analytical tool for allocating canal water among various canal regions and among various crops in each canal region.

Verma and Pant (1978) studied the potentialities of increasing farm income and employment through dairying in Phulsera Tehsil of Jaipur Distric of Rajasthan. Linear Programming was used for developing optimum plans. The results of the study indicated that the farmers who wanted to introduce dairy on their farm would required suitable adjustment in their cropping pattern and divert a significant area from grain crops to fodder crops. The results also indicated that the introduction of dairy on farm proved to be most profitable proposition as it increased the farm income and also created more work opportunities for family labour even in lean period.
Maji and Heady (1978) worked on the evaluation of an optimum reservoir management policy in the Mayurakshi Project. He developed a monthly schedule of reservoir operations including shortage of water in the reservoir, transfer of water from the reservoir to the producing regions through the net work of canals and spillage of water. They used L.P. technique in this study. Deterministic and stochastic models were developed reflecting various resource situation.

Singh, B. (1978) used Linear Programming technique to maximize regional income for three alternative irrigation situations. He concluded that in arid region, the injection or irrigation input, particularly when developed from low erratic precipitation base, fails to make any major use of its land and labour resources. However by crop mix manipulations, it increase to help the income of the region, particularly medium sized farmers.

Pandey and Bhogal (1980) examined the possibilities of increasing income and employment on mixed farms in Aligarh District of U.P. Using L.P.techniques, authors worked out the optimum plans with and without milch animals for small, medium and large farms under synthetic situation. The maximum feasible number of milch animals were found to be 3,6 and 6 on small, medium and large farms respectively. It was also observed that both income and employment could significantly be increased by adopting an optimum production for crops and milch animals in all the synthetic situations.

Panghal and Singh (1980) conducted, a study in the command area of siwani canal for optimum allocation of water among various canal zones and among various crops in each canal zone using L.P. technique. They concluded that the extension machinery should be strengthened to educate the farmers about the optimum use of available water.
Selvarajan and Subramanian (1981) attempted to find the effects of optimization, water resource augmentation on cropping pattern, intensity, labour utilization and income of a representative farm of Parambikulam Aliyar Project region of Tamil Nadu. The profit maximization model of Linear Programming technique was used to find out the normative situation. They concluded that there exists ample scope for increasing incomes and employment through resource use optimization and water augmentation.

Rai and Singh (1982) used the L.P. technique to examine the income and employment effects of new crop production techniques with live stock in dairy farming areas of Haryana. Their finding revealed that there exists scope of increasing farm income and employment by integrating live stock enterprises with crop farming by adoption of the new dry land agricultural production techniques. It was also concluded that the live stock enterprise was more labour intensive and needed to be further extended through intensive development programme.

Bogahawatte (1984) conducted a study in three rain fed villages in the Morergole District in Sri Lanka and examined through a Linear Programming model, which was formulated to test the hypothesis that cropping enterprises interact with live stock production. This analysis of crop livestock farming system was conducted for understanding the existing constraints and interaction between crops and livestock in the farms. They study describes the crop-livestock farming system and the evaluation of these system in terms of maximizing farm incomes from the different crop and livestock components of the system. In the optimum plans, method to increase farm income by replicating hired labour with unutilized family labour were suggested.
Keith Butter Worth (1985) practical Application of Linear / Integer Programming in Agriculture. This paper indicates that in the current economic climate, linear programming could well be worth reconsidering as a maximizing technique in farm planning. This particularly applies when it is used in conjunction with integer programming, which allows many of L.P’s problems to be overcome. ADAS procedures for L.P. integer programming are described. Reference is made to a range of models and more detail given on the new Bedfordshire mixed cropping model. An explanation is given as to how ADAS models are used in advisory and promotional work.

Bhogal et al. (1988) applied the L.P. technique to attain optimum crop and milk production plants for small and marginal farmers belonging to Meerut District of U.P. the alternative procedures considered in deriving the optimum plans, include all important food grains and fodder, borrowing of working capitals. The percentage contribution of dairying in total family income was found increasing with the no. of milch animals in all the developed optimum plans.

Gupta and Arora (1988) applied transportation technique to minimize the cost of transportation of Soybean from different producing centres to various processing plants in Uttar Pradesh. They considered all the supply and demand constraints in their model and compared the transportation cost under existing and optimum plans. The overall total reduction in transportation cost for processing plants comes out to be Rs. 8,87,516 or 12.38% in existing transportation cost which is sizable. The suggested optimum plans are acceptable to all the plants since it results in the reduction of transportation cost.
The majority of the research workers have concluded that even under the existing situation, there exists ample scope of increasing income of the farmers by optimally allocating the limited resources. From the critical review of the various research studies related to application of optimization techniques in agriculture, it emerges that almost all the research workers have used Linear Programming model for optimization. Other optimization model is viz. stochastic programming. Linear fractional functional programming, dynamic programming, transportation techniques, quadratic programming etc. have also been applied but only in a very limited number of cases.

Madhusudan Ghosh (1990) Test of Profit- Maximization hypothesis in Indian Agriculture: A linear Programming Exercise. Linear programming technique has been used to undertake tests for profit maximization hypothesis in a predominantly rice producing agricultural economy. The study is based on Farm management Survey (FMS) data pertaining to Hoogly district of West Bengal for the year 1972. Results of the study reject the validity of profit maximization hypothesis. They also contradict findings of the earlier research pertaining to the question of relative economic efficiency of small and large farms.

K. Srinivas Raju, D.Nagesh Kumar (2000): Irrigation planning of Sri Ram Sagar Project using Multi Objective Fuzzy : Linear Programming. Fuzzy Linear Programming (FLP) irrigation planning model is developed for the evaluation of management strategies for the case study of Sri Ram Sagar Project, Andhra Pradesh, India. Three conflicting objectives net benefits, crop production and labour employment are considered in the irrigation planning scenario. The present paper demonstrates how vagueness and imprecision in the objective function values can be quantified my membership functions in a fuzzy multi objective
framework. Uncertainty in the flow is considered by stochastic programming. Fuzzy Linear Programming (FLP) solution yields 1.633 million Rupees, 0.70 million tons of crop production, 42.89 million mandays with degree of truth (\(\mu\)) 0.69. Analysis of results indicated that net benefits, crop production and labour employment in FLP have decreased by 2.38\%, 9.6\% and 7.22\% as compared to ideal values in the crisp Linear Programming (LP) model. Comparison of results indicated that the methodology can be extended to other similar situations.

A. Ugur Gul, H. Hulusi Acar, Ozgur Topalak (2000): Determination of the Mechanization level for Forestry Operations by Linear Programming. Forestry operations take place under various variables and partly uncontrolled factors. The lack of mechanization level and its application cause quantity and quality losses during production. In this study, seven different production methods were used for felling, logging and barking to determine the best of production method for the Kale region. Seven different models were set up and solved by linear programming for this purpose. Each of these solutions were used with different production methods. Model 1 had the lowest production cost (290779.5) in the other models and production method 6 was chosen in this model. Thus, felling, logging and barking cost per m\(^3\) were found to be 3.75. Furthermore, 1 forest worker, 2 operators concerned with 1 chain saw, 1 processor and 1 rotary ring barker were found to be necessary for the production operations in the region. Machine and human power resources were supplied more rationally by the use of linear programming for minimization of felling, logging and barking costs. By this way, place and time, level of mechanization are determined. However, partial mechanization plans were made.
Bilge Bilgen, Irem Ozkarahan (2000). A mixed – integer linear programming model for bulk grain blending and shipping. This paper addresses a blending and shipping problem faced by a company that manages a wheat supply chain. The problem involves the delivery of bulk products from loading ports to destination ports, which may be served by different vessel types. Since the products demanded by customers are mainly exported in bulk to overseas customer, the shipment planning is of great economic importance. The problem is formulated as a mixed – integer linear programming mode. The objective function seeks to minimize the costs. Constraints on the system include blending and demand requirements, availability of original and blended products; as well as blending, loading, draft and vessel capacity restrictions. When solved, the model produces (1) the quantity of each original product to be used to make blended products, (2) the quantity of each product to be loaded at each port and to be transported from each port to each customer, and (3) the number of vessels of each type to be hired in each time period. Numerical results are presented to demonstrate the feasibility of the real world bulk grain blending and shipping model.

Purshottom Nayak (2000). Allocative Efficiency in a traditional Orissan Agriculture: A linear Programming Approach. The present paper is a humble attempt to test the allocative efficiency of the farmers in a traditional Orissan agriculture system in terms of resource-use and crop selection. While examining their allocative efficiency it is noted that the rational farmers are not necessarily efficient farmers. The farmers in the sample area are found to be rational in taking production decisions and efficient in the selection of crops and allocation of land in obtaining maximum possible outputs with the given resource constraints. However, they have been mis-utilizing their surplus non-hired labour and operating at the low level of efficiency due to some hurdles such as inadequate working capital, irrigation water and lack
of embankments on the rivers. If these hurdles are removed, they would be able to perform at their highest level of efficiency.

Chinmoy Jana, and R.N. Chattopadhyay (2005). Direct energy optimization for sustainable agricultural operation – a fuzzy linear programming approach. Energy consumption in agriculture depends on different types of crop cultivation in different seasons. Cultivation of crops is done mainly on the basis of agro-climatic conditions, potentials of resources of the region and different types of commercial and non-commercial energy application at the firm level. The present paper offers a model which attempts to optimize the direct energy use for different operations in the agricultural sector, taking into consideration certain objective functions against a set of constraints. The exercise is essentially the application of multi-objective fuzzy linear programming solution techniques in which efforts are made to arrive at a compromise solution among the objectives in a fuzzy environment. This model is capable of accommodating the needs at a local level to provide solutions which are sectorally, spatially and sectionally realistic. The dominance of agriculture in the economy has promoted testing its applicability in the situation of a backward community development block, Narayangarh, which is situated in the state of West Bengal in India and hence finding out the capability of the model to provide validation-based recommendation for the purpose of direct energy use for agricultural operations.

Emin Zeki Baskent, Sedat Keles (2006). Developing Alternative Wood Harvesting Strategies with Linear Programming in Preparing Forest management Plans. In this paper, the process of developing alternative wood harvesting strategies in forest management planning is presented. Alternative wood harvesting strategies based on linear programming (LP) include a planning horizon of 100 years, an objective of the maximization of net present value (NPV)
and various constraints such as classical volume control (even flow) and wood assortments. Model outputs are presented and discussed along with NPVs and amounts of the wood assortments by alternative wood harvesting strategies consisting of various discount rates and wood assortments.

2.2 A REVIEW OF LITERATURE ON FRACTIONAL PROGRAMMING

Martos (1964) developed a simplex type computational technique for solving a LFPP and proved that objective function attains a finite maximum on the constraint set x and this maximum exists on at least one vertex of x.

Kanti Swarup (1965) attacked the problem directly without converting it into an equivalent LPP. Starting with a basic feasible solution, he developed a very efficient Simplex type algorithm under the assumption that the set X is regular and the denominator \( d'x + P > 0 \).

Dhawan and Joshi (1967) compared profitability of dairy enterprise in relation to crop cultivation on suburban farms in Punjab. Dairy was kept as a fixed activity at levels of 2, 5 and 10 buffaloes in optimum plan. The analysis showed that the optimum farm plans, thus generated, lowered the return by 1.73% in case of two buffaloes, by 5.6% in case of 5 buffaloes and 9.88% in case of 10 buffaloes compared to the returns for production plan obtained without dairy as a fixed enterprise. The results showed that if the farmers are interested in a regular flow of income throughout the year, commercial dairy enterprise was profitable but some income had to be foregone compared to optimum plans with only crop enterprise.
Geoffrion (1967 A) and Sahible (1976 C, D) also gave some parametric approaches for the solution. An extension of variable transformation technique of Charnes and Cooper (1962 A) for solving L.F.P.P. to the case of quadratic fractional programming was given by Kanti swarup (1956 C). An extension of the same type problem to the case of polynomial fractional program with linear constraints is given by Sharma (1967). A further extension of this technique is given by Aggarwal (1968) by replacing a standard error fractional program involving a non-differentiable form in the objective function by at most two convex programs. Mond and Cravan (1973) considered the fractional programming problem with a still larger class of f and g with linear constraints. Schaible (1973,1974) proved that a concave convex fractional program is equivalent to a parameter free convex program. All these results may be found in the work of Mond and Cravan (1975) and Schaible (1976 C). Some other methods are also available for solving certain specific cases of N.L.P.P.’s in the work of Aggarwal and Kanti Swarup (1966), Bector (1974).

Various papers are available on duality of L.F.P.P.’s

Kanti Swarup (1968 A) have given a paper on it with non linear constraints but he has not given the proof of converse duality. Sharma and Kanti Swarup (1972) proved this result of converse duality by making use of Dorn’s (1960) technique. Kaska(1969) also gave some result on duality involving primal variables in dul. Kyland (1972) has given some approach on duality based on the work of Wolfe (1961). Various research workers used the strict condition of differentiability while giving the paper on duality. Some works on duality in L.F.P.P.’s are available in Chadha (1971), Carven and Mond (1973), Kanti Swarup (1967,1968 A,B) and Bector (1974).
For the solution of L.F.P.P. some other methods were also developed by (Birtran and Novaes (1973), Kanti Swarup (1970) and Gilmore and Gomory (1963). Kanti swarup (1970) also developed a technique for solving L.F.P.P. with upper bond variables.

Attempts have also been made for the solution of Non linear Fractional Programming Problem (N.L.F.P.P.’s). According to Bector (1968), the problems which comes under the category of convex programs can be solved by the usual techniques. There are various methods available for solving convex programming Rosen (1960, 1961) has given the method for the solution of Non linear Programming, called Rosen’s gradient projection method. Zoutendzik (1959) gave a method of feasible direction for its solution. Cheney and Goldsteen (1959) also gave a method called Newton’s method of convex programming. Killey (1960) introduced a new method called cutting plan method for solving convex programs.

(Jagannathan (1973) used parametric approach in duality in N.L.F.P.P.’s Bector (1973) used fractional Lagrangian approach and Schaible (1983,1974,1976 A, 1876B), used variables transformation technique in duality problem. Aggarwal and Saxena (1975) established duality results for standard error fractional program. The work in all these papers are based on the duality theory of Chandra and Gulati (1976). However Mond (1978) has further extended the duality theory of non differentiable fractional programming by including the case of non-linear constraints.

Bector, CR; Chandra, S; Husain (1992): Generalized continuous fractional-programming duality – A parametric approach. Using a parametric approach, duality is presented for a continuous minimax fractional programming problem that involves several ratios in the objective. Duality results presented in the present paper can be
regarded as the dynamic generalizations of those of finite dimensional nonlinear programming problems recently explored.

**G.J. Zalmai (1996)** Continuous – time multi objective fractional programming. Both parametric and semiparametric necessary and sufficient proper parametric are established for a class of continuous- time multiobjective fractional programming problems. Based on the forms and contents of these proper efficiency results, two parametric and four semiparametric duality models are constructed in each case, weak and strong duality theorems are proved. These proper efficiency and duality results contain, as special cases, similar results for continuous time programming problems with multiple non-fractional, single fractional, and conventional objective functions. These results improve and generalize a number of existing results in the area of continuous-time programming and, moreover, provide continuous-time analogues of various kindred results previously obtained for certain classes of finite dimensional non linear programming problems.

**A. Chandra, V.Kumar, I. Husain (1996)**: Symmetric duality for multiplicatively separable fractional mixed integer programming problem. A pair of symmetric dual fractional mixed integer programming problems is formulated and an appropriate duality theorem is established under suitable and multiplicative separability assumptions on the kernel function. A self duality theorem and the extension of the formulation to convex cone domains are also discussed.

**P.Lara and I. Stancu-Minansian (1999)**: Fractional programming: a tool for the assessment of sustainability. Fractional programming is presented as a tool for studying the sustainability of agricultural systems. The essentials tool of the technique
in both the single and the multi-objective cases are outlined. The lack of friendly algorithms embedded in programming packages to solve the models is a shortcoming for the extensive use of a technique well adapted to represent many problems in economics.

C. Bajona Xandri, J.E. Martinez-Legaz (1999): Power subdifferentiability in minimax fractional programming. Minimax Fractional programming problems are analyzed from the viewpoint of lower sub-differentiability, obtaining Kuhn-Tucker type optimally conditions. Multiobjective optimization problems with fractional objectives are also studied.

Houchun Zhou, Wenyu Sun (2003): Without the need of a constraint qualification, we establish the necessary and sufficient optimality conditions for minimax fractional programming. Using these optimality conditions, we construct a mixed dual model which unifies the Mond-Weir dual, Wolfe dual and a parameter dual models. Several duality theorems are established. Consequently, this article partly solves the problem posed by Lai et al. (H.C. Lai, C. Liu and K. Tanaka (1999). Duality without a constraint qualification for minimax fractional programming.

Ahmed Labib Negm, Khairy Hamed El-eshmawiy, Heba Yassen Abd Elfatah and Laila Moustafa El-Sharaif (2006). “The optimal Egyptian Indicative Cropping Pattern using Nonlinear Fractional Programming.” The purpose of the study was to find the optimum cropping pattern, in Egypt, which maximizes the net income return per water cubic meter. Our aim is to achieve the efficient utilization of the scarce water resources. Previous studies revealed the diversion of the current cropping pattern from the efficient utilization of resources. The fractional programming model
was applied in two possible future scenarios for the prices of the Egyptian crops. The first scenario was associated with the continuation of the local prices; while the second one was associated with the dynamic global conditions, like applying the regulations of free trade agreements, which is expected to make the prices of the Egyptian crops approach their corresponding international prices.

### 2.3 A REVIEW OF LITERATURE ON GOAL PROGRAMMING

**Rudra (1973)** studied the seasonal variations in the demand for labour and its employment. On the basis of households belonging to Hoogly District in West Bengal, he concluded that seasonal pattern of employment is very largely determined by the seasonality of the main crop of the region. Employment of all labours on farms and employment of family labours on farms as well as outside, make four humps in the year corresponding to the two sowing seasons and two harvesting seasons of the summer and winter paddy crops.

**Aggrwal and Kumawat (1974)** studies the potentialities of increasing farm incomes through credit and new technology. The data were collected for a sample of 60 farmers of Jaipur District (Rajasthan), which were divided into three size groups viz. small medium and large farmers. The data were pooled and averaged to obtain synthetic situation. Linear programming was used as an analytical tool. The authors found that there was sufficient potential exist for increasing with income on all sizes of farms and the provisions of additional credit would increase farm income even at existing level of technology. The situation of adoption of improved technology without any credit did not increase the income of the farmers.

**Gangwar and Ghakhar (1975)** examined the potential for increasing farm income on small farms in Gurgaon block of Haryana State. Using variable capital programming
technique, a continuous solution of capital requirements for optimum plans were desired at existing and improved level of technology. They found that under traditional technology, an optimum plan for generating a net income of Rs. 2585.5 required a working capital expenditure of Rs. 1462.08, while an optimum farm plan under the improved technology for generating a net income of Rs. 6856.84 required working capital of the order of Rs. 2801.80.

Porwal, Kanti Swarup and Jaidev (1979) suggested a multi objective criteria to the problem of capital budgeting by applying a Goal programming model incorporating priority coefficients for different objectives and also made an attempt to apply G.P model to the C.B.O. problem lovie and saugae.

Evans (1984) proposed an overview of techniques to solve multi-objective programs. Every human system is faced with the problem choosing between alternative options and methods of interactive programming that are suggested as the best way to lead decision maker conclusion that are consistent with his preferences. Even though a large number of interactive as algorithms have been proposed for multi-objective decision making (MODM).

Sharma and Sharma (1984) made an attempt to extent the application of ‘GP’ technique for te manpower planning. As a planning model this one is designed to provide a choice among all possible alternatives in filling vacancies from within, from training and from outside sources in accordance with stated goals. The author suggested multi-objective criteria to the problem of manpower planning.

Ignizio (1985) discussed Goal programming and in particular lexicographic Goal programming (i.e. G.P. within a so called pre-emptive priority structure or having non-archimidean weights) has become one of the most widely use of the approaches for
multi-objective mathematical programming. While also applicable to non-linear or integer models, most of the literature has considered the lexicographic linear Goal Programming and its solutions via primal simplex based methods. However, in many cases enhanced efficiency (and significant additional flexibility) may be gained via an investigation of the dual of the problem.

Choo and Wedley (1985) discussed the repetitive judgment discrete decision making with multiple criteria. The decision makers usually believes as if there is a set of appropriate criterion weights such that the decision chosen are based on the weighted sum of all the criteria. Many different procedures for estimating these implied criterion weights have been proposed. Most of these procedures emphasize the preference trade-off among the multiple criteria of the decision maker, and thus the criterion weights obtained are most preferred solution and what are the chances of finding a better solution by considering additional alternatives? A unified approach to solving this problem used on probability theory is presented and illustrated with numerical examples.

Wiecek (1987) dealt with the mathematical models for identification problems of random fields. Two basic classes of random fields are presented and their applicability of the random field is developed by means of Kriging theory. Several multi objective cases are considered and possible procedures for aiding the decision making identification process of random fields were discussed. Some remarks related to the application as well as the possible extension f presented methods were also included.

Bare and Mendoza (1988) presented the multiple objective programming model for forest land management planning. As the increased land use pressures have stimulated forest land management analysts to develop and utilize more sophisticated planning
aids to address complex multi-resource issues involving multiple objective and decision makers. To illustrate the potential use of M.O.P. in land management planning, a demonstrative example was examined using an interactive technique – the STEM method.

**Kambo, NS: Handa, B.R.; Bose, R.K. 1991, A linear goal programming model for urban energy economy environment interaction.** The last decade has witnessed a growing concern with the adequacy of energy resources and with the quality of the physical environment. This concern stems from such factors as the unrelenting growth of energy use, the end of an era of abundant and cheap energy, adverse environment effects of economic growth, and the increasing participation of governments in decisions pertaining to energy supply and environment protection. Owing to the fact that a significant part of the shortfalls in environmental quality in contemporary societies derives from energy use, issues of “trade-off” between additional energy supplies and environmental and energy-related issues need to be placed in the broader framework of conflicting political priorities. These include meeting energy demands for sectoral end uses; maximizing energy conservation; checking air pollution; reducing the annualized economic cost of utilization of energy systems; reducing import of energy from neighbouring regions; and increasing the capacity for utilization of domestic appliances and different modes of transport. Multi-objectives in decision models arise from the need to take into account the presence of a wide variety of conflicting objectives in ordinal ranking or priorities depending on the degree of importance one wants to assign to each objective. The basic problem related to the existence of multiple objectives is the fact that decisions are normally interdependent so that any decision to increase production has a corresponding impact on energy consumption, pollution emission and vice versa. Pollutants considered for
this study are carbon monoxide (CO), nitrogen oxides (NOx), Sulphur dioxide (SO2) and suspended particulate matter (SPM) which are the emissions caused by combustion or automation. This paper provides a comprehensive and systematic analysis of energy and pollution problems interconnected with the economic structure, by using a multi-objective sectoral end-use model for addressing regional energy policy issues. The multi-objective model proposed for the study is a “linear goal programming (LGP)” technique of analyzing a “reference energy system” in a framework within which alternative policies and technical strategies may be evaluated. The model so developed has further been tested for the city of Delhi (India) for the period 1985-86, and a scenario analysis has been carried out by assuming different policy options.

**Kumar . P; Singh, N; Tewari, N.K. (1991):** A nonlinear goal programming model for multistage, multi-objective decision problems with application to grouping and loading problem in a Flexible manufacturing system. A multistage multi-objective decision problem is formulated as a nonlinear goal programming model. The solution algorithm which uses Box-complex method is presented. The model formation and computational aspects are illustrated on the integrated grouping and loading problem of a flexible manufacturing system.

**Lara and Romero (1992)** dealt with an important problem in the field of livestock ration formulation; the rigidity of the right hand sides of the model. Thus, instead of considering the nutritional requirements as fixed values they are considered as targets which may or may not be achieved. In this way a multi goal programming was formulated. The preferences of the ration formulation were elicited resorting to the interactive method proposed by Zionts and Wallenious. The approach proposed is
applied to a ration formulation problem for a dairy cows in the Predroches valley in Andulsia, spain.

**J.C.Liu (1996):** Optimality and duality for multi-objective fractional programming involving nonsmooth pseudoinvex functions. We establish the Kunh-Tucker necessary and sufficient conditions for an efficient optimum of nonsmooth multi-objective fractional programming problems containing pseudo-invex functions. Bector type dual for multi-objective fractional programming problem is introduced and certain duality results have been derived in the framework of pseudo-invex functions.

**K.S. Raju, D.N. Kumar (1999):** Multicriteron decision making in irrigation planning. Selection of the best compromise irrigation plan is examined in the multi objective context. The study deals with three conflicting objectives; net benefits, agricultural production and labour employment. Three- stage procedure is adopted combining multi objective optimization, cluster analysis and multicriterion decision-making (MCDM) methods. Two MCDM methods, namely, PROMETHREE-2 AND A NEWLY DEVELOPED METHOD exprom-2, ARE EMPLOYED IN THE EVALUATION. Spearman rank correlation test is used to assess the correlation between the ranks. The above methodology is applied to a case study of Sri Ram Sagar Project, Andhra Pradesh, India. Sensitivity analysis studies indicated that ranking pattern is quite robust to parameter changes as far as the first two positions are concerned. It is found that net benefits, agricultural production and labour employment per hectare on average for culturable command area are 8980 rupees ($ 225), 3.75 tonnes and 242 man-days, respectively, in the best compromise plan.

**Sabu Paul, Sudhindra Nath Panda, (2000):** Optimal Irrigation Allocation A multilevel approach. Optimal resources allocation strategies for a canal command in
the semiarid region of Indian Punjab are developed in a stochastic regime, considering the competition of the crops in a season, both for irrigation water and area of cultivation. The proposed strategies are divided into two modules using a multi-level approach. The first module determines the optimum seasonal allocation of water as well as optimum cropping pattern. This module is subdivided into two stages. The first stage is a single crop intraseasonal model that employs a stochastic dynamic programming algorithm. The stochastic variables are weekly canal releases and evapotranspiration of the crop that are fitted to different probability distribution functions to determine the expected values at various risk levels. The second stage is a deterministic dynamic programming model that takes into account the multicrop situation. An exponential season crop-water production function is used in this stage. The second module is a single crop stochastic dynamic programming intraseasonal model that takes the output of the first module and gives the optimum weekly irrigation allocations for each crop by considering the stress sensitivity factors of crops.

**Nhantumbo, J.B.Dent and G. Kowero (2001):** Goal Programming application in the management of the mimbo woodland in Mozambique. Community based management of natural resources (CBNRM) is a priority in Mozambique’s policy of forestry and wildlife resources. In essence the government’s policy is to manage the natural resources in partnership with the rural communities and the private sector. This represents a change in policy in the agricultural and natural resources sector, and has potential for significant impact in economic development. This paper demonstrates the potential for employing goal programming as a planning tool in participatory natural resource management in Mozambique. The focus is on the miombo woodlands, which are the main natural forest resources in the country and which most of the local
communities, the forestry and tourist industries depend on for a variety of forest products and services.

**D.K. Sharma, A. Gaur, and Ghosh (2005):** Goal programming Model for agricultural land allocation problems. Most of the real-world problems in the agricultural sector are multi-objective. Multi-objective programming techniques such as lexicographic goal programming (LPG) can be used to solve agricultural land allocation problems. The purpose of this is to present at LPG model for optimum allocation of land under cultivation and to propose an annual agricultural plan for the various crops. Sensitivity analysis on the priority structure of the goals as defined in the LPG model was performed to obtain different solutions in the decision making environment. The study uses Euclidean distance function to measure distances of all possible solutions from the ideal solution. The minimum distance from different solutions to the ideal solution identifies the best compromise solution, and the associated priority structure is the appropriate structure according to the decision making situation.

**M. Tamiz, D. F. Jones and E. El-Darzi (2005):** “A Review of Goal programming and its applications” This paper presents a review of the current literature on the branch of multi-criteria decision, modeling known as Goal Programming (GP). The result of our indepth investigations of the two main GP methods, lexicographic and weighted GP together with their distinct application areas is reported. Some guidelines to the scope of GP as an application tool are given and methods of determining which problem area are best suited to the different GP approaches are proposed. The correlation between the method of assigning weights and priorities and the standard of the results is also ascertained.
Bhabagrahi Sahoo, Anil K. Lohani and Rohit K. Sahu (2005). Fuzzy Multiobjective and linear Programming Based Management Models for Optimal land –water-Crop System Planning. In this article, linear programming and fuzzy optimization models are developed for planning and management of available and water-crop system of Mahanadi Kathajodi delta in eastern India. The Models are used to optimize the economic return, production and labour utilization, and to search the related cropping pattern and intensities with specified land, water, fertilizer and labour availability, and water use pattern constraints. Due to extreme backwardness of the study area, it has been decided to keep all the three objectives of the linear programming models at the same priority level to obtain the compromised solution in a fuzzy environmental that incorporates the impression in fuzzy goals and fuzzy constraints. These non-structural models facilitate the conjunctive use of available surface water and groundwater resources. A comparative evaluation along with the benefit-cost ratio of the existing and proposed farming system is also presented.

Ching-Ter Chang (2007). Binary fuzzy goal programming. Goal programming is an important technique for solving many decision/management problems. Fuzzy goal programming involves applying the fuzzy set theory to goal programming, thus allowing the model to take into account the vague aspirations of a decision-maker. Using preference-based membership functions, we can define the fuzzy problem through natural language terms or vague phenomena. In fact, decision-making involves the achievement of fuzzy goals, some of them are met and some not because these goals are subject to the function of environment/resource constraints. Thus, binary fuzzy goal programming is employed where the problem cannot be solved by conventional goal programming approaches. This paper proposes a new idea of how to program the binary fuzzy goal programming model. The binary fuzzy goal
programming model can then be solved using the integer programming method. Finally, an illustrative example is included to demonstrate the correctness and usefulness of the proposed model.


**M. Janga Reddy and D. Nagesh Kumar (2007):** Multi-objective Differential Evolution with Application to Reservoir System Optimization. Many water resources system are characterized by multiple objectives. For multi-objective optimization, typically there can be no single optimum solution which can simultaneously satisfy all the goals, but rather a set of technologically efficient non-inferior of Pareto optimum solutions exists. Generating those Pareto optimum solution is a challenging task and often difficulties arise in using the conventional methods. In the optimization of reservoir systems, most of the times there is inter-independence among one or more decision variables. Recently, it is emphasized that the evolutionary operators used in differential evolution algorithms are very much suitable for problems having
interdependence among the decision variables. This paper utilizes this aspect and presents an efficient and effective approach for multiobjective optimization, namely multi objective differential evolution (MODE) algorithm with an application to a case study in reservoir system optimization. The developed MODE algorithm is first tested on a few benchmark test problems and validated with standard performance measures by comparing them with the non-dominated sorting genetic algorithm-II. On achieving satisfactory performance for test problems, it is applied to generate pareto optimum solutions to a multiobjective reservoir operation problem. It is found that MODE provides many alternative Pareto optimum solutions with uniform converge and convergence to true Pareto optimum fronts. The results obtained show that the proposed MODE cab be a viable alternative for generating optimum trade-offs in multiobjective optimization of water resources systems.