CHAPTER - II

LITERATURE REVIEW

2.1 GENERAL

Adequate food production is a pressing need in many countries of the world. The problem is particularly serious in countries with less developed economy, like India, where low agricultural production is contained with the pressure of rapidly expanding population. In India, the production of food can potentially be increased several times over the present supply. This requires a number of agricultural inputs, e.g., better seeds, proper fertilizers and improved farm management. Proper development and management of water, however, is of overriding importance. The success and efficiency of most other agricultural inputs are dependant on quantity, quality and timing of irrigation water supply, the way it is used, and the degree of control over it. This is particularly true for the Distributory No.6 of Kendrapara canal under the Mahanadi – Birupa barrage project agriculture system.

Irrigation water is very costly. It has to be gainfully utilized and thus to be applied judiciously, not less nor more. Assessment of crop requirements and their variability with time are very important for canal irrigation system management. Allocation of areas to crops according to their suitability to soil and climate under scarce water supply and the benefits derived from them involve frequently techniques of Operation Research. Some of the works carried out in these aspects in past are critically reviewed and presented in this chapter.

For the purpose of planning and management of water resources, system analysis is being increasingly used for the past few decades. Potential applications are discussed by Hall and Dracup (1970), Loucks et al.(1981) and
Chaturvedi (1992). In many of the system analysis applications, the combined behavior of the system is represented by a single approximated, technically convenient criterion. A single objective is justified only in certain limited situations. The present day practical water resources management problems involved complicated formulations with multiple and often conflicting objectives.

A number of methods are available to solve the multi-objective water resources problems. Some of the methods largely used for continuous settings are: Sequential Multi-objective Problem Solving (SEMOPS) method (Monarchi et al., 1973), Surrogate Worth tradeoff method (Haimes and Hall, 1974), Trade and Protrade method (Goicoechea et al., 1979), Concordance Analysis (Nijkamp and Vos, 1977), Goal Programming (Loganathan and Bhattachary, 1990), Search Beam method (Bogardi et al., 1991), and Search Beam method associated with Evolutionary Sequential Multi-objective Problem Solving (ESEMOPS) (Bogardi and Duckstein, 1992).

Other important methods particularly related to discrete settings are Multi Attribute Utility Theory (Keeny and Raiffa, 1976; Keeney and Wood, 1977), ELECTRE (Gershon et al., 1982), Compromise Programming (Zeleny, 1982), Analytic Hierarchy Process (Saaty, 1990), Multicriteriaon Q-Analysis (Hiessl et al., 1985), PROMETHEE (Brans et al., 1986). Compromise Programming and ESEMOPS are capable of considering continuous as well as discrete settings. The important literature pertaining to these methods are presented briefly in following sections.
2.2 IRRIGATION PLANNING (SINGLE OBJECTIVE)

It is keenly felt the need for efficient integrated management of an irrigation system. It is due to the growing demand for agricultural products for the escalating cost of supplying water to farmer’s fields and the stochastic nature of the water resources (Pillai, 1992). Due to dwindling supply of irrigation water, the profit conscious irrigators wish to so allocate the water as to maximize the net benefits with competing alternative crops, the investor’s choice is further complicated by the fact that the allocation of irrigation water is required to be optimized over time, among the crops and also among the competing units of the same crop simultaneously. To meet the requirements mathematical models and irrigation management methodologies are developed in command area planning. Most of the important studies carried out so far are discussed briefly below.

Linear Programming (LP) model for maximizing the irrigation benefits for Bari Doab basin in Northern India was used by Lakshmi Narayana and Rajgopalan (1977). Sensitivity analysis on the tube well capacity, the area available for irrigation, the operation costs for canals and tube wells etc., were also carried out. Maji and Heady (1980) developed an optimum cropping pattern and reservoir operation policy for the Mayurakhi irrigation project, India, where the objective was to maximize the net benefits by considering the average inflows and chance constrained inflow by assuming a gamma distribution. The micro-level irrigation planning with a detailed example was discussed by Loucks et al. (1981). Multi-objective analysis was also reported in their studies. Paudyal and Gupta (1990) solved the complex problem of irrigation management in Tinao river basin of Nepal by a multi-level Linear Programming method. The problem consists of determining the optimal cropping pattern in various areas of the river basin, optimal design capacities of irrigation
facilities including surface and ground water resources, and the optimum water allocation policies for the conjunctive use, to obtain a high level of economic efficiency. Various alternative activities, such as surface water diversion and pumpage, ground water withdrawal and recharge, and alternative future operational scenarios were analyzed. Pawar and Murthy (1991) proposed a crop planning model with the objective of maximizing irrigation benefits for a typical irrigation district. Extensive sensitivity analysis was carried out for water and fertilizer availability on the crop calendar. It was concluded that farm planning can be used as an extension tool to convince the farmers on the need for changing the crop planning in the region. Similar studies were also reported by Khepar and Chaturvedi (1982), Chaturvedi and Chaube (1985), Morales et al. (1987, 1992), Mayya and Prasad (1989), Tandaveswara et al. (1992).

2.3 IRRIGATION PLANNING (MULTIOBJECTIVE)

Vedula and Rogers (1981) made an extensive study by employing two objectives, namely, benefits and irrigated area in multiobjective irrigation planning context for four reservoir system in the Cauvery river basin, India. A monthly Linear programming model was used to find optimum cropping pattern subjected to constraints of land, downstream release etc. Constraint method was employed to generate the nondominated alternatives. The results included the two objective transformation curve. This is the first study in multiobjective irrigation planning in Indian context. Onta et al. (1991a) employed LP based planning model considering two objectives, namely, maximizing net benefits and irrigated cropped area to a case study of Bagmati river basin, Nepal. Constraint method was employed to formulate the nondominated alternatives. Evaluation of the alternatives by Compromise Programming was carried out to arrive at the optimal scale of
development cropping plans etc. Kalu (1991) also reported similar studies by considering three objectives of maximizing net benefits, irrigated cropped area and food production.

Siskos et al. (1994) proposed a farm planning model to a case study in Tunisia. Five objectives i.e., to maximize gross margins, maximize employment, minimize seasonal labour, minimize tractor utilization and maximize forge production were considered. The model was solved with a specialized software named ADELAIS in the multiobjective linear programming context to obtain the upper and lower bounds for each objective. An initial efficient solution was estimated in a way that it should be close to the upper bounds in the min-max sense. The system projected the objective values corresponding to the initial solution, upper and lower bounds, satisfaction levels and rate of closeness to the upper bounds. With respect to the initial solution, the objective values were checked and, if needed, an improvement of any objective at the cost of other remaining objectives was used. In order to capture the relative importance of the objectives, the model generated reference decision alternatives and these were ranked accordingly.

2.4 IRRIGATION SYSTEM PERFORMANCE

Performance evaluation of an existing irrigation system is the process to methodically analyze the functioning of the system and to identify the components that are not performing well. The evaluation process will bring into focus the deficiencies in the planning of the project and in its implementation and will help to improve its future performance. The literature in this related field is also reviewed briefly below.
Performance measures such as Adequacy, Efficiency, Dependability, and Equity of water delivery to provide a quantitative assessment of structural and management components of the system as well as overall system performance proposed by Molden and Gates (1990). Spatial and temporal distributions of required, scheduled, deliverable, and delivered water were estimated by field measurements and through simulation studies and the above performance measures were calculated. They applied this methodology to a few typical systems of Sri Lanka and Egypt. Biswas (1990) stressed the need for effective monitoring and evaluation of irrigation projects. He pointed out the primary requirements for effective monitoring as 1) timeliness 2) cost-effectiveness 3) maximum coverage 4) minimum measurement error 5) minimum sampling error 6) absence of bias 7) identification of users for information. He also explained the different aspects in detail.

The performance evaluation of irrigation systems in Multicriterion Decision Making (MCDM) context also studied by Gates et al. (1991) and Heyder et al. (1991). McCormic (1993) examined irrigation water management characteristics including on-farm scheduling practices of a lateral canal command in the Eastern Irrigation District (EID), Alberta, Canada. Supply/demand ratios were used as the key, indicators for the conceptual framework. A sample questionnaire was prepared to assess the water management characteristics in the command area. Similar studies were reported by Seckler et al. (1988).
2.5 CLUSTER ANALYSIS

When conflicting objectives are simultaneously considered, there is no such thing as an optimum solution. Rather, a preferred class of nondominated set of solution results. Since this set can be moderately large, some means must be adopted to reduce it to a manageable subset. The literature reviewed is given below.

Morse (1980) briefly explained the importance of the clustering in reducing the size of the nondominated alternatives to a manageable size. He demonstrated the applicability of three hierarchical clustering methods, namely, Ward’s method, Group Average method, and centroid method with an example problem. He concluded that Ward’s method not only outperformed all other methods but also showed almost equal representation of all alternatives in the clusters. Steuer and Harries (1980) explained forward and reserve filtering techniques that can be used to develop groups of representative solutions from a given set. Gershon et al. (1982) suggested that ELECTRE-1 can be used as a screening tool to choose a manageable subset of preferred systems while ELECTRE-2 can be used to rank the systems of this subset. Burn (1989) employed cluster analysis to divide 213 meteorological stations into five regions for flood frequency analysis in Canada. He used K-means algorithm for cluster analysis. F-statistic and $R^2$-statistic were employed to assess the desired number of clusters and to ensure homogeneity among the stations. He concluded that F-statistic can be used as a basis for selection of optimum number of clusters. Mohan and Raipure (1991) employed ELECTRE-1 to form manageable subset and ELECTRE-2 for final ranking of alternatives of this for Chaliyar river basin, Kerala, India for selecting optimum reservoir combinations.
2.6 RANKING OF ALTERNATIVE PLANS BY DIFFERENT MULTICRITERION DECISION MAKING (MCDM) METHODS

Duckstein et al. (1989) formulated the methodological steps for the selection of the best alternative from a set of available alternatives. They can be summarized as:

a) Defining the problem and fixing the criteria
b) Appropriate data collection
c) Establishment of feasible alternatives
d) Formulation of payoff matrix
e) Determining the set of efficient alternative
f) Selection of the appropriate method to solve the problem
g) Incorporation of decision maker’s preference structure
h) Choosing one or more of the efficient alternatives

They further classified the MCDM methods into four groups i.e. 1) outranking 2) priority 3) distance and 4) mixed.

Mohile and Jagannathan (1984) observed that “Most Indian cases dealing with multiobjectives either resorted to adhoc subjective choice ended with presentation of alternatives and their implications”. They stressed the need for more applications of MCDM methods in Indian context. Stewart (1992) reviewed the MCDM methods in detail. He identified the pitfalls in the usage of various approaches and suggested some robust and effectively usable approaches. He stressed the needs of future MCDM methods as 1) the empirical validation and testing of the various available approaches 2) the extension of MCDM into group decision making situations and 3) the treatment of uncertainty.
In the present study five MCDM methods, namely, ELECTRE-2 (outranking), PROMETHEE-2 (outranking), Analytic Hierarchy Process (priority), Compromise Programming (distance), Multicriteria Q-Analysis-2 (mixed) and are employed. Even though ELECTRE-2 and PROMETHEE-2 are both outranking in nature, their methodological approach is quite different. Detailed study on MCDM methods are available in Cohon and Marks (1975), Cohon (1978), Hwang et al. (1980), Goicoechea et al. (1982), Szidarovszky et al. (1986), Stewart (1992) and Bogetoft and Pruzan (1992).

2.6.1 ELECTRE

This method has three versions ELECTRE-1, 2 and 3. They are based on the outranking relationship between any two alternatives. To establish these relationships, concordance index and discordance index are required. The methods are suitable for the discrete set of alternative criteria. David and Duckstein (1976) employed ELECTRE-1 to obtain the best alternative among the available five for water resources development in Tisza river basin, Hungary. A comprehensive cost-effectiveness approach was adopted to define goals, specifications, criteria and alternatives. The alternatives were compared based on twelve criteria. They concluded that ELECTRE-1 is a suitable method to rank alternatives in water resources systems. Gershon et al. (1982) employed ELECTRE-1 and 2 for the planning of Santa Cruz river basin, Tucson. Twenty five alternative systems were evaluated for thirteen criteria. Only five of these criteria were quantifiable. Sensitivity analysis on weightages and scales showed some shifting of the rankings including the first choice. They concluded that the method showed good response to the preference structure of the decision maker.
Mohan and Raipure (1991) employed ELECTRE-1 and 2 for a case study of Chaliyar river basin, Kerala, India. Twenty seven alternative reservoir configurations were evaluated with respect to six criteria i.e., irrigation, hydropower generation, drinking water, environmental quality, flood protection and the cost of the project. The original twenty seven configurations were reduced to manageable set of eight using ELECTRE-1. ELECTRE-2 was then employed to rank the above eight alternatives. Sensitivity analysis on scales and weightages indicated that the solution was quite robust for these parameters. Similar studies were reported by Roy et al. (1992) for design of water supply systems by ELECTRE-3 in Western Poland.

2.6.2 PROMETHEE

The method has two versions PROMETHEE-1 and 2. They are based on the outranking relationship between any two alternatives. Brans et al. (1986) proposed PROMETHEE-1 and 2 with six types of criterion functions, namely, Usual criterion, Quasi criterion, Criterion with linear preference, Level criterion, Criterion with linear preference and indifference area, and Gaussian criterion. PROMETHEE-1 yields the partial ranking while PROMETHEE-2 yields the final ranking. They illustrated the method with hypothetical problem in which different hydropower projects were compared with regard to six criteria. They also studied stability aspects of both PROMETHEE-2 and ELECTRE-3 and concluded that PROMETHEE-2 was more stable than ELECTRE-3 in some characteristics. Mareschal (1986) proposed stochastic extension to PROMETHEE-2 method and applied it for hypothetical problem consisting of four alternatives, three criteria of six experts. He compared the stochastic version with deterministic one concluded that the deviations between above two approaches were quite significant.
PROMETHEE-1 and 2 for selection of small hydropower plant locations on Dalmatia catchment, Yugoslavia were applied by Mladineo et al. (1987). Six proposed locations along with nine criteria were considered. They concluded that results were quite satisfactory for the selection of the best hydropower plant.

2.6.3 Analytic Hierarchy Process (AHP)

The method of Analytic Hierarchy Process was incorporated the subjective information into multiobjective evaluations by Palmer and Lund (1985). The method was based on eigen values and eigen vectors approach and structures multiobjective evaluations into a series of hierarchies in which pair wise comparisons are made based on Saaty's 1 to 9 scale (Saaty and Gholamnezhad, 1982). The method was demonstrated for the problem of network design for good aquatic monitoring. A two level approach was considered with five activities and three sub objectives. They also reviewed the theoretical aspects of the approach including measures of subjective inconsistency, the sensitivity of inconsistency to pair wise comparisons, subjective scaling factors, and sensitivity of weightages. An extensive review of Analytic Hierarchy Process was made by Saaty (1990).

2.6.4 Compromise Programming (CP)

Compromise Programming is an iterative method used in multiple objective context (Zeleny, 1982). It can also be used in discrete objective analysis. In this method the solutions close to the ideal solution are identified by measure of distance. Onta et al. (1991b) proposed a three-step modeling approach for irrigation planning involving integrated use of surface and ground water resources for a
case study of Bagmati river basin, Nepal. They employed Compromise Programming to select the most satisfactory alternative plan and corresponding water allocation policy. Onta et al. (1991a) and Kalu (1991) employed Compromise Programming in their studies of irrigation planning in section 2.3. Bardossy and Duckstein (1992) employed Compromise Programming in Fuzzy environment to a case study of regional management of Karstic aquifer in Hungary.

2.6.5 Multicriterion Q-Analysis (MCQA)

Hiessl et al. (1985) employed Multicriterion Q-Analysis-1 and 2 (MCQA-1 and 2) to a case study involving control of waste water discharge into San Francisco Bay from the city of SanJose. Five criteria, recreational potential, NH$_3$-N concentration, land use, treatment cost and public acceptance, were considered for five alternative policy scenarios. Payoff matrix was converted into preference matrix using fuzzy-set analysis. Sensitivity analysis on slicing parameters indicated that optimum slicing parameters will be the values contained in the preference matrix. They concluded that both MCQA-1 and 2 were quite robust to the change in weightages.

2.6.6 Multi Attribute Utility Theory (MAUT)

Keeney and Wood (1977) employed MAUT to evaluate overall utility of five alternative water resources development plans for the Tiza river basin, Hungary. Twelve criteria, considering seven of qualitative nature and five of quantitative nature, were used to evaluate the alternative plans. The utility function was of the multiplicative form. Ranking was based on the overall utility value of each alternative plan.
2.6.7 Combined Application of MCDM Methods

Application of various MCDM methods to different case studies are made by some researchers to examine how several MCDM methods may be used as decision aid tools in water resources planning. These are also useful to enhance the selection process (Tecle et al. 1988a). The research works related to combined application of different MCDM methods are presented below.

Duckstein and Opricovic (1980) employed Compromise Programming to select the best alternative plan for the Tisza river basin, Hungary. The best and the worst values of each criterion were selected to define anchor points for distance measure. They concluded that the Compromise Programming solution provided an explanation for the difference between the solutions proposed by David and Duckstein (ELECTRE, 1976), Keeney and Wood (MAUT, 1977).

Gershon and Duckstein (1983) applied four MCDM methods, namely, ELECTRE-2, Compromise Programming (CP), Co-operative Game Theory (CGT) and Multi Attribute Utility Theory (MAUT) to Santa Cruz river basin, Tucson. Twenty five alternative plans were evaluated with thirteen criteria that included five quantifiable criteria. All the methods suggested the same ranking pattern. Sensitivity analysis on weights and scales was also performed.

Tecle et al. (1988a) formulated waste water management problem to find out the best management scheme from fifteen possible schemes for a waste water management project. Twelve non commensurable criteria were defined. Three MCDM methods viz., Co-Operative game Theory (CGT), Compromise Programming (CP) and ELECTRE-I were
used and all of them resulted in giving the same alternative as the best one. They suggested the use of more than one method to enhance the selection process. Similar studies are reported by Tecle et al. (1988b) for forest watershed management problems.

Duckstein et al. (1989) presented an overview of Multicriterion Decision Making (MCDM) methods followed by case studies of hydropower operation. The first case study, Erlauf river diversion scheme, Austria was considered with the aim, 1) to achieve compromise between conflicting economic and environmental objectives measured by two aggregate sets of criteria, and 2) to consider various uncertainties in the criteria. The problem accounted for both randomness and subjective values in the evaluation of environmental consequences. Composite Programming was employed to rank the resulting alternatives. The second case study related to Bavarian state board for water resources, Upper Isar river basin, Germany. Fourteen criteria including hydrological, ecological, legal and recreational issues were formulated. Eleven criteria defined on a numerical scale while the others on a non-numerical scale. Payoff matrix was converted to preference matrix based on 1 to 7 scale. Ten alternatives were formulated based on release flow rates. Three sets of weightages emphasizing energy, balance and environmental scenario were also employed. Three methods MCQA-1 and 2, Compromise Programming and Value cost analysis were applied. They concluded that Compromise Programming and MCQA-2 were giving comparably good results.

Gates et al. (1991) and Heyder et al. (1991) proposed an approach to assess the alternative strategies for an irrigation water delivery system of Alamosa river and La Jara Creek systems in the San Luis Valley of South Central Colorado. Adequacy, efficiency,
dependability, and equity of water delivery were used to evaluate the water delivery performance. Two MCDM methods PROMETHEE-2 and Weighted Average were employed to achieve an aggregate ranking of eleven alternative strategies with regard to water delivery performance, relative cost, social acceptability, political and institutional acceptability and environmental impact criteria. They concluded that PROMETHEE-2 and Weighted Average methods preferred the same alternative strategy.

Shreshta and Paudyal (1992) studied the necessity of adopting smaller reservoir configurations instead of a single big reservoir for Karnali river basin, Nepal. The alternative reservoir configurations were formulated for 4 criteria based on cost, benefit, environmental and social indicators. Three MCDM methods, namely, Compromise Programming, Enhanced Compromise Programming and Fuzzy decision analysis were employed to select the best alternative reservoir configuration.

Shafike et al. (1992) employed a model for ground water management to find a compromise strategy for determining the trading off involving fresh water supply, contamination of the waste and total pumping cost in MCDM context for a hypothetical confined aquifer. A ground water flow model was used to formulate the hydraulic constraints and a linear system model was used to describe draw down and velocity as functions of pumping rates. Constraint method via Quadratic Programming was employed to generate the alternative strategies. Three different MCDM methods, namely, Compromise Programming (CP), ELECTRE-2, and MCQA-2 were used to select the satisfying alternative. Analysis of the results showed that the same preferred strategies were reached by all the three methods uniformly. They claimed that the study was first of its kind in ground water management.
Harboe (1992) presented multi-objective decision making applications for finding the optimal and satisfying operating rules for reservoir systems. The examples included

1) *hydropower versus water supply*: Constraint method via Dynamic Programming (DP) was employed to generate the non-dominated solutions, and based on decision makers' judgement, a final recommendation for real-time operation was made.

2) *flood control versus low flow augmentation*: a sequential DP with the objective of maximizing the minimum flow was solved and seven alternative solutions were obtained from which the best alternative could be selected.

3) *Reservoir system operation involving five objectives and using six multi-objective methods*: a simulation model with synthetic data was emphasized and five objectives were considered; six multi-objective methods, namely, Goal Programming, Tchebycheff method, Compromise Programming, Consensus, ELECTRE-1 and 2 were applied.

4) *Low flow and recreation versus water quality objective*: Constraint method via Dynamic Programming was employed to generate the non-dominated alternatives and compromise Programming was employed to rank these alternatives. The first study was related to two reservoir system, Shsta and Folsom in Northern California, whereas the remaining three case studied were related to Wupper reservoir system, Germany.
Ko et al. (1992) presented two case studies related to Han river system, Korea. The first case study investigated Chungju storage project, in Han river system. Three objectives involving maximization of 1) total annual energy, 2) firm or reliable flow for low flow augmentation, water supply to downstream areas, and water quality enhancement, and 3) firm or reliable energy were considered. Weighting method, Constraint method, Goal Programming, Compromise Programming and Tradeoff Development methods were employed via Dynamic Programming for generation of alternative solutions. Finally the solution close to the ideal solution was selected as the best for each method. They concluded that Constraint method was superior to Weighting method for generation of non-dominated solutions, whereas, Tradeoff Development method was the best search technique for preference solutions. Additional sub criteria were included for solutions generated by Constraint method. Analytic Hierarchy Process (AHP) was employed to rank these modified alternatives. In the second case study, entire Han river system was considered with the objectives of maximizing 1) total generated energy, 2) firm energy at the downstream basin control point, 3) firm energy, and 4) system reliability. Other objectives were considered as fixed constraints. Constraint and Tradeoff Development method were employed via Successive Linear Programming (SLP). Stochastic nature of stream flows were considered as chance constraints with specified reliabilities. Later, Ko et al. (1994) presented an extended version of their second case study wherein different MCDM methods, namely, Analytic Hierarchy Process (AHP), ELECTRE-1 and 2, Compromise Programming were employed. The comparative evaluation of four different MCDM methods showed that AHP was the best suited one.
Duckstein et al. (1994) employed four MCDM methods to a ground water management problem. Three criteria, namely, maximization of pumping yield, minimization of total costs and minimization of water shortage risk, were considered. The management model was based on the finite element method and a combined embedding/response matrix method. Four MCDM methods viz., Compromise Programming (CP), ELECTRE-3, Multi Attribute Utility Theory (MAUT) and UTilite Additive (UTA) were applied. It was observed that all the four MCDM methods yielded similar subset of recommended solutions. They discussed the different aspects of each method in relation to ground water management problem. They opined that the purpose of applying an MCDM method was to aid the decision maker and not to take his place. Similar studies were also reported by Magnouni and Treichel (1994).

2.7 CORRELATION COEFFICIENTS AND SELECTION OF THE SUITABLE MCDM METHOD

The choice of an MCDM method that should be used for a solution, itself constitutes a multi-objective problem (Duckstein et al., 1994). Very few case studies are based on the model of choosing an MCDM method with respect to certain performance criteria. The correlation coefficient concept was also employed by some researchers to check the consistency between the ranks obtained by different MCDM methods. For the case study of Santa Cruz river basin, Tucson, Duckstein et al. (1982) considered six performance criteria i.e., type of required data, nature of alternative systems, consistency of results, robustness of results to changes in parameter values, ease of computation and amount of interaction required between the decision maker and analyst. Three MCDM methods, namely, ELECTRE-2,
Compromise Programming and Multi Attribute Utility Theory (MAUT) were employed. They found that Compromise Programming was the most appropriate method for the case investigated.

Hobbs (1984) discussed the necessity of rank correlation tests to check the correlation among the ranks obtained by different MCDM methods. He explained the applicability of the Spearman rank correlation coefficient for the Santa Cruz river basin planning problem. Szidarovazky et al. (1986) extended the Santa Cruz river basin planning problem by considering 18 performance criteria. Four methods ELECTRE-2, Compromise Programming (CP), Multi Attribute Utility Theory (MAUT) and Nash solution were applied to the planning problem. Compromise Programming (p=1) was employed to evaluate the four MCDM methods. It was found that Nash method occupied the first position whereas MAUT occupied the last position.

Goicoechea et al. (1992) investigated the relative utility and effectiveness of four MCDM methods for the case study of Washington Metropolitan Area (WMA) water supply system. Ten alternative projects and ten criteria were considered. They reviewed Multi Attribute Utility Theory (MAUT), Analytic Hierarchy Process (AHP), ELECTRE and ARIADNE. Two groups of analysts, and decision makers were chosen from U.S. Army Corps and graduate engineers. Evaluation of final ranks were based on a non-parametric Kendall Tau statistic test. The results identified AHP as the preferred MCDM method by both the groups. They concluded that rankings were not significantly affected by either the choice of the decision maker or on the method used. Similar studies are reported by Hobbs et al. (1992). Tecle (1992) performed an evaluation of fifteen MCDM methods based on twenty four criteria and found that Compromise Programming and Composite Programming were ranked first and second respectively.
2.8 LIMITATIONS AND NEED FOR FURTHER INVESTIGATIONS RELATING TO IRRIGATION PLANNING

1) Very few real-world applications of MCDM methodology for irrigation planning have been carried out. The MCDM methods, in addition to Compromise Programming and PROMETHEE-2, need to be employed to rank the alternative policies in the context of irrigation planning and performance evaluation of irrigation systems.

2) Simple and systematic methodology to reduce the non-dominated alternatives to manageable size needs to be developed.

3) Correlation checks between the rankings obtained by different MCDM methods are to be done.

4) Simple and easy methodology is needed for the selection of a suitable MCDM method in the presence of inconsistency.

5) Intensive studies are necessary regarding system characteristics, farmer's responses, involvement of authorities of the project in the decision making process.

6) Relative weights of criteria are to be chosen based on the views of farmers and authorities instead of simply basing on heuristics.

7) As many a number of experts as possible are to be consulted for formulation of payoff matrix.

8) Most of the existing MCDM methods do not consider uncertainties in the evaluations.

The present study pursue all these investigations and the results are applied to a real world irrigation system of command area of Distributary No.6 of Kendrapara canal under the Mahanadi – Birupa barrage project agriculture system, Orissa, India, the details of which are described in the next chapter.
2.9 CONCLUSION

The above literature review indicates that many mathematical models have been developed for operation management of storage reservoirs and few for canal system operation. Orissa has a wide network of canal system. Canal system in Orissa has not been designed to properly meet the irrigation requirements of command area. They have been mostly over designed. This over design causes the high initial construction cost and maintenance cost also becomes more. Thus Government has to spend a huge amount without deriving correspondingly higher benefit. The above review shows that not much study has been undertaken to develop the cropping pattern for the fixed command area under different supply levels of design discharge. How the cropping program changes with the expected management efficiency is another aspect of our present study. The command area of Distributary No.6 of Kendrapara canal has been taken as a study area. The Government of Orissa has taken this area on a pilot basis to bring about a change in agriculture development. The condition of the farmers of this area is poor. Thus, per capita income of the farmer has to be increased. The national goal, on the other hand is to promote the production level. This study has, thus, separately proposed the cropping patterns with the above two objectives. Rainfall contributes a substantial amount to the water requirement of crops as the annual average rain fall amounts to 1497 mm. The distribution of rainfall is erratic and even uneven and hence studies need to be carried out to find out how the cropping pattern changes with stochastic nature of rainfall. Thus, multiple cropping programs have been proposed under possible varying situations for use in the Government as well as by farmers in order to derive the maximum net benefit and maximum production from the canal command area which has been taken as a pilot area and will work as a model for other canal commands.