

ECONOMIC EVALUATION OF DAIRY FARMING SYSTEMS IN HARYANA



**THESIS SUBMITTED TO THE
NATIONAL DAIRY RESEARCH INSTITUTE, KARNAL
(DEEMED UNIVERSITY)
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF**

**DOCTOR OF PHILOSOPHY
IN
DAIRY ECONOMICS**

**BY
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KARNAL - 132001 (HARYANA), INDIA

2003

Regn. No. 1109803

*Dedicated to
the memory of my
brother Sumit Saha*

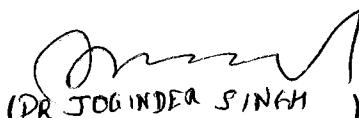
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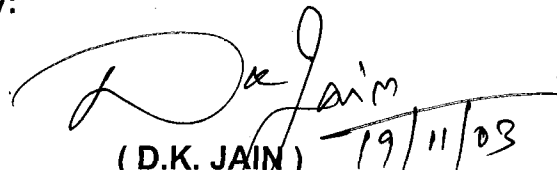
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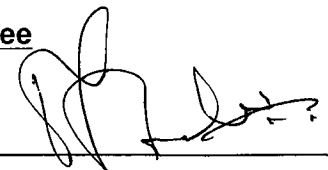
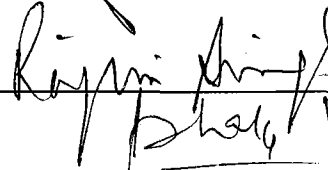
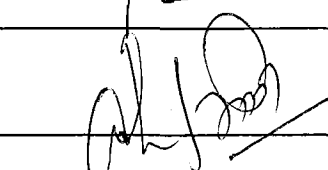
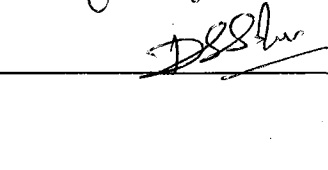
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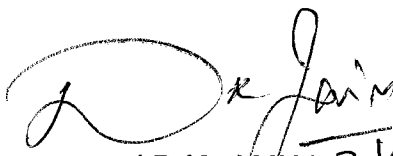


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CERTIFICATE

This is to certify that the thesis entitled, "**ECONOMIC EVALUATION OF DAIRY FARMING SYSTEMS IN HARYANA**" submitted by **Mr. AMIT KUMAR SAHA** towards the partial fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY** in **DAIRY ECONOMICS** of the **NATIONAL DAIRY RESEARCH INSTITUTE (DEEMED UNIVERSITY)**, Karnal (Haryana), India, is a bonafide research work carried out by him under my supervision, and no part of the thesis has been submitted for any other degree or diploma.


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(AMIT KUMAR SAHA)

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LIST OF ABBREVIATIONS

AHP	:	Analytic Hierarchy Process
CGIAR	:	Consultative Group for International Agricultural Research, USA
CMP	:	Clean Milk Production
DAHD	:	Department of Animal Husbandry and Dairying, India
DCSs	:	Dairy Cooperative Societies
FAO	:	Food and Agriculture Organization, Italy
FAPRI	:	Food and Agriculture Policy Research Institute, USA
GIS	:	Geographic Information Systems
GOI	:	Government of India
i.i.d.	:	Independent and Identically Distributed
ICMR	:	Indian Council of Medical Research, India
IFCN	:	International Farm Comparison Network, Germany
IFPRI	:	International Food Policy Research Institute, USA
MCDM	:	Multiple Criteria Decision Making
MOTAD	:	Minimization of Total Absolute Deviation
NDDB	:	National Dairy Development Board, India
OLS	:	Ordinary Least Squares
SAU	:	Standard Animal Unit
SMU	:	Standard Milch Unit
SPSS	:	Statistical Package for Social Sciences
ILL-2	:	Irrigated Landless Dairy Farming System (2 milch animals)
IM-2	:	Irrigated Marginal Dairy Farming System (2 milch animals)
IS-3	:	Irrigated Small Dairy Farming System (3 milch animals)
IL-4	:	Irrigated Large Dairy Farming System (4 milch animals)
RLL-2	:	Rainfed Landless Dairy Farming System (2 milch animals)
RM-2	:	Rainfed Marginal Dairy Farming System (2 milch animals)
RS-3	:	Rainfed Small Dairy Farming System (3 milch animals)
RL-3	:	Rainfed Large Dairy Farming System (3 milch animals)

सारांश

भारत में छोटे दूध उत्पादक को ऐसी व्यवस्था की आवश्यकता है जिसमें उसकी प्रणालीबद्ध भागीदारी हो एवं आत्म निर्भरता केन्द्रित हो जिससे पशुओं की निम्न उत्पादकता, दुग्ध उत्पादन प्रतिस्पर्धा में वृद्धि, उपलब्ध संसाधनों का भरपूर उपयोग आदि चुनौतियों का सामना किया जा सके। प्रस्तुत शोध इन्हीं पक्षों को दृष्टिगत रखते हुए किया गया है जिसके उद्देश्य (1) हरियाणा राज्य में प्रयुक्त विभिन्न डेरी फार्मिंग प्रणालियों का चिन्हन तथा वर्गीकरण (2) इन प्रणालियों की तकनीकी व आर्थिक दक्षता का आकलन तथा (3) इन प्रणालियों के लिए इष्टतम योजना का विकास तथा मूल्यांकन। इन उद्देश्यों की पूर्ति हेतु हरियाणा राज्य में सिंचित क्षेत्र (जिला यमुनानगर) व बारानी क्षेत्र (गुड़गांव एवं भिवानी) से दो-दो गांवों को चुना गया। इन छः गांवों के सभी घरों को भूमिहीन, सीमान्त, छोटी व बड़ी डेरी फार्मिंग प्रणाली (दोनों क्षेत्र सिंचित व बारानी) में कलस्टर अनालैसिस तकनीक के उपयोग द्वारा वर्गीकृत किया गया। 180 कृषि घरों के आकड़ों चुने गए जिनमें प्रत्येक चयनित प्रणाली के न्यूनतम 5 घर सम्मिलित थे। इन घरों में से विस्तृत जानकारी वर्ष 2000-01 के ग्रीष्म, वर्षा, शीत ऋतु में समाजिक आर्थिक विशेषताएं एवं निविष्ट-निपज समष्टियों फसल एवं दुध उद्यम पर लिया गया। सारणिक विश्लेषण, यादृच्छिक सीमान्त फलनीय विश्लेषण (सोकास्टीक फ्रन्टियर) एवं बहु उद्देश्य इष्टतम तकनीक के द्वारा वांछित उद्देश्यों का उपलब्धि हुआ। सभी डेरी फार्मिंग प्रणालियों में प्रति किलो दूध उत्पादन की लागत भैंसों, संकर गायों व देसी गायों में क्रमशः 11.01 से 17.47 ₹0, 7.91 से 10.69 ₹0 तथा 9.38 ₹0 से 14.01 ₹0 के परास में आंकी गई। सिंचित बड़ी डेरी फार्मिंग प्रणाली के आतिरिक्त सभी प्रणालियों में सकुल नकद आमदनी दुधारू पशु धनात्मक रही। विभिन्न डेरी फार्मिंग प्रणालियों के अध्ययन से औसत सकल घरेलू लाभ प्रति घर की परास ₹0 29190 (भूमिहीन) से ₹0 309643 (बड़ी) सिंचित क्षेत्र में तथा ₹0 24069 (भूमिहीन) से ₹0 145809 (बड़ी) बारानी क्षेत्र में पाई गई। तकनीकी व आर्थिक सक्षमता के अध्ययन ने दर्शाया कि उपलब्ध संसाधनों से भैंसों की दुग्ध उत्पादन की लागत 22.8 प्रतिशत घटायी जा सकती है जिसमें से आठ प्रतिशत भैंसों की दूग्ध उत्पादकता है तथा शेष संसाधनों के इष्टतम विनिधान से हो सकता है। सर्वोत्तम फार्म योजना द्वारा दर्शाया गया कि बारानी डेरी फार्मिंग प्रणाली में दुधारू पशुओं की संख्या बढ़ाने से नकद आमदनी में पुनः वृद्धि होगी तथा जीवन स्तर में सार्थक बढ़ौतरी होगी। हांलाकि उससे किसान को फुर्सत कम मिलेगी। योजनाओं द्वारा यह भी दर्शाया गया कि सिंचित व बारानी क्षेत्रों के भूमिहीन तथा सीमान्त किसानों में भैंसों के साथ-साथ संकर गायों को बढ़ावा देने के लिए समुचित न्यूनतम आर्थिक मदद तथा गैर कृषि रोजगार के प्रबंध होना चाहिए। सिंचित क्षेत्रों में छोटी डेरी फार्मिंग प्रणाली में अधिक आमदनी के लिए गन्ना तथा खाद्यानों की खेती तथा चारों की फसल तथा बिक्री पर बल देना जरूरी है। जबकि इस क्षेत्र में बड़े किसान खेती खाद्यानों फसलों की पर अधिक बल दें। जिससे उनकी फुर्सत की वरीयता को स्थान मिल सके। अंततः हरियाणा में किसानों की विभिन्न वरीयताओं का ध्यान रखते हुए दुग्ध उत्पादन की क्षमता एवं जीवन शैली में बढ़ौतरी की संभावनाएं हैं।

ABSTRACT

Smallholder milk production in India needs a systems based participatory approach with focus on sustainability in order to overcome significant challenges such as low productivity of milch animals, improving competitiveness of milk production, optimum use of scarce resources, etc. The present study was undertaken in the Haryana state with the specific objectives, viz., to identify and classify the different dairy farming systems in the study area; to measure the technical and economic efficiencies of the dairy farming systems and to develop and evaluate optimal plans of different dairy farming systems. Six villages were selected from Haryana state, comprising of Bendi and Antawa from Yamunanagar district representing the irrigated zone and Mehra and Dokhaharia from Bhiwani district and Alipur and Berka from Gurgaon district representing the rainfed zone. Based on complete enumeration of all the households in six selected villages, eight buffalo based dairy farming systems viz. landless, marginal, small and large dairy farming systems from each of the irrigated and rainfed zones were identified using cluster analysis. A sample of 180 households was selected randomly with a minimum of five from each of the identified systems from where detailed data was collected on socio-economic characteristics and input-output parameters of crop and dairy enterprises for the year 2000-01 for *kharif*, *rabi* and summer seasons. Tabular analysis, stochastic frontier functional analysis and multiple objective optimization techniques were used to achieve the desired objectives. The per kg cost of milk production was found to range from Rs.11.01 to Rs.17.47 in buffaloes; Rs.7.91 to Rs.10.69 in crossbreds and Rs.9.38 to Rs.14.01 in local cows across dairy farming systems. The net cash returns per milch animal were, however, positive in all the systems except the irrigated large dairy farming system. The average net family returns per farm household ranged from Rs.29190 (landless) to Rs.309643 (large) in the irrigated zone and from Rs.24069 (landless) to Rs.145809 (large) in the rainfed zone across different dairy farming systems. The technical and economic efficiency estimates for buffaloes revealed that the cost of milk production could be reduced up to 22.8 percent with the existing resources through productivity enhancement (8%) and optimal resource allocation at given prices. The optimal farm plans suggested increase in number of milch animals in the rainfed dairy farming systems in order to further increase cash farm income at the cost of less leisure for better living standards. The plans also suggested promoting crossbred cow along with buffalo among the landless and marginal dairy farming systems in both the irrigated and rainfed through suitable minimum credit support and non-farm income provisions. The irrigated small dairy farming system need to give more emphasis on sugarcane and cereals crop cultivation and sale of cultivated fodder crops so as to further increase their cash farm income. The irrigated large dairy farming system need to concentrate more on crop cultivation only, which could plausibly be due to their leisure preferences. Thus, it is possible to bring about improvement in efficiency of milk production and living standards of farm households in Haryana, simultaneously satisfying their several objectives.

CHAPTER - 1

Introduction

1. INTRODUCTION

1.1 GENERAL BACKGROUND

India has made significant achievements in dairying in terms of milk production, milch animal productivity and its contribution to the growth of the country's economy. Milk production, at an average annual growth rate of 4.48 percent, was anticipated as 84.5 million tons in 2001 thus making India the largest milk producer in the world (GOI, 2002). Crossbreeding programmes have partly increased the productivity of cows which is evident from the fact that cow milk production has registered an annual growth rate of 4.56 percent during the period 1990-2001 against a marginal increase of 0.12 percent in milch local cow population and annual increase in crossbred milch cow population by 7.41 percent during the period 1990-2001 (GOI, 1999b). The value of livestock output has grown by 6 percent per annum in the last two decades. The share of livestock sector in 1999-2000 at current prices was 5.51 percent of GDP with a significant share of 69.38 percent in the milk group during 1999-2000 (GOI, 2002).

However, on the other hand, India has the largest number of poor for any developing country, and faces challenges in field of food, health, nutrition and stagnating productivity. About 433 million people in India survive on less than US\$1.00 per day and 45 percent of children under five years of age are malnourished (IFPRI, 2003). Nevertheless, many opportunities for alleviating poverty and food insecurity exist such as Investment in agricultural R&D, rural infrastructure, and high-potential rainfed areas; improved natural resource management and urbanization.

Dairying is referred to as one of the potential means to ensure effective development of living standards of the poor under given conditions in the developing poor countries (Delgado *et al.*, 1999). With 26 percent of the rural population living below the poverty line in 1999-2000 and without or marginal

land holdings, dairying has been contributing significantly to meet their income, employment and consumption needs (Prabaharan, 2000). Thus, dairying is seen as a potential tool to alleviate rural poverty in India.

However, in spite of significant developments in the dairy sector over the last three decades as is evident from the figures given above, there are many challenges that needs to be overcome in order to ensure the sustainability of the dairy developments made so far. With a cattle population of 218.8 million and buffalo 93.772 million in 2000, India accounts for about 15 percent of cattle and 56 percent of buffalo population in the world but it accounts for only around 12.3 percent of the world's milk production in 2000 (FAO, 2000).

Though the crossbreeding programme has started since last twenty five years, only 14.9 percent of the milch cow population is of crossbred cows while the remaining 85.1 percent is still the low yielding local zebu non-descript cow with average milk yield of 1.5 litres per day in 2001 (Sadhana, 2001).

Landless and marginal farm households numbering more than 70 million, owning less than a hectare land, rear more than 80 percent of bovines in India. The average productivity of cow and buffalo in 1997 is much lower at 917 and 1300 litres of milk per animal per year in comparison to world average of 2192 kg per animal (FAO, 2000) or of the other major milk producing countries in the world due to lack of resources to improve upon their genetic potential or the nutrition standards. A high demand supply imbalance of fodder and unbalanced feeding in terms of higher proportion of dry fodder feeding has been reported (Prabaharan, 2000). Thus, Indian dairying is characterized by millions of small producers with little or no land base, use of crop residues and natural herbage with or without costly concentrates as feed supplements, scarce land for pastures and fodder production and low yielding non-descript cows and buffaloes. Some of the developed countries such as Japan, were also practicing small scale dairy farming with a herd size of 1.8 during 1956, but with increasing land and

labour costs, off farm and urban income and government policies, the average herd size increased to 11.2 in 1975 and national number of farms decreased from 410420 farms in 1960 to 44300 farms in 1995. Though the trend all over the world has been to go for specialization and consolidation of farms, the case has not been applicable for India. Thus, dairying in India is led by the motive of utilization of crop residues and home consumption of milk with surplus for sale.

Though the per capita availability of milk in India, estimated at 205 grams per day in 1997 (GOI, 1999b), has substantially increased over the past three decades, yet, it is lower than the minimum recommended requirement of 250 grams per day by ICMR. Against this, some of the major milk producing countries such as New Zealand and Denmark had per capita availability of milk at 8378 and 2312 grams per day, respectively, in 1997.

The demand for milk is estimated to increase to 497 million tons by 2020 assuming the growth rate of the economy at 5.5 percent per annum (Prabaharan, 2000). Milk supply projection indicated a deficit of 200 million tons by 2020. With a fast changing global livestock scenario and the liberalization of agricultural trade, there is a serious threat to the smallholder dairying in India lest they are left behind. Therefore, there is an urgent need to overcome these challenges through development of suitable policies and strategies for dairy development both in the short and long run keeping in view the limitations and constraints under the existing conditions in India.

The government of India has initiated efforts in this direction as is evident from such programmes as comprehensive National Project for Cattle and Buffalo Breeding (a Centrally Sponsored Scheme with allocation of Rs.402 crores and merging the Progeny Testing Programme, Extension of Frozen Semen Technology and National Bull Production Programme) initiated in October 2000. In order to reduce morbidity and mortality in animals, efforts are also being made by the State / Union Territory Governments to provide better health care through the network of polyclinics, veterinary hospitals,

dispensaries, first-aid Centres and mobile veterinary dispensaries. Besides, another Centrally Sponsored Scheme, namely, "Assistance to States for Control of Animal Diseases" is also focusing on animal health and veterinary care. This scheme has got three components, viz., Systematic Control of Livestock Diseases of National Importance, Foot and Mouth Disease Control Programme and Animal Disease Surveillance (DAHD, 2002).

National Dairy Development Board has also prepared a perspective plan 2010, which is an ambitious programme for dairy development with a focus on four thrust areas (NDDDB, 2002). Firstly, strengthening the cooperative businesses through institution building, increased participation of women, farmers' induction, and enhanced milk procurement and marketing. Secondly, enhancing productivity through a scientific and integrated approach towards breeding, feeding, health care and husbandry practices. Thirdly, managing quality through a massive awareness programme on Clean Milk Production (CMP) covering one lakh village dairy cooperative societies (DCSs) across the country. Lastly, building a national information network with Internet based dairy information system on demography, agriculture and land use, livestock population, export and import of dairy commodities, milk production and productivity of animals. Another information system involving Geographical Information System (GIS) software and software for animal enumeration and milk production estimation, society information, veterinary health care and artificial insemination service is already in progress.

Thus, it is evident that concerted efforts are being made in the right direction by the government and NDDDB to boost up the productivity of milch bovines and clean milk production through mass awareness campaign. But many studies have pointed to the inherent complexity of smallholder dairy production (Nicholson *et al.*, 1999). It is, therefore, necessary to undertake research efforts in ensuring better ways to quantitatively analyze dairy farming in a manner that will enable to improve upon its efficiency and productivity in a sustainable manner. This will ensure not only poverty reduction but also food security to the millions of rural poor in India.

1.2 SPECIFICATION OF THE PROBLEM

Productivity of dairy farming can be increased through technological change, economic efficiency change and scale efficiency change. Of these, the options of scale efficiency change and technological change requires proper social, economic and infrastructure investment. Many studies have shown conflicting results with reference to size economies and productivity of milch animals in India (Singh *et al.*, 1988; Pandey, 1988; Gupta and Aggarwal, 1990; Ram *et al.*, 1993; Rai, 1997; Rajender *et al.*, 1998). Efforts to bring about technological change through promotion of crossbreeding technology or adoption of high quality feed and fodder have been continuing since a long time with less success at the macro level. Keeping in view the existing trends, it is pertinent that at least in the short run, the easiest option to bring about productivity improvement is through economic efficiency improvement of smallholder dairy production in India. Smallholder dairying has been and will be the major contributor to dairying and socio-economic development of the poor farm households in India. Efficient utilization of scarce resources such as feed, fodder and capital to produce milk is very much essential in India in view of the demand-supply imbalance of these resources. India is rich in human labour resources due to the high population and problem of disguised unemployment. But in the times to come, efficient utilization of labour resources will become necessary for improving the living standards and the overall development of the nation. Further, queries are often being raised about the efficiencies of operation of these smallholder dairy farming systems. Dairying is often considered more of a managerial issue rather than technical, as a good dairy farmer needs more than just technical skills, the desire, aptitude and managerial skills to take care of his animals. The best option to measure productivity changes due to managerial aptitude is through efficiency studies.

Efficiency means different things to different people. One form of efficiency, referred to as technical efficiency, is the ability of a producer to achieve the maximum output possible from a given set of inputs. Allocative efficiency, in contrast, refers to the producer's ability to respond to economic

signals and choose optimum input combinations (i.e., proportions) given relative input prices. Overall economic efficiency is the product of technical and allocative efficiency.

Under Indian conditions, a number of studies (Rai and Gangwar, 1976; Pandey and Kumar, 1981; Singh *et al.*, 1995; Saxena *et al.*, 1995) attempted to measure some or all of the inputs and outputs of dairy farming but failed to combine these into a satisfactory measure of efficiency. Efficiency was generally believed to be directly correlated with average productivity of animal in dairying. Attempt to construct indices of efficiency in which weighted average of inputs is compared with output failed due to usual index number problems. A few efficiency studies in milk production (Srivastava, 1995; Chand, 1998) have concentrated on the deterministic approach of quantifying the efficiency of resource use in milk production. But there is always the risk of significant biases in deterministic estimates of efficiency due to the inherent assumptions of the approach that all variations in milk production is due to inefficiency of resource use. Dixit (1999) used the Corrected Ordinary Least Square (COLS) approach to estimate the technical efficiency of milk production using stochastic frontier production function. However, this approach has been criticized by Coelli (1995) on account of unreliability of parameter estimates using COLS method when the contribution of technical inefficiency effects to the total variance term is large. A stochastic approach using Maximum Likelihood Estimation (MLE) method to take care of these limitations and thereby estimating efficiency of milk production has not been attempted so far in India. Stochastic frontier approaches to efficiency determination will help in overcoming these problems in efficiency estimation for a reliable policy formulation in the context of whether to go for bringing about technological change or improve the efficiency or should these small farmers quit dairying. So the debate lies on whether there is a problem in technology adoption or in the efficiency of managing the dairy farming systems by the farm households. Till now the policy analysts have been hypothesizing that the problem was in the adoption of technology and that all dairy farms were efficient on the basis of assumptions of functional analysis of ordinary least squares regression. The present study hypothesizes that milk

production by all farms are not efficient and the onus lies in measuring and identifying the efficient farms. This would enable the farmers to understand how efficient farmers operate and increase productivity in a shorter time with minimal resources and minimal external factors such as livestock development programmes, village adoption programmes, technology transfer and lab to land programmes.

A relatively more efficient dairy management system protects the interests of dairy farmers and consumers. An efficient dairy farming system could provide more income to producers and more milk for consumers. When high levels of economic efficiency and productivity and high rates of productivity growth are the desired goals, it is important to define and measure efficiency and productivity in the ways that respect economic theory and provide useful information to managers and policy makers. Performance of dairying is viewed as a function of the state of the technology and the degree of efficiency, with the former defining a frontier relation between inputs and outputs, the latter incorporating waste and misallocation relative to this frontier.

Thus, there is a need for an evaluation and monitoring system at the farm level which can identify best farming systems to locate best practice, identify under-achievers, set realistic peer based improvement targets, uncover greatest potential efficiency gains and allocate resources more effectively. "Standard" estimation procedures for production functions implicitly assume that all producers are technically efficient. Any deviations from the expected output level are attributed to random events beyond the control of the producer. The concept of a production "frontier", however, allows the additional possibility of inefficient input use leading to deviations from the frontier production level. Extending this idea to economic behavior, it is possible that some producers do not respond to input prices in an optimal manner wherein that they do not use cost-minimizing combinations of inputs (i.e., allocatively inefficient). Thus, determining the technical and economic efficiency of the identified dairy farming systems in the study area would help to identify the efficient farm that could serve as a model farm within the

system for technology diffusion and adoption. It has become very important to understand dairy farming in India in a systems perspective so as to suggest suitable policy strategies for improving their efficiency and overall productivity of dairying.

Prior to evaluating efficiency, it is necessary to identify and develop dairy farming systems to provide decision support to the farmers and advisors and also to address more general dairy development questions. The issue is how to describe the diversity of complex dairy farming systems, whilst avoiding the pitfalls of singling out each and every production system as unique. With dairying playing a major role in farming systems in India, dairy-farming systems could be considered a sub component of livestock systems and needs independent analysis. Though a number of studies have been done to study the economics of milk production with land size, as basis of classification (Ram and Singh, 1974; Pandey, 1988; Keshari *et al.*, 1998; Rajender *et al.*, 1998; Yadav and Yadav, 1998), but identifying the different dairy farming systems at a household level in a given region have been only attempted by Dhaka and Jain (1999) in India. Identification of the dairy systems has been done in the international context, where focus has been on specialized dairy farming, with emphasis on grassland utilization (pasture based) or concentrate based stall-feeding or mixed or organic farming (Andersen, 2001). The optimization based on such systems is not relevant under Indian conditions of dairy farming.

Most of the studies have considered profitability as the single major criteria in developing ex-ante strategies for improving upon social efficiency and managerial efficiencies through increase in farm income and employment (Desai, 1960; Gangwar and Bhatia, 1980, 1981; Pandey *et al.*, 1982; Rai and Singh, 1982; Sardana and Panghal, 1984; Singh and Sharma, 1987; Deoghare and Sharma, 1992). However, with farming in India being more of a household and family enterprise, a multi-objective framework consisting of a dual entity, associating human activity system and the production process is better for such analysis. Ordinary linear programming models maximizing total gross margin or profit is used in farm planning by the big commercial farms in

developed countries. Linear programming has been considered an efficient technique despite its unrealistic assumptions such as linearity, divisibility, independence, single valued expectation, single objective and static situation (Bernard and Nix, 1973). This is especially true in case of farm planning where availability of detailed information that is required for more realistic programming is often not available due to the difficulties in data collection and maintaining records and the high costs involved for the same. However, the implicit assumptions in linear programming that all goals included in the constraint set are of equal importance and should be absolutely satisfied in order for the linear programming formulation to be feasible is just not logical. The available literature on evaluation of dairy farming systems in India using multi criteria approach is rather scanty. The limited studies that have been carried out in farm planning are mostly those dealing with minimizing farmers' risk, stability of farm income in addition to maximization of expected total gross margin or profit (Singh and Jain, 1983; Vijayalakshmi, 1985; Sharma *et al.*, 1990; Jha, 1994). This may be mostly due to the perception and belief that other objectives are negligible in the farm business. It may be reasonable to make this assumption for farms in developed countries, but for the small farms in developing countries, majority of which are partly subsistence, this assumption may not hold. The farmer may have other objectives, which should not be neglected in their farm planning, for farming is just not business but a way of life for them. If they face more than two objectives, the above-mentioned methods cannot handle the problem. Under these circumstances, the results obtained from such models have been found so often disappointing under real existing situations. It is in this context that developing techniques which are easy in applying for multi attribute decision making in relation to determining the optimum combination of various enterprises and technology, viz., livestock, food, cash and fodder crops and agricultural technology of crop and livestock production and their interrelationships at a farm household level is necessary. This is especially true in case of India, where mixed farming is the most predominant system and a very few studies on such systems with multi-objective goals or preferences have been carried out.

Therefore, it is hypothesized that the farm households practicing dairy farming can be grouped in a systems perspective and their stochastic efficiencies of milk production estimated vary significantly. Further, it is possible to set a benchmark within the existing systems of the most efficient farms for adoption and diffusion of technology under existing conditions without external interventions of new technological change. There are multiple goals or objectives in taking farm decisions and their preferences vary for different farm households. Satisfying their multiple goals within the existing technology domain of the region will lead to more ideal and easily adoptable farm plans. In view of the justification given above, the present study was undertaken with the following objectives in mind: -

1.3 OBJECTIVES OF THE STUDY

1. To identify and classify the different dairy farming systems in the study area;
2. To measure the technical and economic efficiencies of the dairy farming systems;
3. To develop and evaluate optimal plans of different dairy farming systems.

1.4 ORGANIZATION OF THE STUDY

The study has been presented in six chapters. The first chapter is devoted to general background, specification of problem, delineation of the objectives and organization of the study. A brief review of the work carried out earlier in farm classification, frontier analyses of efficiency determination and multi-criteria optimization of farm planning have been given in chapter two. The chapter three deals with description of the study area. The procedure used in selection of study area, collection of data, analytical framework of study, some important concepts used in the study, procedures adopted in data analysis and limitations of the study are discussed in chapter fourth. The objective wise results and discussion of the results are presented in chapter fifth. The last chapter synthesizes and summarizes the findings of the study.

CHAPTER - 2

Review of Literature

2. REVIEW OF LITERATURE

A comprehensive review of the research work carried out in relation to the present study is presented here in order to understand the developments and drawbacks experienced by the researchers. The review has been conducted on five main broad areas: identification of farming systems; cost of milk production; functional analysis of milk production; measuring efficiencies and farm planning.

2.1 IDENTIFICATION OF FARMING SYSTEMS

Researchers in the field of agricultural economics, extension and other fields related to agriculture have always tried to classify the population on the basis of certain characteristics. In the field of dairying, the basis of classification for analysis has been size of farm / herd size / type of milch animal; adoption of technology / scheme / program; innovativeness / management skills / adoption index / profession; characteristics of milch animals and systems approach.

The first four parts are in fact classification in parts and the fifth approach namely systems approach of classification is a cumulative effort of all the approaches. Though systems approach of classification is not a very new concept, but the necessity of the data on a large number of factors has hindered this approach by most of the scientists. However, the systems approach is found to be the most accurate and sustainable way of classification for policy analysis and strategies.

Studies on dairy farming with land size as the classification criteria for households were carried out by Ram and Singh (1974), Pandey (1988), Keshari *et al.* (1998), Rajender *et al.* (1998) and Yadav and Yadav (1998). Singh *et al.* (1975) used type of milch animal as the basis for classification of farm households. Rai *et al.* (1997), Dixit and Laharia (1998) and Sharma and Singh (1985) used number of milch animals as the criteria for classification in a study in 1981-82 in Haryana. The study conducted by Aneja and Nirman

(1981) has shown some drawbacks in using farm size in terms of herd size in classifying farms for time series analysis as a time series study on the same sampling units showed that the matching of sampling units was not effective in building up improved estimators. It was also found that many producers changed size between the surveys, with small producers becoming large and vice versa.

Radhakrishna (1959) in his study on paddy farmers of Andhra Pradesh used decomposition analysis to segregate the farmers into efficient and inefficient farmers. Agarwal and Sharma (1985), Sharma and Singh (1985), Kumar *et al.* (1993) and Singh *et al.* (1995) classified farm households on the basis of adoption of technology / scheme / program.

Singh and Verma (1985), Sharma and Patel (1988), Singh *et al.* (1991), Chakravarty (1995), Singh and Sharma (1995) and Yadav and Yadav (1997) classified the farms on the basis of innovativeness / management skills / adoption index / social participation / profession.

Lall *et al.* (1995) classified the farm households on the basis of milk yield characteristics of buffaloes in selected villages of Hisar district involving a total of 243 farmers and 535 milch buffaloes.

Malik (1997) surveyed two hundred women practicing dairying from eight villages (25 women/village) in Haryana. He stated that characteristics of the female farmers, including educational level, farm size, knowledge level of farmers in designing training needs and classifying the farming systems could be an important area of research.

Sirohi and Sirohi (1997) classified the households on the basis of adoption of village by Krishi Vigyan Kendra in Chindwara, Madhya Pradesh in 1993. Adoption of village was found to have a medium effect on level of knowledge of scientific dairy farming practices. The level of adoption was, however, low irrespective of adoption due to common constraints faced by acute shortage of water, lack of feeds and fodder, poor veterinary and infrastructural facilities. She showed correlation between farm size and number of milch animals.

Singh and Singh (1998) identified different dairy farming systems for the western dry region of Rajasthan using family education status, knowledge of dairy farming practices and mass media as variables. Dairy farmers with a low level of family education status, less knowledge about dairy farming practices and a low level of mass media exposure had a high level of technological gap with respect to recommended dairy farming practices.

2.1.1 Classification on the Basis of Systems Approach

The approach to view objects and events as part of larger whole and to emphasize on the system as a whole in terms of interrelated parts was conceived as early as 1955 by Boulding. A system is conceived as comparison of a number of subsystems with interactions among them. Sustainable approaches to development require analysis of the problem in an integrated manner. The problem needs to be decomposed into its constituents and studied in an integrated manner (Maji, 1991).

Russell (1970) stated the need for an objective appraisal of the physical, financial and managerial resources available in a region before developing optimum system of livestock production. For it he suggested that a total systems analysis should be undertaken for each large livestock farm that will represent a unique combination of resources and requirements. The combination of level of stocking and of feed and forage production should be based on maximization of the returns produced by that particular farm.

In the systems approach, farming systems has been ascribed by Okibo (1974), Norman (1978), Gilbert *et al.* (1980), Desai (1982), Shaner *et al.* (1982), Remenyl and Coxhead (1985) and Shand (1985) as a specific agricultural situation described in a holistic manner with interrelated subsystems based on resource availability, technology used, preferences and goals pursued by farmers within a specified agro-ecological and socio-political-economic environment. Dillon and Hardker (1993) described farming systems as dynamic involving purposiveness of farmers' behaviour.

Hart (1982), Conway (1985) and Gibbs (1985) stated the complexity and hierarchical nature of agricultural systems as a nested structure comprising in order of:

- Physical and biological systems at the field level;
- Crop and livestock systems to a farm household system;
- Community and infrastructural systems composing the regional and national agricultural systems.

To avoid complications in analysis, Brush and Turner (1987) suggested that systems need to be artificially limited if analysis is to proceed and that described systems are heuristic and artificial devices rather than natural phenomena.

Alavarenga *et al.* (1987) introduced presence of basic elements defining macro variables as the basis of classifying ex-post farming systems. The methodological analytical framework of classifying farms started with the use of principal component analysis to identify important variables defining the farms and cluster analysis to group the farms by Manrique *et al.* (1991), Jain and Dhaka (1993) and Kaine *et al.* (1994). The basis of classification was mainly economic criteria, size of farm, use of resources intensity and management practices.

Sharma *et al.* (1991) classified the farming systems in Himachal Pradesh as remittance supported livestock based, vegetable based and fruit based farming systems.

Jain and Dhaka (1993) suggested choice of classification parameters based on physical, geographical, demographic, socio-economic, farm management and extension variables. Pingali (1995) in a study on evolution of farming systems stated that in Asian countries, the crop-livestock interactions evolve through four stages, viz. the pre-intensification phase, integrated crop-livestock systems, income diversification phase and specialization phase. Unlike developed countries, wherein, dairy farming is specialized type with pastures and /or stall fed, dairying in India is mostly a supplementary enterprise based on crop residues and some concentrates. However, the criteria of classification based on the cropping pattern, which affects the fodder and feed, the land holdings, the type of milch animal (buffalo or cattle) is more relevant in such smallholder farms. The

characteristics of number of milch animals, area under fodder, grazing systems, pasture is either uniformly present or negligible. Hence, the basis of classification needs to consider the unique features of Indian dairying.

Kaine *et al.* (1995) used Cluster analysis to identify different types of farms (dairy producers) in the Hunter Valley, Tamworth and Mid-North Coast regions of New South Wales and to systematically classify farms according to its type. The study used the concept of farm 'context' where context describes the resources, practices and technologies used in production and key attributes of the producer such as their farming and business skills and their farming and business objectives. The factors that constitute 'context' define the production and cost functions of farms and, therefore, determine the capacity of producers to respond to changing economic circumstances. Although the factors that define the production context of farms vary from farm to farm, much of this variation is systematic rather than random -- a consequence of farm development that creates systematic differences in production contexts. The principal objective of the study was to pilot the application of a method for systematically, but parsimoniously, classifying dairy farms into different types on the basis of a set of attributes describing the resource base of dairy enterprises, and their level of technological and managerial development. Given that the differences between farm types reflects differences in development and resources, it was hypothesized that different cost structures would be associated with each type of farm and the differences in cost structures would translate into differences in supply response. Six different types of dairy farms in the Hunter Valley, Tamworth and Mid-North Coast districts of New South Wales were identified using the cluster analysis. The first and second clusters consisted of farmers that operated traditional dairy farms with walk-through milking sheds and hand-shift irrigation systems. The first cluster of farmers differed from those in the second in that they appeared to be devoting some effort to raising productivity through herd recording and artificial insemination. The third cluster of farmers also operated irrigated dairy farms with walk-through sheds. This group of farmers relied on high-pressure travel irrigators and the proportion of these

farms that have labour saving devices in their sheds is relatively higher than in the case for the 'traditional' irrigated farms. This suggested that the management of the farms in this cluster was constrained by the availability of labour. The fourth group of farmers were characterized as 'classic' dry land dairy enterprises with walk-through milking sheds. The fifth cluster of farms was described as 'intensive' irrigated dairy farms and were characterized by herring-bone or rotary sheds incorporating labour saving devices such as backing gates, automatic feeders, in-line cleaners and automatic cup-removers, and a complex feed production system. The farms in the sixth cluster were extensive, large-scale operations characterized by herringbone or rotary milking sheds, which incorporated labour saving devices. The farmers in the fifth and sixth clusters appeared to be striving for maximum production efficiency and labour productivity. The results of the regression and econometric analysis supported the hypothesis that supply response differed across different types of farms. The estimated supply response functions were statistically significantly different from each other. This statistical evidence was reinforced by the fact that milk production could be predicted more accurately using the estimated functions for each cluster rather than a function estimated across the whole sample of farmers.

Moore (1995) suggested the variables at a farm household level such as labour, total assets, land, household demographic composition, crop composition and production techniques and farm and family goal as criterion for identification of farming systems.

Murray (1997) used cluster analysis as a classification method to identify farm systems originating from surveys for rigorous research comparison. The method proved to be successful with 59 crop production practice variables being cluster analyzed into five groups. The groups ranged from a virtually all irrigated monocrop corn system to one that is near organic. This statistical method of classification without a priori knowledge classified farms into homogeneous subgroups based on similarity of their production systems, develops subgroups along a continuum from "conventional" to "alternative", conducts the classification such that results would be suitable for

statistical analysis, and results in an unbiased mathematical classification of the data. The results of the cluster subgroups were: Irrigated-Monocroppers, Young-Business-Technocrats, Integrated and Urban-Fringe (Traditional).

Shah and Sharma (1997) stated that identification and classification of farming systems is usually guided by action or management considerations such as homogeneity and size.

Kumar (1998) conducted a study on economic analysis of farming systems in the Mathura district of Uttar Pradesh. Based on the benchmark survey of six villages selected randomly from three purposively selected blocks representing diverse farming situations in the district, five farming systems groups were identified. These were sugarcane based, wheat-mustard based, potato based, landless and landless goat farming systems on the basis of main source of income from different enterprises. The systems identified were post stratified into two farm size categories for analysis namely small (less than 5 acres) and large (more than 5 acres). Additionally various other factors like soil type, irrigation water availability and quality, availability of credit, sugar mill, cold storage facility, input delivery system, transport, market facility etc. were also considered, while classifying various farming systems. The imposition of water restriction due to depleting ground water resources in the sensitivity analysis of optimal farm plans gave interesting options and activity selection in terms of shift of resource allocation for different activities in the model with marginal decrease in income, thereby signifying its adoption for water conservation. The average annual milk yield per buffalo was observed to be highest (1274 litres) under sugarcane based farming system, followed by potato based (1205 litres) farming system and wheat mustard based farming system (1181 litres). The productivity in terms of average milk yield per buffalo on landless dairy farming systems was observed to be higher in sugarcane belt (955 litres) as compared to other areas (535 litres). The number of milch buffaloes in both the farm size categories increased to five per farm in the optimum farm plan from their existing level of 2.73 on small farms and 3.5 on large farms.

Dhaka and Jain (1999) reported identification of seven dairy farming systems based on animal composition in their study on economic analysis of dairy and crop farming systems in Haryana. The proportion of households with buffaloes was 35.5 percent, buffaloes and crossbred cows at 29.8 percent and only crossbreds at 11.5 percent. The average herd size of milch animals was 1-2, with 47.5 percent of households owning 2 milch animals and 32.8 percent owning only 1 milch animal.

Hennessy (1999) chose representative farms from the Irish National Farm Survey, which surveyed a weighted sample of 1200 farms annually, representing a population of over 120000 farms. Farms were initially segregated by system of farming and then selection was based on technological homogeneity using the cluster analysis procedure. Representative farms were based on the mean farm from each emerging cluster. There were 4 representative dairy farms and 4 representative cattle farms. A multi-period linear programming model was developed for each representative farm using resources and coefficients derived from the National Farm Survey. The farm structure was put in an optimization setting where farm net margin was maximized over the multi-year planning period. The model estimated the probable responses to different policy scenarios. The multi-period nature of the model used by the researcher allowed it to capture the dynamics of farmers' adjustment processes, which was far more enlightening than the alternative methodology of comparative statics. Results were validated historically and when the percentage absolute deviation was significant then the model was calibrated.

Steinfeld and Mäki-Hokkonen (1999) described each livestock production system in terms of feed and livestock resources; livestock commodities produced; production technology; product use and livestock functions; area covered; geographic locations; and human populations supported quantitatively and qualitatively. The classification criteria were limited to three: integration with crops, relation to land and agro- ecological zone. Livestock production systems were considered to be a subset of farming systems. The world livestock production systems were classified into

six systems namely, *Solely livestock production systems (L)*, *Landless livestock production systems (LL)*, *Grassland-based systems (LG)*, *Mixed-farming systems (M)*, *Rain-fed mixed-farming systems (MR)* and *Irrigated mixed-farming systems (MI)*.

FAPRI (2000) classified the dairy farms on the basis of family farm income, income per labour unit, utilized agricultural area in hectares, quota farmed, milk for farm/household, dairy as percentage of total output, size of dairy herd, milk production per cow (in gallons), beef as percentage of total output sheep as percentage of total output, gross margin per hectare, change in farm gross margin (1992-95), change in utilized agricultural area (1992-95), change in milk sold (1992-95), change in livestock units (1992-95), age of operator, full-time / part-time farmer, off farm job status, total borrowings, land rented in hectares, land rented out in hectares, subsidies as a percentage of farm investment, direct cost per gallon milk production, overhead cost per gallon of milk production, milk production in gallons per acre, liquidity, net new investment and new investment per acre. The groups were named as static, large, developer and typical. Static group of farms were found to be least technically efficient.

Sadana (2001) made a reference from NDRI vision 2020 about the strategies for livestock development in India. The packages of practices for animal improvement in terms of breed and type of animals considered were breeding strategies, feed availability, milk product development and marketing etc. This package was based on agro-ecological and agro-climatic zone in a geographical or socio-economic area, which is homogenous in terms of natural conditions, animal health and agricultural activities. Thus, a zone identified as "Dairy zone" can then be focused on only in terms of sustainability of improvement practices but also for optimization of resources utilization. Correlating the entire available social, economic, ecological, geographical parameters could help in developing a map of dairy zones in the country. The basis of future development strategies should be location specific, breed targeted and tailor made for these zones alone and not in form of blanket recommendations, programmes made to cover all animal breeds and states.

A review of the literature (FAO, 1980; Ruthenberg, 1980; Jahnke, 1982; DeBoer, 1992; FAO, 1994) revealed that most farming systems classifications are not backed by quantitative criteria, which would enable cases to be clearly allocated to one class. These classifications are closer to typologies. No attempts at developing a classification of world livestock systems by using quantitative statistical methodologies (cluster analysis and related methodologies) could be found in the literature. This probably relates to the lack of appropriate data sets for such approaches on a global scale.

From the review on the farm level classification in Haryana, it is clear that the average herd size has remained the same since a long time. The increase in the growth rate of buffaloes than cow population favoured the former's increase in number significantly. A few studies (Ram and Singh 1974; Sharma and Singh, 1985; Sirohi and Sirohi, 1997) have correlated the increase in herd size with increase in landholdings positively. Bigger farms have shown to be more labour efficient than smaller farms under organized farm conditions. No differences were found among the five landholding classes (landless, marginal, small, medium and large) on the buffalo feeding, breeding and housing practices in the Rohtak, Hisar and Bhiwani districts of Haryana by Rajender *et al.* (1998). Size of land holding had a strong association with adoption of all the practices except calf rearing practices (Yadav and Yadav, 1998) in Haryana. Use of cluster analysis to classify the dairy farms has been mostly done in the developed countries. Most of the studies in India have identified the problems in a highly aggregated and generalized way. Naturally, the interventions and strategies suggested have also been highly generalized. Hence, there is a wide gap in policy formulation and their adoption at field level. It is in this context the present study will focus on the use of cluster analysis for classification of dairy farming systems in the selected study area.

2.2 COST AND RETURNS OF MILK PRODUCTION

Cost of milk production plays an important role in determining the efficiency of the dairy farming systems. Allocation of resources depends upon the availability of resources and their economic value at a point of time in a

given region. Reducing costs is a very efficient way to maximize returns. Hence, efforts to quantify cost of milk production or to identify low cost technologies and suggest strategies to reduce costs have been made in India by different researchers in different studies from time to time. The present review tries to present a concise picture on the costs and returns of milk production studies carried out in India.

Faroda *et al.* (1978) compared different dairy farming systems under controlled experiment conditions during 1973 to 1975 in Hisar. The plots of 2 hectare size were used for (i) specialized dairy farming, (ii) mixed farming and (iii) arable farming systems. In specialized dairy farming all the land was used to cultivate fodder or feed crops to support 8 Murrah buffaloes. In mixed farming 50 percent of the area was used for cereal and cash crops while fodder crops were cultivated on the remaining area for four buffaloes. Only one buffalo was kept in arable farming systems with 90 percent of the land used for cereal and cash crops. The buffaloes in all the three systems were fed green and dry fodder *ad lib.* with some supplementary concentrate. Average annual net profit was found to be Rs.3434.07, 2540.85 and 1054.70, respectively, in the three systems. It was concluded that small and marginal farmers had better returns from dairy or mixed farming systems than from arable farming.

Sastry *et al.* (1979) studied milk production data and its economics for 1971/72 to 1975/76 from a 2 ha dairy farm with 5 to 8 buffaloes in Haryana Agricultural University Farm. Feed costs were 47 to 57 percent of total cost, and labour made up 14 to 21 percent with the bulk of the remaining costs being due to depreciation and interest. The cost of producing a litre of milk was Rs.1.23 to 2.13 and seemed to be more influenced by lactation length than by individual daily milk yield. It was concluded that with buffaloes yielding 5 kg/day for 300 days, cost/litre milk could be less than Re.0.90. The green fodder produced on the farm comprising of 150 tons was found to be sufficient to support at least 12 buffaloes yielding 1500 kg milk and followers, if supplemented by dry forage.

Rao and Singh (1980) carried out an investigation on small dairy units with a variety of crossbred cows maintained by different categories of urban households of Karnal in Haryana. Examination of the investment pattern in different categories of households showed that investment in fixed assets was observed to be the highest where there was no other occupation but dairying. Overall investment was found to be the highest on crossbred animals, followed by cattle sheds and stores. Major costs were feed and human labour. Net income per milch cow was positive for all breeds and highest for Holstein Friesian. It was concluded that dairy enterprises with crossbreds can be taken up and profitably run by either underemployed or unemployed in urban as well as rural areas.

Handique (1981) in his study on the economic analysis of milk production and optimum combination of dairy and crop enterprises in the tribal areas of north-eastern India found crossbred cow to be more cost-effective than its non-descript counterpart and buffaloes irrespective of the regional variations. The decomposition of cost of milk production revealed that feed costs were the most important component. The lower proportion of in milk to total milch cattle population for non descript cows were found to be responsible for higher costs of local cattle.

Sharma (1982) made an economic appraisal of ICDP project in Karnal, Haryana and found the cost of milk production to be highest in case of local cows across all categories of farm holdings (overall Rs.2.33 per litre) in comparison to crossbred or buffaloes. The overall cost of milk production was the lowest in case of crossbred cows at Rs.1.55 per litre followed by buffaloes at Rs.2.05 per litre in case of beneficiaries of the project. The share of components of costs was the highest in green fodder (33.2%) followed by human labour (28.39%), concentrates (20.25%) and dry fodder (15.05%).

Sharma and Singh (1984) found that the amount of labour per animal was higher on farms participating in a cattle development programme in Haryana, India, than on non-participating farms (av. 1.87 versus 1.42 man-hours/day), with labour time for feeding and transporting fodder being the

main items on participating farms and labour for grazing the main item on non-participating farms. On both the participating and non-participating farms, the amount of labour per cow and the amount of female labour decreased as farm size increased. Annual gross costs of keeping crossbred cows, local cows and buffaloes on participating farms averaged at Rs.3450, 2219 and 3201 per animal, respectively, and gross income averaged at Rs.3953, 1825 and 3318, respectively. Annual costs of keeping local cows and buffaloes, respectively, on non-participating farms averaged at Rs.1847 and 2950 per animal and income averaged Rs.1471 and 2907, respectively.

Gupta and Patel (1985) evaluated the profitability of investment in crossbred cows on a commercial scale, examined the effect of uncertainties on returns to investment and estimated the volume of employment generated by crossbred cows on the basis of time-series data covering the economic life or the main productive period of the animals. The data for the study were obtained from the 30-cows dairy demonstration unit of the National Dairy Research Institute, Karnal, for the period 1971-72 to 1978-79. Capital investment in a herd of crossbred cows on a commercial scale was found to be a highly lucrative proposition. The generation of employment in the dairy enterprise was also quite high.

Sharma and Singh (1985) in a study of landless, small and large farms in Haryana, showed that net cost of producing a litre of buffaloes' milk decreased with increase in size of land holding. Expenditure on green fodders and concentrates had a positive effect on milk yield in all categories; expenditure on dry fodder and human labour had a negative effect on milk yield in the landless category.

Kumar and Gupta (1988) in a study on cost of milk production in the Muzaffar Nagar district of Uttar Pradesh found that the overall cost of milk production tended to be highest in the landless farm households and small farmer groups (up to 2 ha) and lowest in the medium farmer groups among various producer categories classified as landless labourers, and small (less than 2 ha), lower medium (2.01-4 ha), upper medium (4.01-8 ha) and large

farmers (more than 8 ha). Since feeds and fodder costs accounted for the major part of the maintenance costs of all 3 types of animal, it was concluded that reducing the cost of animal feed would have a significant effect in reducing the cost of milk production.

Singh *et al.* (1990) in a study conducted at Haryana Agricultural University Farm, Hisar, based on records maintained from July 1984 to June 1987 found that mixed farming with crossbred cows was more economical than buffaloes under assured irrigation conditions with green fodder availability throughout the year. The cows and buffaloes showed mean annual milk yield of 4378 and 2009 litres, dry period of 43 and 88 days, calving interval of 408 and 420 days, and lactation period of 358 and 303 days, respectively.

Ram *et al.* (1993) conducted a study on the costs and returns of milk production from buffaloes in Saharanpur district of western Uttar Pradesh for 1987 from a sample of 195 landless labour, marginal and small farm households. Costs were found to be lower in the case of landless cattle owners and marginal farmers as compared to small farmers. Feeds and fodder were the major components of total costs (54%), followed by labour (15%). The profit margin showed that dairy farming is remunerative for the weaker sections of the population and may be further developed as a potential source of income and employment for the rural poor in the sugarcane growing regions of the country. The average maintenance cost and milk yield per day was found to be Rs.15.81 and 4.41 litres, respectively. The free availability of sugarcane tops contributed about 10 percent of total costs.

Kumar *et al.* (1994) in a 7-year study on various farming systems in Haryana, revealed that mixed farming of 3 crossbred cows on 1 ha of canal-irrigated land gave a higher economic return of Rs.21323 than Rs.9438 obtained from mixed farming with three Murrah buffaloes. Expenditure incurred on feed was observed to be the highest and accounted for more than 40 percent of the total cost followed by expenditure on labour among all the items in both the units. The expenditure pattern in the two systems indicated

that expenditure on feed was higher in the cow unit than the buffalo unit and more expenditure was recorded on labour in the buffalo unit as compared to the cow unit. Approximately 71.8 and 59.3 percent of income was obtained from the sale of cow milk and buffalo milk, respectively. The per litre cost of milk production was approximately double at Rs.5.29, in the buffalo unit as compared to Rs.2.74 in crossbred cows. These results revealed that for a small farmer with one-hectare land under canal-irrigated conditions in a semi-arid tract of Haryana, mixed farming with crossbred cows is more efficient in utilization of resources than buffaloes.

Gupta and Agarwal (1995) conducted a study on the economics of milk production of buffaloes, local cows and crossbred cows in Himachal Pradesh during 1993-94 based on the data obtained from 280 households of various size categories. Overall results for economics of buffalo, local cow and crossbred cow milk production respectively were found to be as follows: gross per day maintenance costs were Rs.24.25, 13.04 and 39, respectively; net maintenance costs (after subtracting income from dung), Rs.23.47, 12.54 and 25.53, respectively; milk yield was 4.01, 2.43 and 5.48 litres, respectively; milk production costs per litre were Rs.5.85, 5.20 and 4.58; and net returns per litre milk were Rs.1.15, 0.80 and 1.32, respectively. The net returns/litre crossbred cow milk ranged from Rs.1.78 in case of landless labourers to Re.0.84 earned by upper medium farmers. Lowest net returns of Re.0.75 and 0.78/litre were found in case of landless labourers for buffalo milk and by small farmers for local cow milk, respectively.

Kumar (1998) in his study on economic analysis of farming systems in the Mathura district of Uttar Pradesh found cost of maintaining buffaloes to be relatively higher on large farms as compared to small in all the farming systems identified in the region namely, sugarcane based, potato based and wheat mustard based farming systems.

Singh *et al.* (1998) conducted a study on buffalo milk production in Hisar and Kurukshetra districts, Haryana during 1994-95 based on 150 producer-sellers selected from three herd size groups. Net profit per day per

buffalo was observed to be lower due to high maintenance cost and low milk yield. Price of milk was found to be the most important factor influencing the volume of milk marketed.

2.3 EFFICIENCY STUDIES

Efficiency studies have been carried out with two approaches: deterministic input resource use efficiency; stochastic frontier approach of efficiency measurement. Some studies have also used the deterministic approaches of data envelopment analysis method and total factor productivity indices methods to determine efficiencies and productivity of the firm. But these methods require accurate and data on a number of sensitive factors and have been mostly attempted under organized conditions in mostly developed countries where data is more easily available. For rural and subsistence farming conditions as in India, stochastic frontier approaches are found to be better alternatives for efficiency estimation.

The following review analyzes the development of efficiency estimation using both the approaches. Some salient features with reference to efficiency of milk production in India and its factors are also highlighted.

2.3.1 Deterministic Input Resource Use Efficiency

Rai and Gangwar (1975) analyzed resource-use efficiency and cost of buffalo milk production in Haryana using data collected from 51 farms in the Hisar district of Haryana. Of these, 41 had small, 5 had medium and 4 had large herds. Efficiency of utilization of concentrate, roughage and labour was studied; of these input factors, concentrate feeding had the most significant effect on milk yield on all farms in all seasons.

Gangadharan (1978) in his study on the feed-milk relationship relationships in cattle in Kerala found that for milk production, feed resources were not employed efficiently by dairymen in the study area. He suggested that cultivation of nutritious fodder and improving the nutrient status of available roughages (like paddy straw) and concentrates should urgently precede any program for state-wide adoption of crossbreeding technology.

Pandey and Kumar (1981) determined economic efficiency of feed resources in milk production under mixed farming systems using data on fodder production and milk yield collected from farms associated with three project centres in Aligarh and Bulandshahar districts of Uttar Pradesh, and encompassed 332 buffaloes classified as low-, medium- and high-yielding (less than 4, 4-5 and more than 5 litres/day) and 10 crossbred cows. Cobb-Douglas production functions relating intake of green and dried roughages and concentrates (standardized according to TDN content) explained 57-59 percent of the variation in milk yield of buffaloes and 93 percent of that in the milk yield of cows. The results indicated that green roughages were more economic feeds than dry roughages, and that in the absence of any budget restraint the concentrate allowances could be increased for crossbred cows and high-yielding buffaloes, and decreased for medium- and low-yielding buffaloes.

Kumar (1994) conducted a study on technological change and factor shares in milk production and found the factor input demands to be inelastic with respect to price. He found a greater scope for substitution of concentrates by green fodder in case of local cows and buffaloes, while it was possible only at lower levels of milk production in case of crossbred cows. The technical change was found to be concentrate input using and green fodder, dry fodder and labour saving. Decomposition analysis revealed the magnitude of total change in milk output due to change from local cow to crossbred cow to be 155.8 percent of which share of technical change to total output change was 47.55 percent and that of resource input technological change at 109.15 percent. The change from buffalo to crossbred cow showed the quantum of total change in milk output due to adoption of new technology to be 33.13 percent. The share of technical change was 8.21 percent and that of input change was 24.92 percent. For both these changes in technology, the highest share was attributed to concentrates followed by labour and green fodder. The contribution of dry fodder was negative in both the groups. Thus, he concluded that balanced ration and genetic development through crossbreeding were important accelerators of output growth in milk production in the study area.

Singh *et al.* (1995) in a study on the basis of expenditure and income of 400 dairy farm families from 15 villages in the Kurukshetra and Karnal Districts of Haryana, India, over three seasons during 1991-93 determined the economic efficiency of milk production systems. The overall economic efficiency was found to be 3.45 percent, but for Kurukshetra, it was lower (1.02%) compared with 5.75 percent for Karnal. Economic efficiency estimates were found to be negative for the landless and marginal categories.

Saxena *et al.* (1998) analyzed the resource use efficiency of two mixed farming systems namely mixed farming with three crossbred cows and with three Murrah buffaloes each on 1 ha canal irrigated land in the research farm of the Department of Agronomy, CCS Haryana Agricultural University, Hisar. The study revealed that although there had been a degree of resource use inefficiency, the net income from the system with three crossbred cows was higher than that from the system with three buffaloes. The study also suggested that there is much scope for increasing the profitability of these systems by optimizing use of green and dry fodder in proportion with concentrates.

2.3.2 Stochastic Frontier Approach of Efficiency Estimation

Most of the functional analysis have considered ordinary least square modeling (OLS) which implicitly considers all farms to be efficient and variations only due to random uncontrollable factors and thus could suggest only significance or reallocation of resources to improve the output. A brief review of the functional analysis enables to throw light on the inherent limitations of this method and the developments in functional analysis of milk production under Indian conditions:

2.3.2.1 Study on functional analysis of milk production

A large number of studies have been conducted to estimate the milk production relationships using different production functions for different types of milch animals and for farms.

a) At enterprise level

Linear production functions were used to estimate milk production of cows and / or buffaloes in studies conducted by Bhattacharjee (1955), Dhondyal and Singh (1955), Agarwal *et al.* (1974), Ready *et al.* (1978) and Sharma (1982). Linear, Semi-log and / or log-linear models were used by Rao (1978), Patel *et al.* (1982) and Agarwal *et al.* (1989) on crossbred cattle or local cattle and / or Buffaloes. A few studies have been carried out using quadratic production functions on specific breeds of cattle (Thari cows) and crossbreds by Jacob *et al.* (1959) and Bajpai *et al.* (1983), respectively. In a number of studies, linear, Cobb-Douglas and quadratic models were fitted on local / crossbred cattle and / or buffaloes and linear model was found to be the best fit such as by Aul *et al.* (1974), Patel *et al.* (1975), Bodkhe (1982). The Cobb-Douglas production function as the sole model or in combination with linear and / or quadratic models for milk production by crossbreds and / or locals and /or buffaloes and /or specific breeds of cattle / buffaloes was used by Singh (1970), Jacob *et al.* (1971), Kumar and Raut (1971), Dass and Sidhu (1973), Kumar *et al.* (1973), Aul *et al.* (1974), Chikkara and Gangwar (1975), Kumar *et al.* (1975), Sankhayan and Joshi (1975), Ram (1977), Singh (1977), Rao (1978), Pandey *et al.* (1980), Bodkhe (1982), Kumar (1991) and Rajendran and Prabharan (1993).

Chander *et al.* (1999) in a study of the major determinants of milk production conducted in the Jaipur district of Rajasthan during 1994-95 found that Green fodder and concentrates were the important inputs that determined milk yield in the villages. It was concluded that it would be possible to increase milk yield by feeding more green fodder and concentrates to the animals. The Cobb-Douglas form of production function was used. Dry fodder had no significant effect on milk yield of indigenous cows, Friesian and Jersey crossbreds and buffaloes in both villages.

Parekh (2001) reported the factors affecting milk production as age of the cow, calving interval, dry period, season of calving and system of management, frequency of milking, age at calving, age at maturity, age at first

calving. Standardization of records maintained relating to lactation length, frequency of milking, age and month of calving, days dry and days open, milk composition and herd standardization are necessary for any kind of evaluation of the economic performance of milk production / dairy herds.

Most of the studies on specific milch animals have concluded that proper feed allocation, and that feeds and fodder are the most important inputs in milk production in milch animals. Some studies have stressed on optimal utilization of labour or labour reduction and management input. The importance of herd size, lactation stage and order of lactation were also significant in some studies.

Dairying at the household level cannot be evaluated in isolation at enterprise level. The studies depicted above have analyzed for resource use for different types of milch animals separately, but investigations at farm level reveal that the effect of herd composition is as important as herd size. Hence, resource use efficiency at farm level should consider standardization of different enterprises to enable comparison of different farms.

b) Studies at farm level

Studies on milk production at the farm level using production function analysis were conducted by Heady *et al.* (1954), Singh (1955), Sankhayan and Miglani (1973), Kumar *et al.* (1974), Singh and Jha (1975), Chamak (1980), Handique (1981), Pandey and Kumar (1981), Rao (1987), Sharma and Rajpali (1989). These studies have shown constant, increasing or decreasing returns to scale under different situations.

Kumar *et al.* (1975) examined the relative importance of various inputs in milk production according to order of lactation for the Haryana breed of cattle maintained under village management. By using data from a survey conducted by the Indian Agricultural Statistics Research Institute, New Delhi during 1953-55, a Cobb-Douglas milk production function was fitted on per milch animal basis for a sample of 105 Haryana breeds. Inequalities in milk production pattern for cows under different lactations were studied using a Lorenz Curve and a concentration ratio was estimated. Feed, depreciation

and miscellaneous expenditure items were found to have a positive and significant impact on milk production. The elasticity of production was highest for feed, which was the major factor influencing milk yield. The production elasticity of feed was elastic for the third (1.45) and fourth (1.28) lactation cows whereas it was inelastic for the first (0.57) and second (0.51) lactations. The inequalities in milk production pattern were observed for cows in each order of lactation.

Singh and Jha (1975) in their study titled "Economic optima in milk production" used multiple regression analysis showed high association between the inputs considered and milk output. The importance of better care and management of livestock was highlighted by the very high marginal value product of labour input. A significant scope existed for raising milk production by readjustment of the feed inputs in the summer and rainy seasons.

Pandey *et al.* (1980) developed milk production functions for understanding variations in milk yield in the Bundelkhand region of Uttar Pradesh. Multistage stratified sampling design was used in selection of 120 farming households with at least one dairy cow or buffalo. Data on feed, milk output, lactation and season were analyzed to establish input-output relationships. Dairy input (fodder, concentrates, labour and other cash expenditure) and lactation were found to be responsible for 40 to 85 percent of the variation in milk yield. Fodder was found to be the most significant production factor, followed by concentrates. Manipulation of feed levels had relatively more effect on milk yield in the rainy season for cows than in the winter season for buffaloes. It is recommended that dairy farmers should be educated on the rational use of feed, labour, etc.

Sharma (1984) conducted an economic study of crossbred cattle in Bangalore using feed milk response function. The most important significant factors affecting milk production positively in order were found to be management index, concentrates, family labour, dry fodder, green fodder, herd size and value of animal in case of small farm category. Stage of lactation had a negative significant impact at one percent level across all categories of herd size. He concluded from his study that the scale of

operation of dairy enterprise had a positive and significant impact on productivity, whereas feed conversion efficiency, labour utilization and returns over feed costs had negative impact on cost of milk production.

Shah (1991) conducted a study on milk production and supply in Bullandshahr district of Uttar Pradesh. Cobb-Douglas production function for Murrah buffaloes for different herd size categories in the two areas were fitted. The function explained 45 to 77 percent of the variation of milk yield and was significant at one percent. Among the feed inputs, expenditure on concentrates was observed to influence the milk production at one percent level of significance.

Kairon *et al.* (1995) in a study carried out in the operational area of the Ambala-Kurukshetra Regional Rural Bank revealed through regression analysis, concentrates to be the most important input affecting milk production. The optimization of resources with existing capital indicated that it should be possible to increase milk output by diverting a part of funds from green fodder and human labour to concentrates.

2.3.2.2 Frontier approach to efficiency estimation

To separate the random factors from the factors controlling efficiency, the approach of analysis needs to be different namely frontier approach. Before 1971, deterministic production function was used to determine efficiency estimates of firm. But Timmer (1971) cast doubts on such techniques and stochastic production function based on composed error model of Aigner *et al.* (1977), Meusen and Van der Broeck (1977), Jondrow *et al.* (1982) and Devlin *et al.* (1994) brought about stochasticity of frontier models.

A number of studies attempted to measure some or all of the inputs and outputs of the sector but failed to combine these into a satisfactory measure of efficiency. Efficiency was generally believed to be directly correlated with average productivity of labour in industry, of land in agriculture and of animal in dairying. Attempt to construct indices of efficiency in which weighted average of inputs is compared with output failed due to usual index number problems.

The current interest in efficiency measurement finds its origin in Farrell (1957) who introduced the concept of the production frontier. Among the alternative methods proposed for the estimation of stochastic frontier models (and the subsequent measurement of technical efficiency), the stochastic decomposition methodology has gained popularity among researchers because it offers an explanation of technical efficiency based on economic theory. In this framework, each farm faces its own frontier rather than a sample norm (Aigner *et al.*, 1977). Ever since then, considerable progress has been made towards refining the production frontier methodology (Battese, 1992; Bravo-Ureta and Pinheiro, 1993).

Farrell (1957) developed the production (cost) frontier – a deterministic cost frontier – by using linear programming requiring all observations to lie on or above the frontier. Farm efficiency has been measured in terms of technical efficiency, allocative efficiency and economic efficiency. Technical efficiency is the ability of a firm to achieve the maximum possible output (minimum average cost) with available resources (given level of output). Allocative efficiency refers to the ability of a firm to contrive an optimum allocation of given resources. Economic efficiency is product of technical and allocative efficiencies.

Aigner and Chu (1958) criticized least squares techniques allowing positive residuals in frontier production function estimation and recommended linear and quadratic programming techniques which minimize the sum of absolute residuals and sum of squared residuals, respectively, subject to the constraint that all residuals be negative. Thus, coefficient of non-parametric frontier function could be estimated, which, however, could not be subjected to further statistical treatments.

The stochastic frontier function analysis started with Schmidt (1975) who criticized non-parametric estimation procedure due to non-statistical properties of estimators. He suggested use of Ordinary least Squares (OLS) if one is concerned with only the parameters to test for returns to scale. However, if the constant term is of intrinsic importance or if the frontier is to be estimated, maximum likelihood method is suitable.

Aigner *et al.* (1977) refined the stochastic frontier concept with a more appropriate specification defining the disturbance term as the sum of symmetric normal and (negative) half-normal random variables.

Following Aigner, a number of studies on the lines of stochastic frontier approach were conducted by Just and Pope (1978); Schmidt and Lovell (1979) considering duality between cost and production frontiers; Forsund and Hjalmarsson (1979) on Homothetic frontier production functions; Forsund *et al.* (1980); Greene (1980a); Stevenson (1980); Olson *et al.* (1980) in a comparative study of estimators of Corrected Ordinary Least Squares (COLS), a two step Newton-Raphson method (2 STEP) and maximum likelihood method found 2 STEP method disappointing as well as COLS for sample size below 400 and λ less than 3.15; Broeck *et al.* (1980) on a comparison of the deterministic and stochastic approach of frontier production function found the latter more stable and less sensitive to removal of a frontier unit; Greene (1980b) used a flexible functional form such as translog or generalized quadratic functional form; Schmidt and Lovell (1980) on a model which allows for correlated technical and allocative inefficiencies; Kopp and Smith (1980) and Wagstaff (1989) found non significant differences between different frontier estimation models.

A few studies on economic efficiency have been conducted using dummy variable technique as by Bagi (1981) who studied the relationship between farm size and economic efficiency on irrigated, partially irrigated and dry farms in Haryana. Intercept differential were found to be negative signifying higher technical efficiency of small farms. The studies conducted by Herdt and Mandie (1981); Kalirajan and Flinn (1983); Lingard *et al.* (1983); and Dawson and Lingard (1989) in Philliphines using dummy variable technique found positive relationship between efficiency and various management variables such as farmers' experience, information, education and extension contact and 25-50 percent inefficiency in rice production.

Makary and Rees (1981) introduced index of management efficiency as a variable in the production function of cotton for five geographical regions.

Distinct differences in scope for improving management efficiency between regions were found.

Jondrow *et al.* (1982) solved the technical specification problem of stochastic frontier model in separating the v and u components of error term by considering the expected value of u , conditional on $(v-u)$.

Improvements on the iterative algorithm of Fair's (1977) were given by Lee (1983). Different methods were compared and the Newton's method was found to be more time saving than these algorithms.

Ray (1985) utilizing linear programming approach in farm efficiency studies, decomposed overall efficiency into output and informational efficiency. Output efficiency was found to be very less, whereas information efficiency was very high for small size of farm.

Ekanayake and Jayasuriya (1987) applied frontier approaches to farm data from Sri Lanka and stated that deterministic methods tend to yield biased estimates of technical efficiency and to over estimate the variability of technical efficiency over time.

Battese and Coelli (1988) estimated a stochastic frontier production function for the analysis of three-year data for dairy farms in Australia. The results enabled to obtain the best predictor for the firm-effect random variable, which is time-invariant, and have a general truncated normal distribution. The differences between the traditional symmetric random errors and this non-negative random variable gave the disturbances associated with observations for a given firm, and the appropriate technical efficiency of an individual firm.

Roest (1990) in his study utilized reallocation of production factors and improving technical efficiency as methods to improve profitability of dairy farms. Bravo and Rieger (1990) studied different production frontier models and found that frontier functions are upwardly scaled versions of the ordinary least squares or average model. Secondly he concluded that though different models give different efficiency results, the correlation between the indexes from the various methods was high, which implied that ordinal ranking of farms according to their measured level of technical efficiency appeared to be

independent of the method used for a given year. Also correlation between efficiency and farm size or returns over variable costs yielded consistent results.

Cloutier and Rowley (1993) used a relatively newer technique, the Data Envelopment Analysis (DEA) to explain the distribution of productive efficiency across some Quebec dairy farms in 1988 and 1989. Sensitivity checks were made with respect to sample size and herd size. Overall efficiency scores from the DEA approach were reasonably informative but some troublesome issues need to be resolved.

Thomas and Tauer (1994) showed that input aggregation could bias empirical measures of technical efficiency through non-parametric estimation downwards. The source for this downward bias is allocative efficiency. Hence, estimated technical efficiencies actually combined technical and allocative efficiencies. For this reason, measured efficiencies may still retain value as a measure of economic efficiency; however, they are not strictly technical efficiencies.

Arias *et al.* (1993) tried to analyze the efficiency of 112 Spanish dairy farms using stochastic production frontier model and the fixed assets model. Both the models gave consistent results of ranking the farms in terms of the efficiency index. Use of Farrell's index indicated that management improvement could help the farms below their potential efficiency to improve but production factors were highly heterogeneous and hence a fall in the significance of factors.

Decomposing the technical inefficiency component into the persistent and residual component was first done by Kumbhakar and Heshmati (1995a) in a study on Swedish dairy farms during 1975-88 using rotational panel data. The advantage of this method was the robustness of parameter estimates to distributional assumptions on the error components.

Hallam and Machado (1995) measured the technical efficiency of Portuguese dairy farms using frontier production functions estimated from panel data. Alternative estimators were compared and evaluated. The results

suggested an average efficiency of 50 to 70 percent. The relationship between efficiency and farm characteristics was explored. Efficiency appeared to be positively correlated with farm size but independent of degree of specialization.

Parikh and Shah (1995) also studied the technical efficiency of 397 farms in north west frontier province in Pakistan using cross section data and compared non parametric, parametric, deterministic and frontier methods. Socio-economic and demographic variables such as credit, age, education, and assets had a significant contribution to improve efficiency positively.

Srivastava (1995) used deterministic frontier production functions to study efficiency of dairy farms in India by fitting different functions separately for best practiced and poorly managed farms. He found that there existed a potential of increasing productivity to the extent of 82, 45, 14, 11 and 23 percent, respectively, on cow, buffalo, cow mix and buffalo mix and overall mix technology farms. The causative factors responsible for the gaps were suggested as technological efficiency and differences in input use. The percentage contribution of these two factors on corresponding group of the farms were 44 and 37, 28 and 17, 11 and 3, 19 and -9, and 14 and 9, respectively higher on cow farms.

Chand (1998) analyzed the technical, allocative and economic efficiencies of commercial dairy farms of different herd sizes (1-20; 21-37 and more than 38) using deterministic frontier production function. The technical efficiency at the average level of input use was 92, 91 and 93 percent on small, medium and large categories of dairy herds, respectively, indicating that there existed a potential of 8,9 and 7 percent to increase milk production and returns without incurring any extra expenditure in respective categories. The distribution of dairy herds according to the technical efficiency revealed that there is a possibility of increasing the milk yield by 20,15 and 10 percent on 5, 22 and 35 percent of the dairy herds, respectively. The decomposition analysis carried out between most efficient and average production function

revealed that the contribution of the technical efficiency and input use to overall productivity gap for small, medium and large categories of dairy herds was 8 and –5, 10 and 5 and 7 and 2, respectively.

Reinard *et al.* (1999) estimated environmental efficiency of Dutch dairy farms, where the environmental inefficiency is defined via the amount of nitrogen overused in the production process relative to a required technological minimum.

Paul (2000) stated that issues of productivity and efficiency fundamentally boil down to a comparison of costs and benefits. In the production context these concepts can be framed in terms of the resource or input costs of producing the benefits deriving from commodities, or output. Implementation of this basic notion is much more complex than it sounds, of course, since production costs and benefits – or the prices and quantities of inputs and outputs – must be very carefully measured both to capture the actual economic values of marketed factors or commodities, and to recognize non-marketed values. It also requires characterizing various internal and external aspects of the production structure that affect the relationship of costs and outputs, such as production rigidities, cost economies (from, say, scale and scope), and spillovers. It is not easy to develop the model and measure the impacts of these real-world production characteristics for generating interpretable and useful measures of productivity and performance.

Saha and Hemme (2003) estimated the technical efficiency of 68 dairy farms from 26 countries using stochastic Cobb-Douglas frontier production functional analysis and found that the efficiency for the dairy farms in New Zealand, Australia were the most efficient and cost competitive. The commercial farms in India were cost competitive but not highly technical efficient.

The empirical literature has mainly focused either on the measurement of farm technical efficiency (Dawson *et al.*, 1991; Bravo-Ureta and Evenson, 1994), or on the effect of technological change on output growth (Blayney and

Mittelhammer, 1990; Kumbhakar and Heshmati, 1995b). Studies reporting such decomposition for agriculture include Fan (1991), Ahmad and Bravo-Ureta (1995) and Wu (1995). However, the above studies utilized a Cobb-Douglas form, with the exception of Fan, who used a strongly separable translog production function. Furthermore, various effects explaining output growth were estimated in a residual base. Fan utilized a flexible translog functional form to represent the underlying technology, while a single time trend was used to capture the effect of technological changes. In addition, none of the effects explaining output growth were estimated in a residual base. These effects constituted an unexplained portion of output growth accounting for sub-equilibrium effects associated with the existence of quasi-fixed inputs and capacity under-utilization, learning-by-doing effects, cost of adjustments etc.

Previous studies, which have tested for links between farm size and efficiency, have produced conflicting results. Whilst Lau and Yotopoulos (1973) and Trosper (1978) found evidence that small farms are the most efficient, Nehring *et al.* (1989), Bravo-Ureta and Rieger (1990) and Kumbhakar (1993) arrived at the opposite conclusion. Then, Byrnes *et al.* (1987) and Lund and Hill (1979) suggested that medium sizes farms are the most efficient, while Bagi (1982), Bagi and Huang (1983), Bravo-Ureta (1985) and Moussa and Jones (1991) were unable to establish any significant relationship between farm size and efficiency. Lack of consensus is perhaps unsurprising given that the studies were conducted with data from different countries and regions and reflect different production systems. Most of the studies focused on one particular commodity type of farm, and it is feasible that results could differ even within one region for different farm types. It may be inappropriate to generalize results too widely. Differences may also be explained by the use of different methodologies for measuring efficiency. Most studies were based on Farrell-type measures of technical efficiency (Farrell, 1957) relating to production frontiers, but others adopted a profit function or cost function approach. Even within production frontier studies, a variety of

methodologies were employed. Bravo-Ureta and Rieger (1990) found that when four types of frontier methodology were applied to the same data, this resulted in markedly different efficiency levels between farms, however, it did not lead to any significant difference in the ordinal ranking of farms.

Thus, it may be concluded that not much work has been done in India on estimation of efficiency of milk production using stochastic frontier concepts. Further, the methodology on frontier analysis is still developing and the debate is on the best means of efficiency determination. Since the relation between herd size and productivity in case of dairy farms is still not clear is evident from the review above, hence, constant returns to scale was assumed for the following study.

2.4 OPTIMAL FARM PLANNING

At the micro level, different approaches to farm household modeling have been developed which can assist in understanding and structuring an adoption choice: these include models based on adaptive behaviour theory, production theory and technical functioning. There is a wide range of techniques for modeling the farm household and evaluating various land use options against a number of technical, financial, economic and social criteria. Farm planning techniques have started with the simple budgeting to complex multiple objective fuzzy and stochastic dynamic programming techniques. However, under Indian conditions, optimal farm planning has been mostly limited to use of linear programming and some studies with quadratic programming. For more realistic farm planning, incorporation of risk and uncertainty has seen development of MOTAD and target MOTAD. The present review covers the development in farm planning techniques under the following heads:

- Linear programming
- Risk and uncertainty in farm planning
- Multi objective optimization

2.4.1 Linear Programming

Deterministic linear programming technique has been used frequently to bring out most profitable enterprise mix, income and employment potential, credit requirements, etcetera at the farm level.

Gangwar and Bhatia (1980) highlighting the high returns of crossbred cows stated that in Haryana in 1978, average net income/lactation from Murrah buffaloes, crossbred cows and Haryana cows was Rs.257.01, 757.92 and 85.12, respectively, with average daily milk yields of 4.89, 7.05 and 2.5 litres and per litre costs of Rs.1.57, 1.25 and 1.75, respectively. These figures show the economic advantages of crossbred cows. A linear programming study of 35 marginal farms (less than 1 ha) and 24 small farms (1-2.2 ha) in Karnal district revealed that at improved levels of technology marginal farms could raise their net income from Rs.2850 to 8090.92 by adopting the optimal combination of 2 crossbred cows, 0.18 ha jowar fodder, 0.55 ha paddy, 0.51 ha wheat and 0.12 ha berseem, whereas small farms could increase their income from Rs.7259.14 to 17 582 by using the combination of 5 crossbred cows, 1.12 ha jowar fodder, 0.03 ha paddy, 0.15 ha wheat, 1 ha berseem and 1.58 ha sugarcane. At existing technology levels, optimal crop combinations with buffaloes (2 on marginal farms and 5 on small farms) would also increase income substantially (to Rs3940.25 and Rs12 203.30, respectively). All these combinations would require borrowed capital of Rs788.51 and 5491.35. Without borrowed capital optimization gave much smaller increases in income and at improved levels of technology the optimal combinations did not include livestock at all. In view of these findings, the need to increase credit facilities and encouraged use of crossbred cows was emphasized. They concluded that local cows could not compete at all even with existing level of technology. With improved technology, buffaloes could not compete with crop production even if credit was available

Pandey and Bhogal (1980) attempted to determine how much farm income and employment could be increased on typical farms from the optimal crop and milk production plans derived by using the common and improved technologies. The results were obtained by making use of farm business

records of 124 farmers comprising of 30 small (below 1.0 ha.), 50 medium (1 to 3 ha) and 34 large (above 3 ha), from a cluster of five villages in Aligarh district of Uttar Pradesh, India over the period of 1974-75. The profit maximization type of linear programming model was used to derive the optimal farm plans. Farm income and employment could be raised by 158 and 79 percent, 125 and 107 percent and 70 and 58 percent on the small, medium and large farms over the base period (1974-75) using common and improved processes. For dairy enterprises, fodder was difficult to obtain on small farms whereas human labour was the major limiting factor on the large farms. The medium size mixed farms enjoyed a comparative advantage over the small and large ones. The large-scale adoption of improved crop production technology on the typical mixed farms complemented the milk production processes through increased availability of crop by-products enabling them to maintain more milch animals.

Singh and Saini (1980) described how improved crop and milk production practices can play an important role in providing employment and reasonable incomes for rural people in India, and may dissuade them from migrating to the cities. This article describes the difference that scientific breeding and feeding of cattle and improved crop production practices have made to the incomes of farmers in six villages in Karnal district, Haryana State.

Bhatia and Gangwar (1981) applied an optimization model to data from small farms (less than 2.2 ha) collected from 8 villages in Karnal district. The results showed that net returns could be improved by 3 to 10 percent by reorganizing existing resources and could be increased by 25 to 50 percent if improved technology and a different cropping pattern were used. Local Haryana cows could not compete economically with buffaloes under existing technology, and optimization plans called for 1-2 buffaloes/farm. Buffaloes could not compete with crossbred cows under improved technology. Although the optimization plan did not allow for cows (except for 1 cow on unirrigated farms of 1-2.19 ha) yet the value of milch animals in providing regular income was emphasized.

Pandey *et al.* (1982) analyzed data from 55 farms in which crop production (wheat, cotton, bajra, sugarcane, etc.) was combined with dairy enterprises using a variable price programming technique to determine optimum livestock/crop production plans. The analysis showed that dairy buffaloes were not profitable unless the price of buffalo milk was at least Rs2.00/kg. When the price of buffalo milk was increased from this minimum level to Rs3.25/kg, the number of buffaloes in the optimum plan increased from 3 to 31, accompanied by increase in farm income and the need for credit, hired labour, bhusa and concentrates. Cows were not economic at any of the cow milk prices in the range studied (Rs0.75-2.25/kg).

Rai and Singh (1982) used linear programming methods to examine the income and employment effects of new crop production techniques with livestock in the dry farming areas of Haryana. The findings of the study revealed the scope for increasing farm employment and incomes by integrating the livestock enterprise with crop farming and by adoption of the new dry land agricultural production techniques. It also showed that the livestock enterprise is more labour intensive and needs to be further extended through an intensive development programme.

Saini (1982) in a study on optimum allocation and normative milk supply functions for Patiala district, Punjab found that the marginal value productivity of land had a decreasing trend with farm size. Thus, land was the constraining resource for the marginal and small farms. Hence, a policy of allowing renting of land by these farmers from the larger farms could increase their farm income and maximize the total productivity of land in the study area. The marginal value productivity of human labour was zero in almost all crop periods in marginal and small farmers particularly in the optimum plans developed with owned funds. This showed that available labour force on these farms was more than required and it would be advantageous if off farm employment opportunities could be generated in the area to provide employment for these farmers. He suggested that the farmers could solve the problem of short-term credit needs with introduction of milch animals in their

farm business. However, the urgent need to finance the farmers with adequate and timely medium term loans for the purchase of high yielding milch animals and other requisite of dairy enterprises was stressed.

Sharma (1982) in an economic appraisal of ICDP project in Karnal, Haryana found marginal value product of human labour to be higher than its price in almost all seasons on medium and large categories of cattle holdings. This suggested that there was enough opportunity of increasing returns by using more of human labour on these cattle holdings.

Sardana and Panghal (1984) using a linear programming model applied to data from small and marginal farmers in Bhiwani district of India showed that the introduction of 2 rather than 1 buffalo for milk and draught use and the use of improved technology could considerably improve income and increase employment. They used linear programming in farm planning and concluded that reallocation of existing resources even at existing technology could increase income and employment in small farms.

Vijayalakshmi (1985) conducted a study on optimum crop and livestock decisions under uncertainty in Bangalore district, Karnataka found land to be the unique and biggest constraint in enhancing the income of farmers even with improved technological inputs. He said that dairying with crossbred cows as advanced technology was not size neutral. To make dairying with crossbred cows profitable, he suggested provision of subsidized or cheap feed inputs that meet minimum nutritional requirements through development of fodder farm and rationing of fodder to the small land owners undertaking dairying.

Singh and Sharma (1987) developed farm plan models using linear programming and stated increased income and employment in small farms of mid-western U.P. under different farming systems. Maximum potential existed in crop-dairy-goat farming. A purely crop farming system proved to be the poorest choice in terms of income and employment generation.

Singh (1988) formulated optimum crop milk plan for different holding size groups in Meerut district of U.P. The profit maximization model of linear programming technique with extension to mixed integer programming and

variable price programming was used for developing optimal crop and dairy plans on different categories of farms. Under existing conditions, the number of milch animals suggested varied from two buffaloes on marginal farms to two buffaloes and fourteen crossbred cows on large farms. Under improved technology, the optimal number of milch animals suggested in the optimal plan were one buffalo and one crossbred cow in marginal farm to three buffaloes and twelve crossbred cows on large farms. Reallocation of fixed farm resources in mixed farming had a positive effect on income, employment and milk production on all synthetic farm situations.

Singh and Saini (1988) investigated the optimal level of integration of crop enterprises and milk production for farms in Patiala District of Punjab using a mixed integer-programming model. Four optimal farm plans were developed, comprising the combinations of existing and improved technology with and without a dairy enterprise. Dairying was found to be a feasible, labour intensive enterprise, which could be incorporated into existing production systems.

Deoghare *et al.* (1990) assessed the impact of mixed farming activities of livestock and poultry rearing on the marginal and small farms in Karnal district by using a linear programming technique for four categories of mixed farms namely crop, crop-dairy, crop-poultry and crop-dairy-poultry, at existing and recommended levels of technology adoption. The data was collected from 50 randomly selected farms for the year 1985-86 classified into bullock-operated and tractor-operated farms. Under conditions of liberal credit all four systems displayed better results with and without the use of recommended technology. Crop-dairy-poultry farming, however, appeared to have been most successful, raising per capita income by up to 32 percent on bullock-operated farms and up to 58 percent on tractor-operated farms. Human-labour employment rose from 4 to 140 percent as a result of the system on bullock-operated farms while tractor-operated farms experienced a relatively lower level of employment generation of about 104 percent. It was concluded that mixed farming yields promising prospects for income and employment generation among farmers who are poorly endowed with natural resources.

Deoghare and Sharma (1992) investigated the optimum cropping pattern and livestock combination at varying capital levels, both at existing and improved levels of technology, in the Karnal district of Haryana state. A mixed linear programming technique was used to estimate and optimize net returns from different crops and dairy and poultry produce, in order to assess the impact of credit and technology on income and on-farm employment generation. The results indicated that if farm incomes are to significantly improve, there is a need for a liberal credit policy in rural areas, to enable small and marginal farmers to best utilize existing resources and to move towards recommended levels of inputs.

Patil *et al.* (1993) in their study on designing new farming systems for conditions representative of the rain-fed farming around Baroda in Gujarat observed that the mixed farming system is more rewarding than the system of cash crops only, provided that the animal productivity is adjusted to the feed quality, so as to be able to utilize the available feed biomass. The use of urea-treated straw or stover or supplementary concentrates resulted in increased milk production, especially in highly productive cows.

Thus, it can be concluded that various studies stressed on the necessity for crop-livestock integration for optimum returns and employment. However, in these studies except Saini (1982) have not stressed on the role of non-farm employment in meeting working capital needs of farm households, which is a significant lacuna, which needs to be overcome.

2.4.2 Risk in Farm Planning

Freund (1955) made the first application of active stochastic programming to farm management. He introduced risk into a programming model of a farm by describing risky outcomes as probability distributions and choosing from among alternative possible distributions by the expected utility hypothesis.

Hazell developed a technique leading to a linear programming problem, which incorporates the mean absolute deviation in place of variance as the measure of risk (Hazell, 1971a,b; Chen 1971). This is generally referred to as MOTAD – minimization of total absolute deviations.

Hazell (1971b) developed an approach for minimization of total absolute deviation (MOTAD), which can be solved using a linear programming algorithm, but gave results similar to those of quadratic programming. This approach has been used successfully at both farm and regional planning by Nieuwoult *et al.* (1975); Brink and McCarl (1978); Schuzle and Bernard (1979); Hazell (1982) and Rodriguez and Anderson (1988).

Some of the drawbacks of the MOTAD models such as non-compliance to the criteria of stochastic dominance theory were overcome by Tauer (1983) while proposing the Target MOTAD model. This model measured risk as deviation from target unlike mean in MOTAD model. The Target MOTAD model generated solution comprising of stochastically efficient mixture of risky alternatives. Target MOTAD has been used in farm planning by Zimet and Sprean (1987); Novak *et al.* (1990) and Parton and Cumming (1990).

Dairy has contributed to increased farm income and stability in terms of returns has been shown in the studies conducted on deriving optimal farm planning done by Mruthyunjaya (1975); Bhowmick (1982); Singh and Jain (1983); Vijayalakshmi (1985) and Sharma *et al.* (1990).

However, all these approaches seem to bear in mind a single objective function, which combines both objectives of total gross margin or profit maximization and of risk minimization. To apply these approaches to the linear goal-programming model, it is desirable to modify them appropriately. Romero and Rehman (1985) showed how the MOTAD approach (along with its main variant, target MOTAD) could be incorporated within the MCDM (multiple criteria decision making) framework.

2.4.3 Multicriteria Optimization

Thus, most of the multicriteria problems analyzed till now in the area of agriculture can be grouped under four headings: 1) interaction of economic and environmental goals; 2) planning in a macro perspective; 3) planning in a micro perspective and 4) linking of the macro and micro perspectives to solve on-farm and regional problems.

At the micro level, some of the examples of farm planning done by using multi-objective optimization are shown in Table 2.1.

Barnett *et al.* (1982) developed a methodology to estimate empirically the weights for a multiple objective function of Senegalese subsistence farmers. The methodology included a farmer oriented goal preference survey and an application of multidimensional scaling technique to the survey data.

Soon (1983) developed a linear goal programming model for the semi-subsistence farmers so as to reflect the farming concerns of farmers more realistically. The goals considered were: expected total gross margin, survival, financial self-support and leisure.

Sankhayan (1988) developed optimum cropping plans for a typical Punjab farm with multiple objectives by using compromise programming. A set of compromise farm plans assigning different weights to the different objectives were generated through this technique. In this model, seven crop productivity activities, a labour hiring activity in each of the four periods, a capital transfer activity from *kharif* to *rabi* season, capital borrowing activities for *kharif* and *rabi* season and eight human labour deviational activities were considered. This could give more freedom to the farmers to choose an optimum farm plan in the light of the weights that he wishes to assign to different objectives. The plan through this method showed a gross margin of Rs.53288.14 against Rs.52553 through his existing farm plan.

Pertiwi *et al.* (1992) used six criteria namely working hours of labour, farm work plan stability, initial cost of machinery, operation cost, technological and managerial considerations to reflect the priorities of the decision maker.

Mawapanga and Debartin (1995) in a study on choosing farming system using Analytic Hierarchy Process (AHP) found health concerns to receive the highest rank followed by profit maximization, sustainability and concern for the environment in selecting between a conventional farming system, an organic farming system and a biological farming system.

Under Indian conditions, Pal and Basu (1995) showed how a priority-based goal-programming model could be used for land use planning of the

Table 2.1 Farm plan models developed by different researchers using multiobjective decision making techniques.

Authors	Country	Model ^a	O/C/V ^b	Type
Wheeler <i>et al.</i> (1977)	UK	GP (W)	4/6/9	A representative 600 acre mixed farm employing six men
Higuchi (1979)	Japan	GP (L)	3/16/12	An individual farm (family labour: 2, Paddy field: 50 a, upland field: 120 a)
			5/16/23	A full time farm (3, 70a, 120 a)
			5/18/26	A part time farm (2, 40 a, 20 a)
Flinn <i>et al.</i> (1980)	Philliphines	GP (L)	6 ^c /7/18	A representative 1.48 ha (average) farm with 6 family members under share tenancy (research on direct-seeded rice at IRRI's Cropping systems site)
Barnett <i>et al.</i> (1982)	Senegal	GP (W) +MDS	5/513/916 ^d	Subsistence 3-12 ha farmers who employ 3-6 workers
Romero <i>et al.</i> (1987)	Spain	CP (1,∞)/ 1+W	3/17/17	A cooperative in an irrigated arable farm of 100 ha in Andalusia
Sankhayan <i>et al.</i> (1988)	India	CP (1,∞)/ 1+W	5/16/22	A typical farm in the Punjab (12 acres)
Berbel (1989)	Spain	mPAD	4/60/70 ^e	Four types of family farms (in protected horticulture) classified by size (0.7 – 2 ha) and marketing channels
Berbel <i>et al.</i> (1991)	Spain	IMOP	2/99/35 ^f	A horticultural company working with 600 ha of green houses and with over 2000 employees

Contd....

^a GP = Goal Programming; W = weighted; L = lexicographic.

CP = Compromise programming; (1,∞) = compromise solutions when $q = 1$ and $q = \infty$ are obtained, where q is an exponent of Minkowski's metric.

IMGP = Interactive Multiple Goal Programming

Eff = generation of pareto efficient solutions (extreme points); W = the weighted method; C = The constraint method; S = the multicriterion simplex method.

MGA = Modeling to Generate Alternatives.

IMOP = Interactive MultiObjective Programming

VIG = Visual Interactive Goal Programming

mPAD = the mean PAD model which is equivalent to the target MOTAD model

MDS = MultiDimensional Scaling.

^b O = the number of objectives (goals); C = the number of constraints; V = the number of decision variables. NA = not available.

^c The number of goals is four and the number of objectives is two

^d Deviation variables seem to be included.

^e Including deviation variables

^f Since the second objective, minimization of the deviations from the targets, is formulated using the same method as GP(W), 92 out of 99 constraints are goal constraints and 92 x 2 deviation variables are included in addition to 35.

Contd....(Table 2.1)

Authors	Country	Model	O/C/V	Type
Fahmy <i>et al.</i> (1991)	Egypt	GP(L)	3/28/37	The AUC (American University in Cairo) desert farms growing crops and raising livestock (20 acres)
Hayashi (1991)	Japan	CP (1- ∞)/1	2/61/38	A full time horticultural farm with plastic greenhouses (family labour : 2, paddy field: 30 a, plastic greenhouse: 20 a)
Manos (1991)	Greece	CP(1)/3+W	2/32/20	An average farm including crops and livestock in northern Greece (6.5 ha, 2.7 equivalent man work units)
Maino <i>et al.</i> (1993)	Chile	Eff(S)	3/16/4	A family farm cultivating 13.8 ha with livestock (as a part of on-farm experiments following the diagnostic phase of farming systems research)
Piech <i>et al.</i> (1993)	UK	GP(W), Eff(S), CP (1, ∞)/ 1+W	5/8/9	A university farm run as a commercial concern (640 ha)
Willis <i>et al.</i> (1993)	USA	Eff(C), MGA	2/52/28	Greenhouse production (vegetable and ornamental plants) by family and hired labour in Massachusetts (9.3 acres)
Milan <i>et al.</i> (1994)	Spain	mPAD	2/28 ^g /8	A representative farmer in Southern Spain who owns 50 ha and employs hired labor (including vegetable and feed grain)
Lee <i>et al.</i> (1995)	W. Samoa	IMOP (VIG)	5/NA/72	A small family farm producing taro, tomato, and head cabbage (7 ha)
Okoruwa <i>et al.</i> (1996)	Nigeria	Eff(C)	2/15/10	Three agropastoralists and a crop farmer (crop-livestock mixed farming, 3.5 – 5.1 ha)
Nibbering <i>et al.</i> (1998)	Indonesia	IMGP	10 ^h /NA/NA ⁱ	Typical farm households in three agroecological subregions in research area (quantified farming systems analysis)

^g Including chance constraints.^h Other goal variables are added if they are believed to be important.ⁱ Including 22 crops and crop combinations, and three kinds of livestock.

agricultural sector at district level. Besides the sensitivity analysis with the variations of priority structure and use of Euclidean distance function to identify the solution, which is closest to the recognized ideal solution, enabled to recognize the most appropriate priority structure. The provision of incorporating different environmental constraints in different planning horizons could solve complex agricultural planning situations in the current multi-objective decision making arena.

Alphonse (1997) used AHP for qualitative judgments in multicriteria decision models in areas of resource allocation, selecting builder locations, choosing between subsistence and cash crop farming, and determining crop production technology.

Aromolaran and Olayemi (1999) used the goal programming approach to develop farm plan for the Nigerian small farmers seeking to satisfy multiple and conflicting goals. It was recommended that efforts be made by the government to develop the need for efficiency and growth-oriented goals among the farming population for the economic efficiency or any appreciable growth in farm output.

Butterfield *et al.* (1999) explored the use of goal programming as a tool to aid end users who are faced with complex decisions. The use of goal programming model as a decision support tool was examined in lieu of the following objectives: (1) balancing trade-offs and costs between competing alternatives; (2) ease in formulation by end users using common spreadsheet packages without any software coding for adoption to different decision situations; and (3) the requirement of end user to only enter the constraints and relative priorities in a series of tables.

Most of these farm plans have used leveling of gross margins, income, or expected returns as their primary goal followed by leveling of labour requirements, minimizing fluctuations of revenue, minimizing labour fluctuations, minimizing cost, self-sufficiency and environmental goals such as nitrogen loss, biocide accumulations, and soil loss in that order (Table 2.2).

Table 2.2 Goals (objectives) used in farm plan models by different researchers^a.

Authors	Goal 1	Goal 2	Goal 3	Goal 4	Goal 5,....
Wheeler <i>et al.</i> (1977)	Gross margin	Seasonal cash exposure	Labour utilization and smoothing		
Higuchi (1979)	Individual farm: Income Full time farm: Income Part time farm: Income	Income fluctuation Leased land Income fluctuation	Leisure Labor hiring Leisure	Leisure Lending land	Income fluctuation Daily side job
Flinn <i>et al.</i> (1980)	A basic quantity of rice sufficient for family sustenance	Cash for food supplies, education and other priority demands of the household	Borrowings from relatives and friend	Borrowings from a landlord	Indebtedness (min.) Surplus (max.)
Barnett <i>et al.</i> (1982)	Food production to feed the entire family	Inputs (includes annual installments on equipment, fertilizer and seed)	Income to buy animals	Leisure	Yields
Romero <i>et al.</i> (1987)	Seasonal labour fluctuations (min.)	Labour employment (max.)	Gross margins (max.)		
Sankhayan <i>et al.</i> (1988)	Gross margins (max.)	Family labour hours (max.)	Working capital borrowing (min.)	Labour hiring (min.)	Seasonal labour fluctuation (min.)
Berbel (1989)	Gross margin (max.)	PAD (min.)	Family labour utilization (min.)	Seasonal labour fluctuation (min.)	
Berbel (1991)	Gross margin (max.)	The weighted sum of deviations from the monthly marketing target (min.)			

Contd....

^a In the case of objectives, "max" for maximize or "min" for minimize is presented in []. In the case of goals, the goals excluding targets (goal values) are shown in principle. The lexicographic ordering in LGP is not equivalent to the ordering of objectives (goals) in this table.
PAD = the sum of Partial (negative) Absolute Deviations below target of gross margins;
MAD = the sum of Mean Absolute Deviations of gross margins.

Contd....(Table 2.2)

Authors	Goal 1	Goal 2	Goal 3	Goal 4	Goal 5,....
Fahmy <i>et al.</i> (1991)	AUC income	Farmer income	Variable costs		
Hayashi (1991)	Expected returns (max.)	Worst possible returns (max.)			
Manos (1991)	Gross margins (max.)	Variable costs (min.)			
Maino <i>et al.</i> (1993)	Gross margins (max.)	MAD (min.)	Family labour utilization (max.)		
Piech <i>et al.</i> (1993)	Gross margins (max.)	Labour utilization (max.)	Labour hiring (min.)	Variable costs (min.)	Trading surplus (max.)
Willis <i>et al.</i> (1993)	Expected net revenues (max.)	Unpaid family labour hours (min.)			
Milan <i>et al.</i> (1994)	Gross margin (max.)	PAD (min.)	Technological risk (chance constraints)		
Lee <i>et al.</i> (1995)	Net revenues (max.)	Taro produced for social cultural purposes in February through April (max.)	Ditto (May-july) (max.)	Ditto (August – October) (max.)	Ditto (November-January) (Max.)
Okoruwa <i>et al.</i> (1996)	Gross margins from livestock (max.)	Gross margins from crops (max.)			
Nibbering <i>et al.</i> (1998)	Agro technical : a) staples production (max.) b) pulses production (max.) c) Fruit production (max.) d) Meat production (Max.)	Household socio-economic: a) Monetary input (min.) b) Employment (min.) c) Gross margin (max.)	Environmental (min.) : a) Nitrogen loss b) Biocide accumulation (min.) c) Soil loss (min.)		

Nhantumbo (2000) stated that if it is considered that there is no trade-off between the multiple objectives, a technique called 'Lexico-graphic goal programming' or 'Hierarchical Goal Programming' can be used. Lexicographic simply implies that goals and values can be placed in a hierarchical order (sequence) like the letters in the alphabet (lexicon) and that in searching for what is the best solution we satisfy higher order priorities before lower order priorities. The goals are satisfied in a pre-emptive manner, which denies the possibility of trade-off. The most important consideration and difference from compromise programming are that in this case, a hierarchy for the goals is selected and, thus, not allow any trade off between them. So, goal 1 is infinitely important than goal 2 and must be satisfied before goal 2; goal 2 is vastly more important than goal 3; and so on. This methodology is thought to be particularly useful for multi level resource use planning. It is assumed that there is a natural hierarchy from the International level, down through national and regional levels to local district and individual levels. Hence, goals and priorities can be transmitted in the order in which they are to be achieved.

Thus, it can be seen that lot of methodological developments in multi-objective programming or decision making have taken place, but their specific application in Indian agriculture in an integrated manner is very rare (Vedula and Rogers, 1981; Sankhayan *et al.*, 1988). Thus, with the aim of developing simple, effective and more reliable models of dairy farming systems incorporating farmers' preferences or goals, the present study has been undertaken, in a major milk producing state of Haryana.

In the nutshell, only a few studies on identification and evaluation of dairy farming systems have been conducted in India. The early works started with Faroda *et al.* (1978) and Kumar *et al.* (1994). Dhaka and Jain (1999) reported identification of seven dairy farming systems in Haryana based on animal composition. Thus, efforts to classify the dairy farming systems existing in a given region have been made only sparingly using either land size, herd size or milch animal composition. A lack of systems approach and the involvement of the end users to problems and their solutions is evidently lacking.

Functional analysis to understand milk production relationships has mostly concentrated on resource use efficiency, technical and technological change to improve productivity. Studies to evaluate efficiency of dairy farming systems have been mostly neglected except a few studies carried out by Srivastava (1995) and Chand (1998) wherein they used deterministic approach to efficiency estimation of commercial dairy farms. Dixit (1999) conducted a study to estimate the technical efficiencies of dairy farming systems under village conditions using COLS method of stochastic frontier analysis. However, determination of efficiency using MLE method of stochastic frontier analysis, which gives better and reliable estimates than COLS method has not been attempted under Indian conditions. Optimal farm planning have mostly confined to maximization of income with risk minimization and human labour employment. Efforts to measure the preferences of farmers in a multiple objective or goal setup for mixed farming situations have been attempted only by Sankhayan *et al.* (1988) under Indian conditions.

Hence, the present study tries to overcome the lacunae through a systems approach to evaluation and planning strategies for dairying in Haryana.

Description of Study Area

3. DESCRIPTION OF STUDY AREA

3.1 DESCRIPTION OF HARYANA STATE

A quotation from Vikrami Samvat, 1385¹ "There is a region called Haryana, which is like a heaven on earth", speaks of Haryana being the hub of social and cultural activity in India from times immemorial. Haryana together with Punjab is called the 'Grain Bowl' of India. At the national level, Haryana is next only to Punjab in crop productivity. The people of Haryana are simple, straightforward, enterprising and hard working. They are known for their love for cattle and their simple food habits with dairy products being an integral part of their diet. Haryana is known throughout the country for its milch and draught cattle and claims the honour to be the home of two of the best Indian breeds of cows and buffaloes namely 'Hariana' and 'Murrah'. The agro-climatic and physical conditions are suitable for breeding good livestock. The state has a vast potential for the development of the dairy industry. Dairying is one of the most important activities for income and employment generation for the landless and marginal farm households in the state. Agriculture is the main occupation of the people of Haryana. About 70 percent of the population in the state are dependent upon agriculture for their livelihood. The women are devoted and diligent and assist their men-folk on the farms.

3.1.1 Location and Boundaries

The state of Haryana forms part of the northern region of India. It is surrounded by Uttar Pradesh in the east, Punjab on the west, Himachal Pradesh on the north, and the Rajasthan in the South. The natural boundaries of the state comprise of the Shivalik hills in the north, and the river Yamuna in the east. The southwestern boundary is provided by the range of Aravalli Hills, which run through southern Delhi and the Gurgaon district up to Alwar. River Ghaggar is the boundary in the west.

¹www.haryana-online.com

3.1.2 Agro-Ecological and Geographical Conditions

Haryana is divided into three major agro-climatic zones namely arid, semi-arid and dry sub-humid with tropical to sub-tropical climatic conditions (Gupta *et al.* 1989). Arid zone covers southwestern parts of Haryana covering districts of Sirsa, Hisar, Bhiwani, Jind and parts of districts Rohtak and Mahendergarh. Arid zone receives inadequate rainfall against high evaporation rates. The semi-arid zone covers the remaining parts of districts of Rohtak and Mahendergarh, and districts of Gurgaon, Sonapat, Karnal, Kurukshetra, Faridabad and Yamunanagar. The rainfall in this zone is higher than the arid zone. Due to water retentive soils in this zone, rainfall water is better exploited for water intensive crops such as paddy, vegetables, fruits, maize, sorghum and arhar. The dry sub-humid zone includes the northern part of Ambala district. Though this zone receives good amount of rainfall during rainy and winter seasons, the soil retention capacity is lesser than other zones and surface run-off due to foothills features causes soil erosion. Natural vegetation is quite thick in this zone.

On the basis of geographical features, Haryana is divided into four zones,

1. **Shivalik Hills:** The altitude of hills varies between 900 to 2300 meters. These hills are the source of the rivers like Saraswati, Ghaggar, Tangri and Markanda. It includes parts of Panchkula, Ambala and Yamunanagar districts.
2. **Ghaggar Yamuna Plain:** It is divided into 2 parts - the higher one is called 'Bangar' while the lower one is called 'Khadar'. This alluvium plain is made up of sand, clay, silt and hard calcareous balls like gravel the size of nuts known locally as 'kankar'.
3. **The Semi-Desert Sandy Plain:** This area borders the state of Rajasthan and includes the districts of Sirsa and parts of Fatehbad, Hisar, Bhiwani and Mahendergarh district.
4. **Aravali Hills:** This is a dry area with uneven, irregular landscape.

3.1.3 Area and Population

The area of the Haryana state is 44212 square kilometers extending from 28°3' to 31°9' north latitude and 74°5' to 77°5' east longitude. For administrative purpose the whole state is divided into four divisions - Ambala, Rohtak, Gurgaon and Hisar. There are a total of 19 districts, 47 sub-divisions, 57 tehsils, 45 sub-tehsils and 115 blocks. Haryana has a total of 81 cities and towns. It has 5759 villages. The total population of Haryana, according to 2001 census is 21.085 million with males being 11.330 million and females being 9.755 million. The population density is 477 persons per sq.km. Hindus constitute about 90 percent of the population followed by Sikhs (5.2%), Muslims (4.05%) and Christians (0.10%). The Hindus are divided into a number of castes like Jats, Brahmins, Ahirs, Aggarwals, Gujars, Arora Khattris, Sainis, Rajputs and Rors. Among them, the Jats occupy a preeminent position in Haryana, being the largest group and found throughout the state. The artisan castes such as Sunars (goldsmiths), Lohars (blacksmiths), Telis (oil extractors), Nais (barbers) and dhobis (washermen) are found throughout the state and especially in villages. The other demographic features of the selected districts as well as of the state are shown in Table 3.1.

Of the three selected districts for the study, Bhiwani is the largest district making up 10.81 percent of the area of state while Yamunanagar is the smallest covering 4 percent and Gurgaon 5.3 percent of the state. In terms of population, Gurgaon covers 7.9 percent of the population while Bhiwani and Yamunanagar 5.8 and 4.7 percent, respectively, of the total population of Haryana. Thus Gurgaon has comparatively more human density than Bhiwani. But surprisingly, the percentage of agricultural labourers to total main workers in Gurgaon is comparatively lower at 13.7 percent than Yamunanagar at 23.9 percent. This could be correlated with the main workers in the non-farm sector in Gurgaon due to its industrialization than in the other two districts. The percentage of cultivators is relatively more in Bhiwani while that of agricultural labourers in Yamunanagar as can be seen from Table 3.1. The average size of landholdings is also higher in Bhiwani at 2.89 hectares in comparison to Yamunanagar at 1.99 ha and Gurgaon at 1.5 ha. In literacy rate,

Table 3.1 Socio-economic profile of the selected districts and Haryana state (1999-2000).

Socio-economic parameter	Yamuna-nagar	Bhiwani	Gurgaon	Haryana
Area (sq. kms.)	1768	4778	2766	44212
Towns	10	6	11	106
Villages	654	439	730	6955
Total population (in lakhs)	9.8	14.2	16.6	210.8
a) Male	5.3	7.6	8.8	113.3
b) Female	4.5	6.7	7.7	97.6
Density (per sq. km)	556	298	599	477
Males (in lakhs)	5.3	7.6	8.8	113.3
Females per 1000 males	863	880	874	865
Literacy rate (% of total)	62.2	57.6	51.0	58.0
Percentage of scheduled caste (1991 census)	25.0	19.0	13.6	20.0
Main workers as percentage to total population	27.6	27.9	27.8	28.7
In the total working force:				
a) Cultivators (%)	25.3	47.0	34.8	44.7
b) Agricultural labourers (%)	23.6	11.1	11.9	16.1
Percent rural population to total	60.0	81.0	77.7	71.0
Percent urban population to total	40.0	19.0	22.3	29.0
Number of households (rural)	82571	140772	130154	1882390
Persons per household (rural)	7	7	7	7

Yamunanagar with 62.23 percent literates is comparatively better than the other two districts or overall Haryana at 57.99 percent. The percentage of urban to total population according to 2001 census is the highest in Yamunanagar among the three districts and the state as a whole. This is mainly because of larger number of towns per unit area in Yamunangar and whereas industrialization in Gurgaon has been confined only to adjoining parts of Gurgaon while the remaining area still being predominantly rural.

3.1.4 Climate, Rainfall and Soil

The climate of Haryana is characterized by very hot in summer and markedly cold in winter. The temperature varies from 21.5 to 43°C in the month of May to June and from 4 to 22°C in the month of December to February. Rainfall in the state is low and erratic except in the sub-humid eastern zone of Haryana i.e. in parts of Karnal and Ambala districts. The amount of rainfall increases in the state in the direction of southwest to northeast. The maximum rainfall is about 215 cm, occurring in the Shivalik foothills only. The minimum rainfall is 25 to 38 cm occurs in the southern part of Haryana in the Aravalli hills region. The rainfall pattern is highly uneven and erratic with maximum rains (about 80%) occurring in the *kharif* season beginning mid June to September due to the southwest monsoon. This rain is very important for the *kharif* crop and the spring sowing. The winter rains from December to February benefits the *rabi* crop. However, from Annexure-I, it can be seen that winter rains are often insignificant in quantity in the selected districts thus relying on irrigation is very important for winter crops during this period. The rainfall pattern of Haryana is considerably affected by the region's continental location and nearness to the sub-tropical upper-air high pressure of Thar Desert. This results in low rainfall and variation at different places.

Haryana can be divided into three regions on the basis of type of soil namely loamy sand, loam and sandy loam. In some places sand, silty loam, clay loam or clay are found, but these are in insignificant quantity. The soil is medium textured sandy loam for most part of Haryana. The districts of Yamunanagar and Bhiwani belong to the sandy loam category while Gurgaon

has loamy sand soil. However, what make Yamunanagar and Bhiwani different are the ground water status and the rainfall. Yamunanagar has shallow and deep fresh ground water while Bhiwani has saline shallow and deep ground water and in some parts fresh shallow water.

3.1.5 Land Utilization Pattern

The state of Haryana has a geographical area of 44.20 lakh hectares. About 85 percent of the geographical area is cultivable, of which 95 percent has already been brought under plough. Therefore, there is hardly any scope for bringing additional area under cultivation, except for reclamation of degraded lands affected by water logging, salinity and alkalinity. About 75 percent of the cultivated area in the State is irrigated, wherein the contribution of tube wells / pumping sets is about 50 percent. The cropping intensity in the State is nearly 170 percent.

Crop cultivation is the predominant way of utilizing land in Haryana as can be seen from Table 3.2. Among the districts selected, Bhiwani has the maximum area under crop cultivation at 85.6 percent followed by Yamunanagar at 72.7 and Gurgaon at 71.9 percent. Yamunanagar has more area under forests than the other two districts at 7.6 percent against Bhiwani at 1.1 and Gurgaon at 2.34 percent. In Gurgaon 18.1 percent of the land is not suitable for cultivation with the area coming under the Aravalli ranges. The cropping intensity of 170 percent in the state signifies the intensive crop cultivation practices followed in Haryana with more than one crop in a year.

3.1.6 Distribution of Land Holdings

Land is one of the most important assets of farm households in rural Haryana. Land signifies the socio-economic stratification as well as the standard of living of the people in the region. This can be seen from the prevailing inequity in land distribution among the cultivars in Haryana as a whole as well as in each of the three districts as shown in Annexure-II. The average size of land holding is 2.13 hectares in Haryana while it is 2.89 hectares in Bhiwani district, 1.99 hectares in Yamunanagar district and 1.5 hectares in Gurgaon district. Inequity in land distribution in Haryana is also evident from

Table 3.2 Land use pattern of selected districts and Haryana state (1999-2000).

(In '000 ha)

Classification of land	Yamuna-nagar	Bhiwani	Gurgaon	Haryana
Total geographical area	172 (100)	466 (100)	270 (100)	4400 (100)
Area under forest	13 (7.6)	9 (1.9)	3 (1.1)	115 (2.6)
Land put to non agricultural use	28 (16.3)	19 (4.08)	42 (15.6)	368 (8.36)
Barren and unculturable land	5 (2.9)	23 (4.9)	5 (1.85)	96 (2.18)
Permanent pastures and other grazing land	2 (1.16)	--	2 (0.74)	22 (0.5)
Net sown area	125 (72.7)	399 (85.6)	194 (71.9)	3552 (80.7)
Culturable area	127 (73.8)	415 (89.1)	221 (81.9)	3821 (86.8)
Area sown more than once	68 (39.5)	222 (47.6)	104 (38.5)	2477 (56.3)
Total cropped area	193 (112.2)	621 (133.3)	298 (110.4)	6029 (137.02)
Cropping intensity (%)	154	156	154	170
Net area irrigated to net area sown (%)	82.4	52.1	39.2	81.3
Monthly average rainfall during 1999 (cm)	77.1	21.9	44.3	42.5

Source: Director of land records, Haryana in Statistical abstract of Haryana, 2000-01.

the fact that 47 percent of the cultivars with less than one hectare land are operating only 11 percent of operational land holdings while 14.3 percent of cultivars with more than 20 hectares of operational holding are cultivating 51.2 percent of the land area under cultivation (Annexure-II). Besides this the number of landless farm labourers are about 19 percent of the total main workers in Haryana. This scenario was found to be true for all the three selected districts with the difference that Bhiwani has less of landless and marginal farm households, and more of small and large farm households while Yamunanagar has more of landless farm labourers and Gurgaon has less of large farm households.

3.1.7 Cropping Pattern

Cropping pattern in Haryana is diverse in different regions and is mainly determined by the agro-climatic and geographical features, the soil conditions and irrigation. To keep district as a unit of analysis and to determine cropping pattern zone-wise, the three main agro-climatic zones in Haryana are further divided into five zones²:

1. Sub-humid zone : It covers the district of Yamunanagar and Ambala. The cropping pattern in this zone is paddy, sugarcane, wheat and maize.
2. Semi-arid zone I : It covers the districts of Karnal, Kurukshetra and Sonapat districts and the main crops grown are paddy, wheat and sugarcane.
3. Semi-arid zone II : It covers the districts of Jind, Gurgaon and Faridabad. The cropping pattern of this zone is diversified and consisted of crops like bajra, paddy, wheat, barley, oilseeds and sugarcane.
4. Arid zone I : It covers the districts of Hisar and Sirsa. The cropping pattern consists of crops like cotton, bajra, wheat and gram.

² Gupta, D.D., Singh, V.K., Singh, J.P., Khatri, R.S., Tomer, B.S. and Singh, U.B. 1989. Existing and suggested cropping pattern in Haryana, Research Bulletin No. 23, Department of Agricultural Economics, CCS Haryana Agricultural University, Hisar – 125004, pp.1-86.

5. Arid zone II: It covers the districts of Bhiwani, Mahendragarh and Rohtak. Main crops of this region are bajra, guar and gram while other crops are sugarcane and wheat. This region has started now also growing paddy in the areas, which are becoming water logged due to high water table conditions.

The classification here is based on maximum area similar to the adjacent zone; thus Yamunanagar is included in the sub humid zone and Rohtak in arid zone II.

Haryana is self-sufficient in food grains production and one of the top contributors of food grains to the Central pool. The state contributes 40 to 45 lakh tons of food grains to the Central pool being the second largest in the country. The world famous Basmati rice produced in Haryana finds an easy market abroad. The total foodgrains production in the year 2001-02 was 139.27 lakh tons. The production of oil seeds for the year 2001-02 was 6.70 lakh tons. At present about 37.50 lakh hectares is covered under cereal crops like wheat, rice, maize and bajra yielding a total cereal production of 109.6 lakh tons (Annexures III and IV).

There are two main types of growing seasons in Haryana: *Rabi* and *Kharif*. The main crops of Haryana are wheat, rice, sugarcane, cotton, oilseeds, gram, barley, corn, millet, etc. The major *Kharif* crops of Haryana are rice, jowar, bajra, maize, cotton, sugarcane, sesame and groundnut. The major *Rabi* crops are wheat, gram, linseed, rapeseed and mustard. The production of some of the main crops and the area under cultivation is shown in Annexure-IV.

3.1.8 Socio-Economic Development and Indicators

Haryana has a skewed population distribution of humans with male to female ratio at 1000:855. The overall percentage of scheduled caste is 19.75 percent and most of them belong to the landless category. The proportion of main workers to total population is 28.55 percent. The proportion of cultivators to total working force is 44.57 percent and that of agricultural labourers is 15.11 percent (Table 3.1). Haryana is predominantly rural with 71 percent of

population living in rural areas. The average size of members per household is 7 persons. The literacy rate has been improving over time and 58.59 percent of population was literate as per 2001 census.

The percentage of agricultural labourers to total working force is higher in Yamunanagar than in Bhiwani or Gurgaon. Accordingly the wage rate of agricultural labourers for different types of agricultural activities are higher in Gurgaon and Bhiwani than in Yamunanagar. The percentage of urban population is also higher in Yamunanagar than in Bhiwani or Gurgaon signifying the development of towns and the associated economic activities more in the Yamunanagar district than in Bhiwani or Gurgaon. Bhiwani has the maximum rural population (81%) followed by Gurgaon (77.7%).

3.1.9 Dairy Development Scenario

Dairy farming constitutes an essential part of Haryana's rural economy. It has been known as the 'milk pail' of India. Dairy products like Milk, Ghee, Butter, Dahi and Paneer are a major part of the diet of Haryana's people. The total milk production in the state was 48.45 lakh metric tons in 2000-01 (Annexure-V). Animal husbandry has been taken up as an integral component of diversified agriculture. Haryana has a livestock population of 98.97 lakh (Annexure-VI). Haryana is the home tract of Murrah buffaloes, which is best suited for the agro-climatic condition of the state. The state is endowed with 4.82 million buffaloes, 0.67 million crossbred cows and 1.73 million local cattle (Annexure-VII). Buffaloes constitute 45 percent of the total livestock population and they contribute 80.5 percent of the total milk production. About one lakh 'Murrah' buffaloes are exported every year to other States and abroad. Haryana supplies the bulls of Murrah breed to all parts of India to improve the breed of buffalo stock. The National Dairy Research Institute, Karnal, a premier institute in the field of dairy education and research in Asia, and Central Institute for Research on Buffaloes, Hisar are constantly developing the breed of 'Hariana' cow and 'Murrah' buffaloes. The milk production of the state is 48.45 lakh tons and the average per capita milk availability is 637 grams per day in 2000, which is much higher than the

national average of 205 grams. With a view to promote the dairy industry, the Haryana government provides loans to identified beneficiaries under different schemes for small farmers, marginal farmers with 1 acre land, widows and scheduled castes to purchase milch animals from 2 to 10 in number. Besides, schemes for purchase of grass cutting machines, construction of sheds and mandatory training are the regular activities of dairy development department of the state³. Other provisions such as one year insurance scheme for animals purchased under the schemes and free medical aid are also promoting dairy development in the state. Some of the Dairy development programmes implemented are the state sponsored insurance of dairy milch animals, finance for purchase of milch animals, and construction of sheds under mini development schemes.

To give farmers good price for their milk and milk products and to help in marketing, a vast network of milk producers' societies has been set up in the state. About 1500 milk cooperative societies are now working. Six milk plants were set up in the cooperative sector of which five are now working in Jind, Ambala, Rohtak, Hisar and Ballabgarh while one at Bhiwani is being shut down. One more is being set up in Sirsa. High tech dairying through technologies such as embryo transfer technology to improve the quality of livestock is being developed at NDRI, Karnal. The break up of milk production in the state is shown in Annexure-V. Haryana has 7 Intensive cattle development projects, 620 Veterinary hospitals, 864 Stockman centers, 749 dispensaries, 60 Regional artificial insemination centers and 10 Semen banks.

3.2 DESCRIPTION OF SELECTED DISTRICTS

The districts of Yamunanagar, Bhiwani and Gurgaon were purposively selected for this study based on the variations in agro-climatic features, cropping pattern, irrigation intensity, dairy and other livestock enterprises and socio-economic characteristics (Fig. 3.1). Part of Yamunanagar falls in sub-humid zone and partly in semi-arid zone, Bhiwani in the arid zone and

³ Hindustan Times, March 12, 2003

Gurgaon in the semi-arid zone. On the basis of geographical features zoning, Yamunanagar falls in the Shivalik hills and the Ghaggar Yamuna plain zone, Bhiwani falls in the semi-desert sandy plain while Gurgaon in the Aravali hills zone. Gurgaon being close to commercial capital city of India, Delhi has its influence in the industrialization of the adjoining areas close to Delhi. Besides, Gurgaon region has the Aravalli ranges forming the western border of the district. Gurgaon and Bhiwani are considered as arid rainfed zone in this study mainly because of their similarity in cropping pattern, gross area irrigated (59%) and ground water status (Annexures IV and IX). This region has shallow fresh water and deep saline making it unsuitable for intensive use for crop cultivation (Fig. 3.2). Yamunanagar, on the other hand, has fresh ground water both in shallow and deep zones and 88.1 percent of the area is irrigated. This makes the cropping pattern having dominance of irrigation intensive crops such as paddy and sugarcane (Fig. 3.3). Plantation crops such as poplar are also being extensively introduced in the area with good marketing facilities for the product in the district. Yamunanagar also has comparatively more average rainfall at 134.7 cm in comparison to Bhiwani or Gurgaon at 41.02 and 55.52 cm, respectively.

3.3 DESCRIPTION OF SELECTED VILLAGES

From the purposively selected three districts of Yamunanagar, Bhiwani and Gurgaon, the blocks of Radaur, Dadri and Sohna, respectively, were purposively selected. The socio-economic profile of the households in the selected villages in Haryana in terms of land holdings is given in Annexure-VIII.

Based on the criteria of selection, village Bendi was selected close to Radaur town and village Antawa was selected away from town in Radaur Block. Similarly the village Mehra was selected close to Dadri town and Dokhaharia a little away from town. From the Sohna block, Alipur village was selected close to Gurgaon town and Berka away from the town.

Haryana

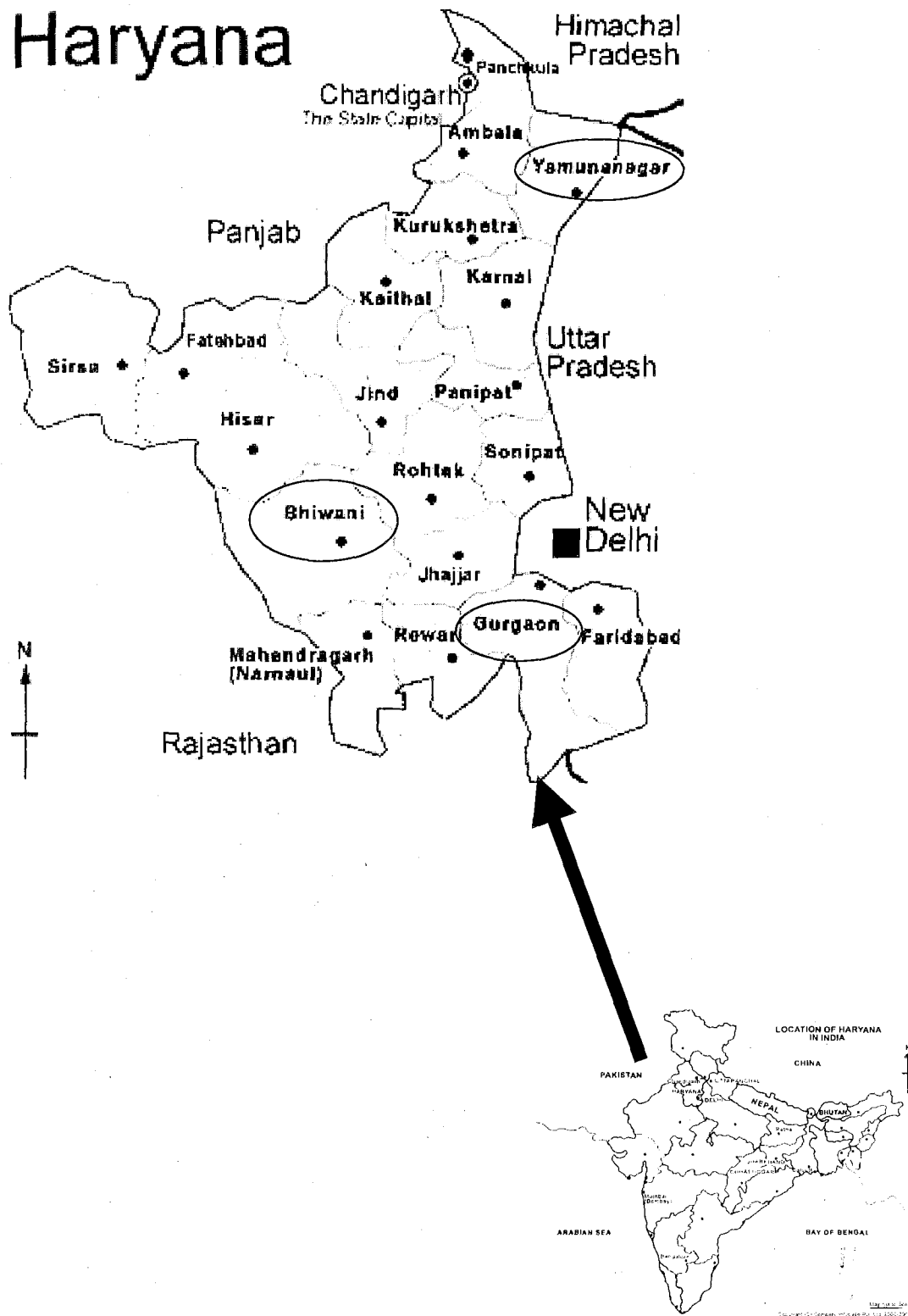


Figure 3.1 Map of Haryana showing the selected districts in the study area.



Figure 3.2 Tilled and fallow land during April in Bhiwani district in the rainfed zone of Haryana.



Figure 3.3 Sugarcane being harvested in April in Yamunanagar district in the irrigated zone of Haryana.

CHAPTER - 4

Methodology

4. METHODOLOGY

4.1 SAMPLING DESIGN

4.1.1 Selection of the Study Area

The state of Haryana has been selected for the present study considering both the importance of dairying for Haryana's economy and the significance of this study to serve as a model to be replicated in other regions of the country. For any work to serve as a model it is necessary to be a representative study of the region. Haryana is an important state in terms of milk production and consumption. It is a state with large variations in agro-climatic features, technology adoption and farm size. The significant presence of problems relating to fodder scarcity, health of the milch animals, problems relating to productivity, longer dry period, silent heat have been prevailing in buffaloes since a long time and is hindering productivity enhancement.

Approaches to tackle these problems have been highly generalized to the milch animal specific without consideration for the interactions within and between factor namely the household, the resources and the management factor. In short, a systems perspective of analysis of problems has been lacking.

4.1.2 Sampling Plan

Keeping into view the variations in agro-climatic features, cropping pattern, irrigation intensity, dairy and other livestock enterprises and socio-economic characteristics, the districts of Yamunanagar, Bhiwani and Gurgaon in Haryana were purposively selected for the study.

From each of the districts, one block was selected to represent the unique characteristics of the selected district in terms of climate, agri-inputs, socio-economic, cropping pattern and infrastructure characteristics. The blocks selected were Radaur block from Yamunanagar, Dadri block from Bhiwani and Sohna block from Gurgaon.

From each of the selected block, two villages were selected in such a way that one village is within the periphery of the town / city and the other away from it in the same block. The villages selected near and away from town were Bendi and Antawa from Yamunanagar, Mehra and Dokhaharia from Bhiwani, and Alipur and Berka from Gurgaon district.

Complete enumeration of all the households in the selected villages was done. The outliers from the farm households for each of the agro-climatic zone were identified with respect to the variables to be used for cluster analysis. The dairy farming systems were identified using cluster analysis for the farm households belonging to each of the agro-climatic zones in Haryana after removing the outliers in the selected villages. The number of dairy farming systems to be taken up was on the basis of logic and manageability. The number of dairy farming systems identified were eight, four from the irrigated zone of Yamunanagar and four from the partially rainfed zone of Bhiwani and Gurgaon.

A total of 60 farm households per block were selected from the dairy farming systems identified on the basis of probability proportional to size subject to a minimum of five from each dairy farming system identified (Table 4.1).

Table 4.1 Selection of sample households from the study area.

Sl. No.	District	Block	Village	Total number of households	No. of selected sample households
1.	Yamunanagar	Radaur	Bendi	203	28
			Antawa	158	32
2.	Bhiwani	Dadri	Mehra	350	34
			Dokhaharia	472	28
3.	Gurgaon	Sohna	Alipur	340	29
			Berka	178	29

This included 35 households from the irrigated landless dairy farming system, 8 from the irrigated marginal, 12 from the small irrigated and 5 from large irrigated systems in the irrigated zone. From the rainfed zone, 23

households were selected from the landless rainfed system, 37 from the marginal rainfed, 51 from the small rainfed and 9 households from the large rainfed system. Thus the total number of sample households was 180 from the three selected districts. The detailed data on parameters relating to the socio-economic characteristics and input-output parameters of crop and dairy enterprises was collected from the selected 180 sample households for the year 2000-01 using a well structured and field tested schedule. The data was collected through household surveys, personal interviews and group discussion for three seasons, namely, *kharif*, *rabi* and summer. The information on prices, infrastructural facilities and demographic characteristics of the study area was collected through various secondary sources.

4.2 ANALYTICAL FRAMEWORK

4.2.1 Identification and Classification of Farming Systems

4.2.1.1 Cluster analysis

Cluster analysis is a data reduction technique to form natural groups or convenient groups. The object of cluster analysis is to partition a set of objects into groups or clusters in such a way that the profiles of objects in the same cluster are very similar, whereas the profiles of objects in different clusters are quite distinct. This procedure attempts to identify relatively homogeneous groups of cases (or variables) based on selected characteristics, using an algorithm that starts with each case (or variable) in a separate cluster and combines clusters until only one is left. Raw variables or a variety of standardizing transformations can be analyzed. Distance or similarity measures are generated by the proximities procedure. Statistics are displayed at each stage to help you select the best solution. Cluster analysis techniques can be classified into five major types: hierarchical, partitioning, Q-sort, density and clumping.

Cluster analysis was used to identify the dairy farming systems in the study area. Complete enumeration of all farm households in the selected villages was carried out to get the desired information on selected variables for cluster analysis. In order to remove the impact of outliers in the data for

cluster analysis, they were identified on the basis of extreme values of the variables to be used for cluster analysis using SPSS software (Statistical Package for Social Sciences). These outlier farm households were removed from the sampled households for cluster analysis. The variables considered for cluster analysis were total milk production in the farm/day in the month of survey (most frequent yield), herd size, total number of lactating animals species wise, operational holdings and area under fodder crops. The three sequential steps involved in the cluster analysis were partitioning, interpretation and profiling. The number of clusters of farming systems to be selected was decided on the basis of logic and manageability.

Let n = number of enumerators / farm households in the block

p = number of features

X is a $(n \times p)$ matrix of mean centered or standardized measurement of n sampled farm households with respect to ' p ' features

' r ',' s ' = observational units, i.e., farms (1,2... n)

Proximity measure (Euclidean distance) is given by the formulae:

$$d_{rs}^2 = \sum_{r=1}^n \sum_{s=1}^n (X_{rj} - X_{sj})^2 = (X_r - X_s)'(X_r - X_s) \quad (1)$$

The clusters were characterized with respect to variables used to derive them, i.e., relating the new categorical variable to original ' p ' variables in X .

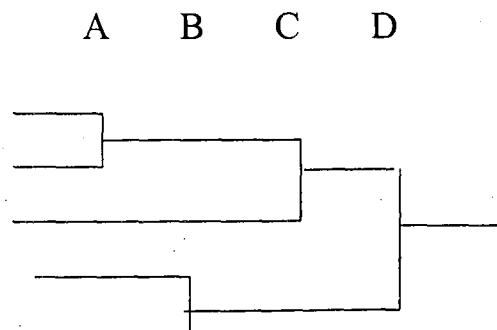


Figure 4.1 Schematic diagram representing hierarchical cluster analysis.

Hierarchical technique of cluster analysis has been used in the present study. This approach proceeds sequentially such that at each step only one object or a group of objects change group membership and the groups at each step are nested with respect to previous groups. Thus once an object has been assigned to a group it is never removed from the group later on in the clustering process.

This method produces a complete sequence of cluster solutions beginning with n clusters (one for each object) and ending with one cluster containing all ' n ' objects. The method followed in hierarchical approach is agglomerative, complete linkage method. In agglomerative approach, the process moves sequentially from n clusters (n objects) to one cluster. The complete linkage or farthest neighbor measure of proximity between two groups is derived from the weakest link between objects in the two groups. For a dissimilarity type measure such as Euclidean distance, the largest possible distance between objects in the two groups is used to represent the proximity between the groups. To take care of the mixture of categorical and interval scale variables, the variables were standardized using pivotal condensation method.

The selection of the stage of selection of clusters is based on the optimality criterion value. The optimality criterion value is the closest proximity value among the groups at that stage of the process as determined by complete linkage method. In each case the process begins with the standardized Euclidean distance matrix. At each step in the process, the revised proximities are obtained using formula:-

$$P_{tu} = \alpha_r p_{ru} + \alpha_s p_{su} + \beta p_{rs} + \gamma |p_{ru} - p_{su}| \quad (2)$$

Where t is the reference for the group resulting from the combining of groups r and s .

U is the reference for some other group other than r or s

α_s, β, γ are coefficients that depend on the proximity measures

The complete linkage method employs $\alpha_r = \alpha_s = 1/2, \beta=0, \gamma=1/2$

4.2.2 Cost Components of Dairy Farming Systems

The costs involved in dairy farming consisted of the following elements:

- Milk production
- Raising of dairy animals
- Forage production and / or feed purchased for dairy animals

Total costs consisted of cash costs, depreciation, interest on fixed capital, and opportunity costs for farm-owned factors of production (family labour, own land, own capital in the form of fixed assets and equipments). The estimation of these opportunity costs needs to be interpreted with caution because the potential income of farm owned factors of production in alternative uses is difficult to determine. In the short run, the use of own production factors on a family farm can provide flexibility in the case of low returns when the family can choose to forgo income. However, in the long run, opportunity costs must be considered. To indicate the effects of opportunity costs, they were shown separately from the other costs in most of the figures presented in the study.

For the estimations and calculations of various costs, the following assumptions were made:

a) Herd size

It was assumed that the farmer maintains the same herd throughout the year. Further, it is assumed that the farmer himself raises all the animals and do not go for their purchase. This is to avoid complications due to capital costs of animals purchased have not been considered in this analysis. This is based on the logic that the cost of rearing calves till they are in lactation will balance the capital costs of the milch animals. The net depreciation on milch animals was considered to be zero assuming that the animals appreciate in the first three lactations and thereafter remain neutral in the fourth and fifth lactations and then depreciate in the subsequent lactations.

The standard animal unit¹ was derived to determine the maintenance cost and returns of standard animal unit for milk production in the farms.

b) Labour costs

The hired labour costs were calculated based on the existing daily labour wage rate in the region whereas the average wage rate for permanent farm labourer in the region was used to impute the value for unpaid family labour.

c) Land costs

The rents paid by the farmers were used for rented land. Rent prices as charged by the local authorities for the farmers were used for owned land.

d) Capital costs

Owned capital in the form of fixed assets, machinery and equipments used for dairying without land was considered as capital. The existing savings bank interest rate of 4.0 percent was used for interest on fixed capital.

e) Depreciation

Machinery and buildings were depreciated using a straight-line schedule on purchase prices with a salvage value of zero. The rate of depreciation was thus based on the life span of the particular machinery or building, which was taken as standards for the study area.

f) Adjustment of fat content

All cost components and forage requirements were established to produce FCM (fat corrected milk with 4.0% fat). The milk output per farm household was adjusted to 4 percent fat.

¹ Standardization of herd size of the farm households were done using the standards given by Patel *et al.* (1982)

Milch buffalo	1.30	Local cow young animal	0.50
Milch crossbred cow	1.40	Buffalo bull	1.00
Milch local cow	1.00	Crossbred bull	1.00
Buffalo heifer	0.75	Local cow bull	1.00
Crossbred heifer	0.75	Buffalo calf	0.33
Local cow heifer	0.75	Crossbred calf	0.33
Crossbred young animal	0.75	Local cow calf	0.33

$$\text{FCM milk} = (\text{milk production} * \text{fat in \%} * 0.15) + (\text{milk production} * 0.4)^2 \quad (3)$$

4.2.3 Cost of Milk Production

The total costs of the dairy enterprise are related to the total returns of the dairy enterprise including milk and non-milk returns (cow dung returns). Therefore, the non-milk returns have been subtracted from the total costs to show the cost of milk production only that can be compared with the milk price. This has been done separately for the three different types of milch animals viz. buffaloes, crossbred cows and local cows.

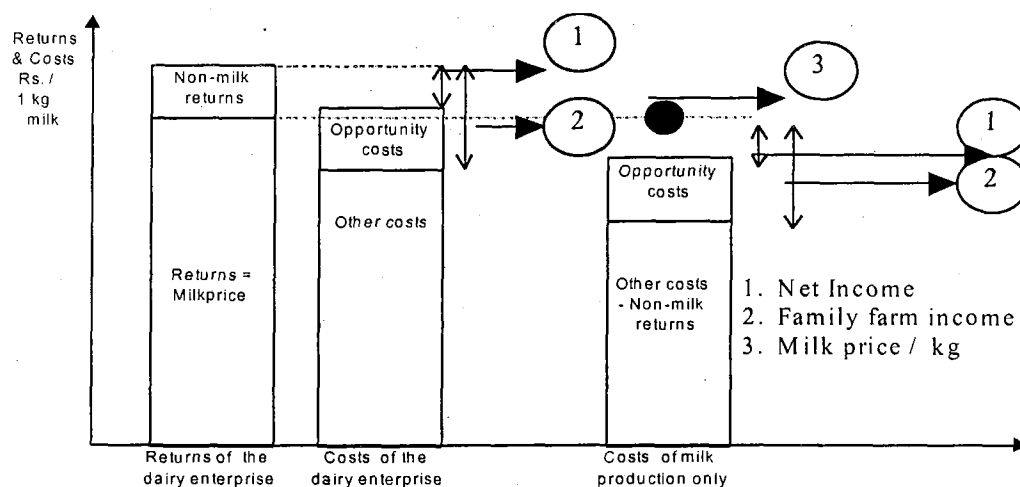


Figure 4.2 Schematic diagram of computation of costs and returns of milk production.

Other costs in Figure 4.2 refer to costs of dairying minus non-milk returns (cow dung returns). Costs of dairying includes fixed costs such as depreciation and interest on fixed assets and variable costs such as feed and fodder costs, labour costs, veterinary costs, miscellaneous expenses.

Opportunity costs mentioned in the figure given above refer to costs for using own production factors (owned land * regional land rents, family working hours * farm wages, capital: own capital * 4%).

4.2.3.1 Returns of the dairy enterprise

The returns of the dairy enterprise were obtained species-wise which consisted of total milk production at the farm level and other returns such as

² Hemme (2000).

returns from cow dung. The valuation of the milk returns was based on the prevailing market prices of milk and of cow dung used as fuel or manure.

4.2.3.2 Components of costs

a) Fixed costs

Fixed costs in dairying are the costs, which are incurred irrespective of whether dairy operations are carried out or not. Depreciation and interest on capital (fixed assets, machinery and equipments) excluding land were considered as fixed costs. Though some studies consider family labour as fixed costs but since here the labour used is being allocated to dairy of the total family labour employed based on actual hours worked by the family in dairying, hence it is considered as variable costs.

b) Variable costs

The variable costs are those costs, which vary with the level of production. The costs on feed and fodder, labour, veterinary input and miscellaneous expenses were considered in this group. The costs on feed and fodder included cost of home grown as well as purchased feeds and fodders. In case of homegrown feeds and fodder, the actual expenses in cost of cultivation of the feeds and fodder crops by the farmer were used in determining the costs. For purchased feeds and fodder, the costs were based on the rates at which the farmer purchased them.

c) Labour costs and returns

Labour costs: Paid wages and opportunity costs for own labour of the dairy enterprise.

Returns to labour: Returns to labour were net income of dairying plus labour costs (wages paid plus opportunity costs of labour) divided by total labour input. Total labour input refers to the hours worked by family and hired labour. Labour costs in family farms was determined on the basis of existing wage rate of permanent farm labour and hourly wage rate of farm labourer in the

study area in case of hired labour. However, it needs to be interpreted with caution as there may not be alternative employment available in the area at the existing wage rate at that point of time.

d) Interest on fixed assets owned

Paid interests and opportunity costs for own capital (excluding land capital). For equity, present bank interest rates on savings at 4.0 percent per annum.

$$\text{Interest on fixed assets owned} = \text{Non-land assets} * \text{interest rate (equity} * 0.04). \quad (4)$$

e) Cash and non-cash costs

i) Cash Costs: Cash costs for purchase of feed, fertiliser, seeds, fuel, maintenance, land rents, interest on liabilities, wages paid, veterinary and medicine, etc

ii) Non-cash costs

Depreciation: Depreciation of buildings and machinery used in dairy farming. The mean depreciation rates of buildings based on their life period was found to be 5 percent and that of machinery 5 and equipments 10 percent per annum.

Opportunity costs: Costs for using own production factors (land owned, family labour input, equity).

4.2.4 Cost of Crop Cultivation

The cost of crop cultivation for various dairy farming systems was estimated by using the concept proposed by the estimation committee on cost of cultivation, 1981, Directorate of Economics and Statistics, Govt. of India. As per their guidelines, the costs of crop cultivation were categorized as cost A1, A2, B1, B2, C1, C2.

Cost A1 = all actual expenses in cash and kind incurred in production by farmer

Cost A2 = cost A1 + rent paid for leased in land

Cost B1 = cost A1+ interest on value of owned capital assets (including land)

Cost B2 = cost B1 + rental value of owned land + rent paid for leased in land

Cost C1 = cost B1 + imputed value of family labour

Cost C2 = cost B2 +imputed value of family labour

Depreciation and interest on working capital was determined separately and added to cost C2 to get full economic costs.

To allocate the costs of joint products such as byproducts of wheat or paddy, e.g., wheat straw, paddy straw, the ratio that existed in the income of the main and byproduct was used in apportionment of their costs of production.

4.2.5 Whole Farm Accounting

The whole farm accounting was done at gross, net family and net returns on the basis of following calculations:

Gross family returns = Gross crop returns + Gross dairy returns + Net non-farm or other farm income

Total cash farm expenses = Variable costs + Paid wages + Paid land rent + Paid interest on liabilities

Net cash farm income = Total cash farm receipts – total cash farm expenses

Family farm income = Net cash farm income – depreciation + non market crop receipts + non market dairy receipts

Net income = Net cash farm income – depreciation – opportunity costs (calculated interest on own capital + calculated rent on owned land + calculated cost for own family labour)

Family income = Family farm income + Non farm and other farm receipts, e.g., working as farm labourer or part-time artisan job.

4.2.6 Evaluation of Dairy Farming Systems

Scientists have proposed different methods for evaluating efficiency of production of a firm using both deterministic and stochastic frontier modeling. Reviews and description of these methods are found in Farrell (1957), Aigner and Chu (1968), Timmer (1971), Afriat (1972), Richmond (1974), Schmidt (1976), Aigner *et al.* (1977), Meeusen and Broeck (1977), Førsund, Lovell and Schmidt (1980, 1986), Bauer (1990), Battese (1992), Lovell (1993) and Greene (1993). Keeping in view the variations in the variables of the present study and the developments in the field of efficiency determination, it was decided to use stochastic frontier modeling for the purpose. The stochastic frontier model permits the estimation of standard errors and tests of hypothesis using traditional maximum-likelihood methods, which was not possible with the earlier deterministic models because of the violation of certain Maximum likelihood regularity conditions (Schmidt, 1976). Thus, various identified Dairy farming systems were evaluated in terms of efficiency of milk production by the farm households across each one of them using stochastic frontier production function approach.

4.2.6.1 Frontier production function model

Michael Farrell (1957) in his paper on "The measurement of productive "efficiency" first described a methodology to measure economic, technical and allocative efficiency. According to Farrell, technical efficiency is associated with the ability to produce on the frontier isoquant, while allocative efficiency refers to the ability to produce at a given level of output using the cost-minimizing input ratios (Fig. 4.3).

Alternatively, technical inefficiency is related to deviations from the frontier isoquant, and allocative inefficiency reflects deviations from the minimum cost input ratios. Thus economic efficiency, which is equal to the product of technical and allocative efficiency, is defined as the capacity of a firm to produce a predetermined quantity of output at minimum cost for a given level of technology (Farrell, 1957; Kopp and Diewert, 1982).

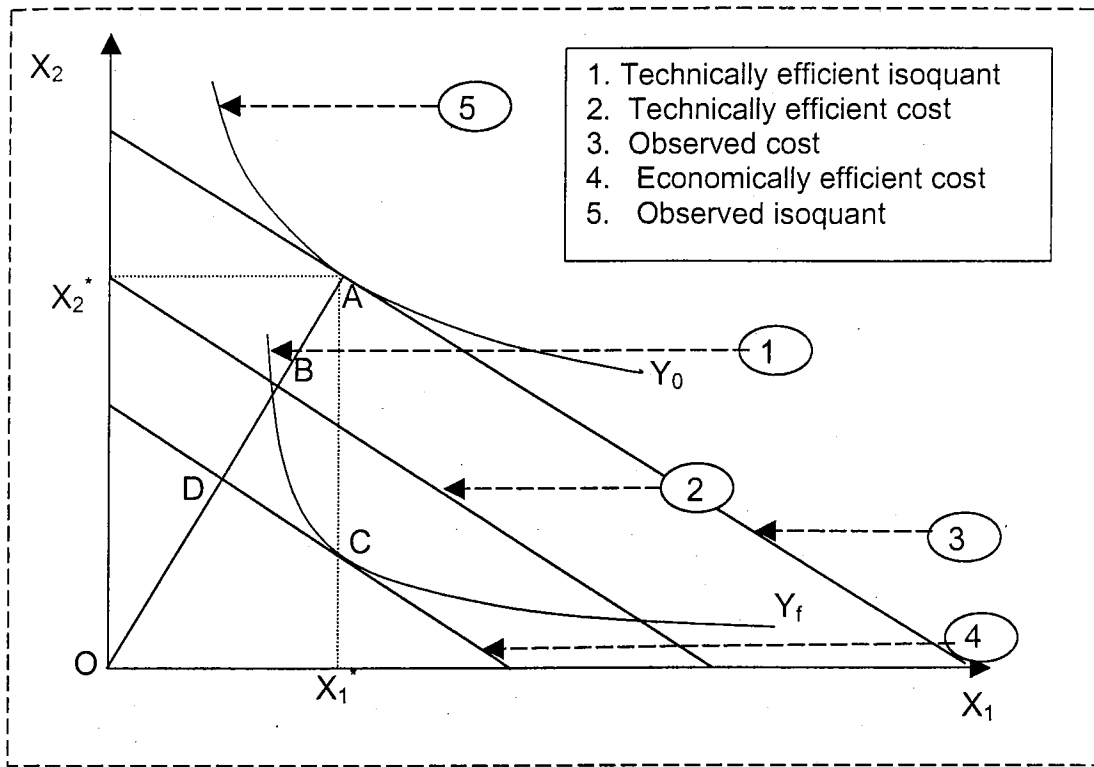


Figure 4.3 Schematic diagram showing frontier and observed levels of output and costs of milk production.

For simplicity, consider milk output (Y) in terms of milk yield per animal per year is expressed in terms of two inputs, say green fodder (X_1) and labour (X_2). Let point A be the combination of observed levels of green fodder X_1^* and labour X_2^* yield observed output of milk yield Y_0 for a given farm, and isoquant-1 be the technically efficient or frontier isoquant associated with output Y_f . The isocost lines 2, 3, 4 reflect observed, technically efficient and economically efficient cost levels while points B and C are, respectively, the TE and EE combinations of inputs X_1 and X_2 associated with output Y_0 .

The technical, allocative and economic efficiency indices were given by:

$TE = OB/OA$; $AE = OD / OB$; $EE = TE * AE = OD / OA$ on the basis of the equation of deterministic production frontier given by

$$Y_j = g(X_i; \beta); X_1 / X_i = k_i \quad (5)$$

Where k_i is the ratio of the observed levels of inputs X_1 and X_i ($i > 1$) at output $\check{y}$. Assuming the production frontier above is self dual, e.g., Cobb-Douglas, the corresponding cost frontier is expressed as:

$$C = h(P, Y; \alpha) \quad (6)$$

Where, C is the minimum cost to produce output Y , P is a vector of input prices, and α is a vector of parameters. The system of minimum cost input demand equations could be obtained by differentiating the cost frontier with respect to each input price applying Shepherd's lemma. Thus the economic efficient input quantities could be obtained from the farm's input prices P and output quantity $\check{y}$.

However, this model was criticized by Schmidt (1986) on the ground that efficiency measures obtained from deterministic models are affected by statistical noise. Subsequently, Bravo-Ureta and Reiger (1991) used a stochastic production frontier in order to remove the random element from the efficiency component before deriving the various efficiency indices. Hence, in the present analysis, the technical efficiency was determined by considering the stochastic frontier translog and Cobb Douglas production function approach. The input variables specified for the frontier milk production function at farm household level were green fodder, dry fodder, concentrates, machinery, buildings, veterinary expenses, labour, miscellaneous expenses per animal unit per year. Different functions were fitted for different species of milch animals. To take care of variations in type of fodder fed at different times and the mixture of fodder fed; the feed inputs were standardized to nutrition units in terms of a feed index developed from standard DCP and TDN content in the feeds and fodder. Further, the examination of correlation matrices suggested that some variables (various forms of feeds and fodders and forms of labour) tended to move together rather significantly, hence to avoid the problem of multi-correlation, the indexes of feed and fodder and labour units were used for specification of the model. The labour was considered in mandays and depreciation on machinery and building, veterinary expenses, miscellaneous expenses in rupees, as no substitute of

physical terms was available. The output variable was taken as milk production per animal unit per lactation in litres. Some of the important variables such as herd size, order of lactation of milch animals, stage of lactation of milch animals have been purposively eliminated as the purpose of the model was estimation of efficiency of milk production at farm household level, and the difficulty in incorporating these information at an aggregated milk production function. Hence it was assumed that the eliminated variables were not significantly varying between farm households in the dairy farming systems. Though there were a number of outputs, which are produced along with milk, it was very difficult to quantify them in a specific scale of measure of production in the production function analysis approach. Hence only milk production was considered as the output of the farm.

Two different functional forms were analyzed, viz., the Cobb-Douglas and the translog. The Cobb-Douglas production function as the sole model or in combination with linear and / or quadratic models for milk production by crossbreds and / or locals and /or buffaloes and /or specific breeds of cattle / buffaloes was used by Singh (1970), Jacob *et al.* (1971), Kumar and Raut (1971), Dass and Sidhu (1973), Kumar *et al.* (1973), Aul *et al.* (1974), Chikkara and Gangwar (1975), Kumar *et al.* (1975), Sankhayan and Joshi (1975), Ram (1977), Singh (1977), Rao (1978), Pandey *et al.* (1980), Bodkhe (1982), Kumar (1991) and Rajendran and Prabakaran (1993).

Cobb Douglas form of function was estimated with the specification

$$\text{Log } Y_{kl} = \alpha + \sum_{i=1}^8 \beta_{il} \log X_{ikl} + \varepsilon_{ikl} \quad (7)$$

$$\varepsilon_{ikl} = u_{ikl} + v_{ikl}; \quad u \leq 0 \quad (8)$$

The specification of translog milk production function for stochastic frontier approach can be stated as under

$$\text{Log } Y_{kl} = \beta_0 + \sum_{i=1}^8 \beta_{il} \log X_{ikl} + \frac{1}{2} \sum_{i=1}^8 \sum_{j=1}^8 \gamma_{ijl} \log X_{ikl} \log X_{jkl} + \varepsilon_{ikl} \quad (9)$$

$$\varepsilon_{ikl} = u_{ikl} + v_{ikl} ; \quad u_{ikl} \leq 0, \quad l=1,2, \quad l \neq 3,4. \quad (10)$$

It was not possible to estimate the translog frontier model for crossbred and local cows due to the number of sample observations being less than the number of parameter coefficients. A direct estimate of translog involves too many parameters hence not highly reliable.

The description of various variables used in the models is stated as under:

i, j = independent input variables used in the model (1, 2, ..., 8);

k = sampled 180 farms of the study area (1, 2, ..., 180);

l = milch animals species used in the study (1, 2, 3, 4) namely standard milch unit, buffalo, crossbred cow, local cow;

ε_{ikl} is a stochastic error term consisting of two independent elements. The symmetric component ' v_{ikl} ' takes care of measurement error and random variation in output due to factors outside the control of one farm, such as weather, unexpected incidences and diseases together with the combined effects of unspecified input variables in the production function. Aigner *et al.* (1977) assumed that v_i 's were independent and identically distributed (i.i.d.) normal random variables with mean zero and constant variance, σ_v^2 , independent of the u_{ikl} 's, which were assumed to be i.i.d. exponential or half-normal random variables.

Y_{kl} = total milk produced in k^{th} farm per l^{th} milch species per annum

X_{1kl} = Index for green fodder used in k^{th} farm per l^{th} milch species per annum

X_{2kl} = Index for dry fodder used in k^{th} farm per l^{th} milch species per annum

X_{3kl} = Index for concentrate used in k^{th} farm per l^{th} milch species per annum

X_{4kl} = hired labour used in k^{th} farm for dairy management activities (number of man days) per l^{th} milch species per annum

X_{5kl} = unpaid family labour used in k^{th} farm for dairy management activities (number of man days) per l^{th} milch species per annum

X_{6kl} = depreciation and interest on fixed assets (Rs.) per l^{th} milch species per annum

X_{7kl} = variable cost of veterinary expenses (Rs.) per l^{th} milch species per annum

X_{8kl} = variable cost of miscellaneous expenses (Rs.) per l^{th} milch species per annum

γ_{ijl} = total variations in output from the frontier which is attributable to technical inefficiencies, i.e., $\gamma = (\delta_l^2 / \delta_j^2)$; $0 \leq \gamma \leq 1$

β_{il} = Parameters of regression coefficients of the i^{th} variable for the l^{th} species

Standard milch units were determined on the basis of the following standard units: milch buffalo: 1.3; milch crossbred cow: 1.4; milch local cow : 1.

The total milk produced per annum per milch unit of each of the l^{th} species was derived on the basis of data collected for three seasons (summer, rainy, winter) for each of the species of milch animal per day multiplied by the number of days per season (summer: 125 days; rainy: 120 days; winter: 120 days).

The quantity of feeds and fodder per milch unit of the l^{th} species was derived on the basis of data collected for three seasons based on quantity of feed and fodder fed to each of the milch unit per day multiplied by the number of days per season.

The family and hired labour per milch unit of the l^{th} species was derived on the basis of data collected on labour used per day for all the dairy operations multiplied by the number of days in a year and apportioned to per milch unit of the l^{th} species separately.

The quantity of feeds and fodders fed were converted to DCP and TDN equivalents using the standardized conversion units of different types of Indian feed and fodder as per the standards given by Sen and Ray (1971). Estimates of feed index were worked out for the feeds and fodder for the individual farms using the formulae $DCP + (TDN/7.5)$ given by Kumar and Singh (1980).

The model defined by equation (7) and (9) is called the stochastic frontier production function because the output values are bounded above by the stochastic (random) variable, $\exp(x_i\beta + v_i)$. The random error v_i can be positive or negative and so the stochastic frontier outputs may vary about the deterministic part of the frontier model, $\exp(x, \beta)$. The basic features of the stochastic frontier model are illustrated through two-dimensional diagram given in Figure 4.4.

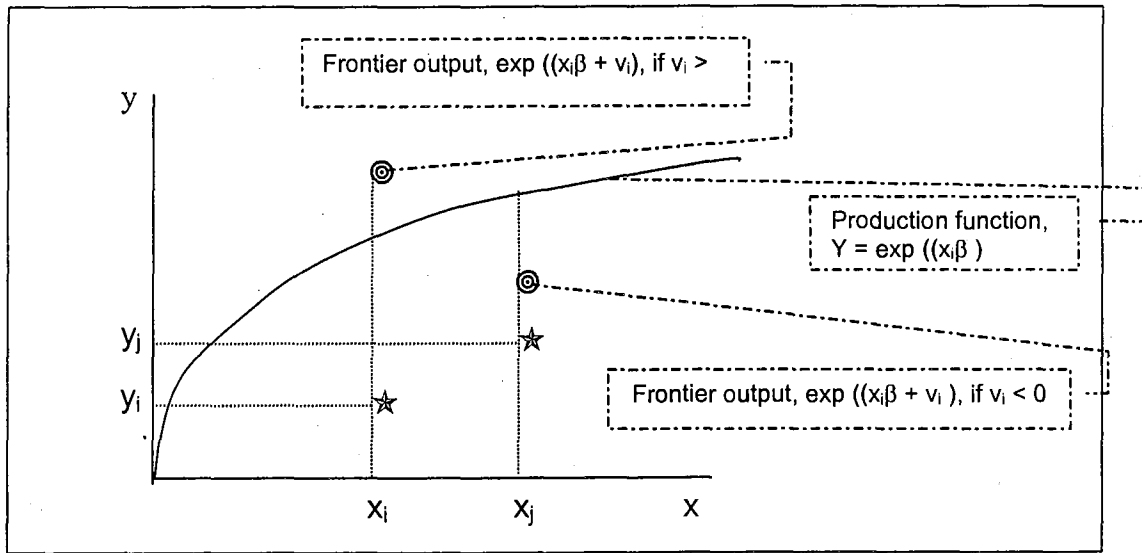


Figure 4.4 Diagram depicting stochastic frontier and observed output.

The inputs are represented on the horizontal axis and the outputs on the vertical axis. The deterministic component of the frontier model, $y = \exp(x\beta)$, is drawn assuming diminishing returns to scale apply. The observed input-output value is indicated by the point marked with ★ above the value of x_i representing x_i input required to produce y_i output. The value of the stochastic frontier output, $y_i^* \equiv \exp(y_i + u_i) \equiv \exp(x_i\beta + v_i)$ is marked by the point ⊙ above the production function because the random error v_i is positive.

Similarly, the j^{th} farm uses the levels of inputs, x_j and produces the output, y_j . However, the frontier output, $y_j^* \equiv \exp(y_j + u_j) \equiv \exp(x_j\beta + v_j)$ is below the production function because the random error, v_j is negative. Of course the stochastic frontier outputs, y_i^* and y_j^* are not observed because the random errors v_i and v_j are not observable. However, the deterministic part of the stochastic frontier model is seen to lie between the stochastic frontier outputs. The observed outputs may be greater than the deterministic part of the frontier if the corresponding random errors are greater than the corresponding inefficiency effects, i.e., $y_i > \exp(x_i\beta)$ if $v_i > u_i$. The parameters of the stochastic frontier production function, defined by the equation (7) can be estimated using either the maximum-likelihood method (ML) method or using Corrected Ordinary least Square (COLS) method. The finite sample properties of the half-normal frontier model were investigated in a Monte Carlo experiment in Coelli (1996), in which the ML estimator was found to be significantly better than the COLS estimator when the contribution of the technical inefficiency effects to the total variance term is large. Computer software, such as the LIMDEP econometric package (Greene, 1992) and the FRONTIER program (Coelli, 1992,1994), both of which automate the ML method for estimation of the parameters of stochastic frontier models are now available easily to estimate the parameters using the computationally demanding ML method. Hence FRONTIER program 4.1 was used in the present analysis to estimate the ML estimates of the frontier model of milk production by the dairy farming systems.

In order to deal with the case of the half-normal distribution for the technical inefficiency effects, Aigner *et al.* (1977) derived the log likelihood function for the model, defined by equation (7), in which u_i is assumed to be i.i.d. Truncations (at Zero) of random variable $[N(0, \sigma^2)]$, independent of the v_i s which are assumed to be i.i.d. They also expressed the likelihood function in terms of the two variance parameters, $\sigma_s^2 \equiv \sigma^2 + \sigma_v^2$ and $\lambda \equiv \sigma / \sigma_v$. Battese and Corra (1977) suggested that the parameter, $\gamma \equiv \sigma^2 / \sigma_s^2$, be used because it has a value between zero and one, whereas λ could be any non-zero value.

They showed that the log-likelihood function in terms of this parameterization is equal to

$$\ln(L) = -N/2 \ln(\pi/2) - N/2 \log(\sigma_s^2) + \sum \ln[1 - \Phi(z_i)] - 1/2(\sigma_s^2) \sum (\ln y_i - x_i\beta)^2 \quad (11)$$

Where, z_i is $(\ln y_i - x_i\beta) / \sigma_s \sqrt{\gamma / (1-\gamma)}$ and $\Phi(\cdot)$ is the distribution function of standard normal random variable.

The ML estimates of β , σ_s^2 and γ can be obtained by finding the maximum of log likelihood function defined in the above equation. The ML estimators are consistent and asymptotically efficient (Aigner *et al.*, 1977).

Accordingly, the parameters for this model were obtained by using the software program FRONTIER version 4.1. This program uses a three-step estimation procedure:-

1. The first step involves calculation of the OLS estimators of β and σ_s^2 . These are unbiased estimators of the parameters in equation 8.3, with the exception of the intercept, β_0 and σ_s^2 .
2. The likelihood function is evaluated for a number of values of γ between zero and one. In these calculations, the OLS estimates of σ_s^2 and β_0 are adjusted by $\sigma_s^2 = \sigma_{OLS}^2 [\pi(T - K)] / [T(\pi - 2\gamma)]$ and $\beta_0 = \beta_{0(OLS)} + \sqrt{2\gamma\sigma_s^2} / \pi$, respectively. The OLS estimates are used for the remaining parameters in β .
3. The final step uses the best estimates (that is, those corresponding to the largest log-likelihood value) from the above step as starting values in Davidon Fletcher Powell (DFP) iterative maximization routine that obtains the ML estimates when the likelihood function attains its global maximum.

4.2.6.2 Estimation of technical efficiency

The mathematical expectation of the technical efficiency of the i^{th} farm given as,

$$TE_i = \exp(-u_i) \quad (12)$$

This involves the technical inefficiency effect, u_i , which is unobservable. Even if the true value of the parameter vector, β , in the stochastic frontier model (1) were known, only the difference, $e_i \equiv v_i - u_i$ could be observed. The best predictor for u_i is the conditional expectation of u_i , given the value of $v_i - u_i$. The result was first recognized and applied in the stochastic frontier model by Jondrow, *et al.* (1982), who derived the result

$$E[u_i | e_i] = -\gamma e_i + \sigma_A \{ \Phi(\gamma e_i / \sigma_A) / (1 - \Phi(\gamma e_i / \sigma_A)) \} \quad (13)$$

Where, σ_A is $\sqrt{\gamma(1-\gamma)\sigma_s^2}$; e_i is $\ln(y_i) - x_i\beta$; and $\phi(\cdot)$ is the density function of a standard normal random variable.

The ML estimator for the technical efficiency of the i^{th} farm was obtained by substituting the ML estimators for the relevant parameters in the above equation.

Battese and Coelli (1988) pointed out that the best predictor of $\exp(-u_i)$ is obtained by using,

$$E[\exp(-u_i) | e_i] = [1 - \Phi(\sigma_A + \gamma e_i / \sigma_A) / (1 - \Phi(\gamma e_i / \sigma_A))] * \exp(\gamma e_i + \sigma_A^2 / 2). \quad (14)$$

This is a special case of the general result that the expectation of a non linear function of a random variable is not equal to the function of the expectation of the random variable {i.e., $E[g(x)] \neq g([E(x)])$ for a non-linear function, $g(\cdot)$ }.

The technical efficiency predictor implemented in the FRONTIER 4.1 program was obtained by replacing the unknown parameters in the above equation with their ML estimates. The computer program calculates predictions of the individual farm technical efficiencies from estimated stochastic production frontiers, and predictions of individual farm cost efficiencies from estimated stochastic cost frontiers. The measures of technical efficiency relative to the production frontier (9) and of cost efficiency relative to the cost frontier (17) are defined as:

$$EFF_i = E(Y_i^* | U_i, X_i) / E(Y_i^* | U_i = 0, X_i) \quad (15)$$

Where Y_i^* is the production (or cost) of the i^{th} farm, which will be equal to Y_i when the dependent variable is in original units and will be equal to $\exp(Y_i)$ when the dependent variable is in logs. In the case of production frontier, EFF_i will take a value between zero and one, while it will take a value between one and infinity in the cost function case.

To test the significance of the inefficiency estimate u_i , one-sided generalized likelihood ratio test was used. The generalized likelihood ratio test requires the estimation of the model. Under the null hypothesis, $H_0 : \gamma = 0$, the model is equivalent to the traditional average response function, without the technical inefficiency effect, u_i .

The test statistic is calculated as

$$LR = -2\{\ln[L(H_0)/L(H_1)]\} = -2\{\ln[L(H_0)] - \ln[L(H_1)]\} \quad (16)$$

Where $L(H_0)$ and $L(H_1)$ are the values of the likelihood functions under the null and alternate hypothesis, H_0 and H_1 , respectively.

If H_0 is true, the test statistic LR has asymptotic distribution which is a mixture of chi-square distributions, namely $1/2\chi_0^2 + 1/2\chi_1^2$ (Coelli, 1995) and reject $H_0 : \gamma = 0$ in favour of $H_1 : \gamma > 0$ if LR exceeds $\chi_1^2 (2\alpha)$.

4.2.6.3 Frontier cost function model

The stochastic Cobb-Douglas functional form of cost function is chosen despite its well-known limitations because the methodology employed requires that the production function used be self-dual. Besides Cobb-Douglas functional form has been used widely in farm efficiency analysis for both by developing and developed countries (Kalirajan and Flinn, 1983; Battese *et al.* 1989; Battese, 1992; Bravo-Ureta and Pinheiro, 1993; Parikh and Shah, 1996). Moreover, recent work suggested that choice of functional form might not have a significant impact on measured efficiency levels (Ahmad and Bravo-Ureta, 1996).

A stochastic Cobb-Douglas cost frontier, is of the form:

$$\text{Log } C_{kj} = \beta_0 + \sum_{i=1}^4 \beta_i \log X_{ikj} + v_{kj} + u_{kj}, i = 1, 2, 3, 4. \quad (17)$$

Where C_k is the observed cost of production for the k^{th} farm season-wise;

X_{1k} is the output quantity of milk produced (in litres) in the k^{th} farm for the j^{th} species

X_{2k} is the price index of the green fodder

X_{3k} is the price index of the dry fodder

X_{4k} is the price index of the concentrates at the k^{th} farm

'j' refers to the species, standard milch unit, buffalo, crossbred, local cow.

β_i is a vector of known parameters to be estimated; and

u_{kj} is a non-negative cost inefficiency effect (which is assumed to have a half-normal or truncated normal distribution).

However, its worth mentioning that the cost frontier functional form as stated above is not completely the dual of the production frontier function as given by equation (7). This is because the prices of family and hired labour, fixed capital costs, working capital costs being constant in the study area have not been included in the model. Though it is well known that the imputed value of labour or capital varies across systems, it is difficult to measure it, hence they have been eliminated from the analysis of cost functions. That may of course lead to biased interpretation of economic efficiency, but within the limitations of the research, the economic efficiency analysis has been done for the milk production species wise of the different dairy farming systems.

Hence the economic efficiency estimates based on the model (17) above are biased upwards. Though the opportunity costs of labour and capital varies for different farm households it is difficult to compute them due to the lack of information. Hence the interpretation of U_i in a cost function is less clear, with both technical and allocative inefficiencies possibly involved. Thus efficiencies relative to the cost frontier can be referred to as "cost efficiencies" rather than economic efficiencies. The exact interpretation of these cost efficiencies will depend upon the particular application.

4.2.6.4 Estimation of economic efficiency

The inefficiency effect, u_{kj} is added to the cost frontier, as cost function represents minimum cost. The u_{kj} 's provide information on the level of the cost efficiency or the overall economic efficiency of the k^{th} farm. This can be calculated as the ratio of frontier minimum cost (with $u_{kj} = 0$) to the observed cost, which can be shown equal to:

$$EE_k = \exp (-u_{kj}) \quad (18)$$

Where, EE_k refers to Economic efficiency of the k^{th} farm.

The total milk produced per annum per milch unit of each of the l^{th} species was derived on the basis of data collected for three seasons (summer, rainy, winter) for each of the species of milch animal per day multiplied with number of days per season (summer: 125 days; rainy: 120 days; winter: 120 days).

The weighted price index of green fodder, dry fodder and concentrates were determined on the basis of the following formulae:

$$X_{jk} = \sum_i (C_{ijk} * Q_{ijk}) / \sum_i Q_{ijk} \quad (19)$$

Where,

X_{jk} = Price index of j^{th} feed in k^{th} farm

C_{ijk} = Cost of production per quintal of i^{th} type of j^{th} feed in k^{th} farm

Q_{ijk} = Quantity in quintals of i^{th} type of j^{th} feed in k^{th} farm fed per milch animal

j = 1,2,3, refers to green fodder, dry fodder and concentrates, respectively.

4.2.7 Multiobjective Optimization

In the farm sector, farm activities and the environment surrounding it or processes generally decide the farming systems. Farming systems focuses on alternative activities. Actual and real decision making problems are almost invariably characterized by multiple conflicting objectives. Nevertheless, in the

traditional single objective model, total gross margin maximization for example, is implicitly assumed to be the only objective and other objectives are set into the absolute constraints. This method can be acknowledged as rational only if other objectives can be fully met or are relatively negligible. Otherwise, the problem has to be solved with one of the multi-objective decision making methods. Generally farm households in India, where farming is more a way of life, have more than one objective or goal. These cannot be fully met but are also too important to be neglected in their farm planning. The major objectives include:

- Maximizing expected total gross margin
- Minimizing cost
- Maximizing family labour use with minimum amount of leisure
- Meeting working capital needs
- Financial self support
- Ensuring the farm family's survival
- Minimizing the risk and bringing stability in family farm income through diversification, flexibility and income dispersion
- Meeting home consumption demand for certain food items such as cereals, milk, pulses, jaggery, oil, vegetables, etc.
- Preferences for productive technology for crops, livestock, etc.

The total number of objectives were attempted to minimize by testing to determine whether the accomplishment of one objective may actually satisfy or even dominate the accomplishment of another. Thus the two objectives of maximizing expected total gross margin and minimizing cost were replaced by the single objective of total gross margin maximization. It is also possible that the achievement of one objective makes the importance or preference of another negligible. Thus the family farm's risk averse behaviour is greatly concerned with the anxiety that he may not be able to meet the requirements for his family's survival. If he can meet these requirements, the importance of

risk aversion goal will be much decreased (Binswanger, 1980). Such logic enables us to replace the two objectives with one objective, i.e., increasing the probability of the family's survival. Similarly the objective of meeting working capital needs depends upon the extent of credit availability and the preference of farmer to go for credit. Thus if the goal of financial self support in terms of how much he prefers to be dependent on external credit is fixed, the objective of meeting working capital needs is achieved. Generally small farmers are averse to be dependent too much on credit and hence prefer financial self-support to a great extent. Some of the objectives can be considered as constraints under given set of conditions. Thus, the need to meet home consumption demands from farm produce could be considered as a strict constraint under the given conditions of time, space and location. The objective of selective choice of productive technology has something to do with choice of activities / processes, therefore, can be undertaken only in terms of selective incorporation of the concerned activities selectively into the desired farm plan model. Thus the last objective of preferences for productive technology for crops, livestock, etc. could be taken care of. Thus the nine objectives stated above could be reduced to four goals:

Goals

- Maximizing expected total gross margin
- Ensuring farm family's survival with a specified level of probability
- Achieving desired Financial self support
- Maximizing family labour use with minimum amount of leisure

The strict constraints considered in the model were:

- Maximum land availability
- Maximum farm family labour availability
- Maximum non farm employment availability
- Minimum production constraint for home consumption
- Maximum credit availability

- Minimum crop residue production for livestock feeding and cow dung for home use as fuel and household use

4.2.7.1 Measurement of farmers' preferences

One of the common characteristics of farming in the study area is the strong connection of farm business with family considerations. Thus family consumption considerations and the economic and social criteria are equally important in taking a decision and often tend to conflict directly with decisions concerning productive investment in the farm business. Hence an important element of conservatism is added to family farming, which often policy planners and researchers interpret as non-innovativeness or laggardness. Farm households in the study area were also characterized by the existence of disguised and real unemployment. With the type of cropping pattern being practiced, mechanization of crop operations has been forced in Haryana due to lack of sufficient labor force in peak seasons, which in turn has led to the unemployment of family labour and underemployment in off season as only limited opportunities are available as far as off-farm employment is considered. Though dairying is a labour intensive enterprise, it is being practiced in the study area mostly as a supplementary enterprise due to the requirement for multiple products by the farm household (food, fuel, manure, liquidity, culture, customs). Hence the paradox of preference of unemployment vis-à-vis potential employment in dairying is noteworthy. The goal-programming model is expected to partly answer this question.

Another characteristic of the farms is with respect to combination of enterprises, which is based on optimizing their farm organization according to their own criteria, which varies from system to system. The study of evaluating the efficiency of the dairy farming systems in the present investigation has considered only milk production and suggests further potential to increase efficiency in terms of inputs reallocation or change in resource productivity. However, the holistic multidisciplinary approach is necessary to suggest strategy changes, in order to take care of the deficiency in measurement of stochastic frontier approaches to account for rapid change in technology and

demand, price and productivity relationships. The interaction of various factors that decide the farmers' choice is highly fuzzy and complex. However, linear goal programming can partly take care of such problems through its consideration of multiple goals explicitly.

To measure the preferences of the farmers quantitatively, Analytic Hierarchy process (AHP) was employed. AHP is a systematic procedure for representing the elements of any problem, hierarchically, i.e., setting priorities in steps. The relative importance of various criterion namely maximizing profitability, minimizing risk, leisure preferences and financial independence with reference to overall goal of selecting the most preferred farming system was determined on the basis of a well structured questionnaire to quantify the farmers' preferences. For the third level element, the constructed scale for measuring variations in second level of parameters with respect to different identified farming systems was considered as relative weights for comparing pair wise alternatives to achieve the objective at the second level. Thus from a set of pair wise comparison matrices, a set of local priorities which expressed the relative impact of the set of elements on an element in the level immediately above was determined. A set of eigenvectors for each matrix was computed and normalized to unity to obtain the vector of priorities. The multiplication of these two matrices of priority levels gave the composite priorities of the alternative criteria. Thus the weightage and preferences of the various criteria in 0-1 scale of the dairy farming system were identified.

4.2.7.2 Model formulation

The formulation of the farm plan for different dairy farming systems was viewed as the selection of an appropriate set of crop and dairy activities for the farm and the most suitable level at which each activity was to be conducted. Recognizing the difficulty in working out the suitable plans for each of the selected households individually, the resource use data and input-output coefficients of selected respondents of the identified dairy farming systems were pooled and averaged to form synthetic farm situation

representative for each category of dairy farming system. The activities incorporated in the linear programming were categorized as real activities, i.e., crop activities and dairy activities separately for crossbred, indigenous and buffalo; capital borrowing activities month wise, human labor hiring activities, and selling activities for fodder, food and cash crops, milk etc. The risk goal was incorporated through the incorporation of target MOTAD model into the weighted goal program model wherein the gross margin of the i^{th} activity in the h^{th} year would be constrained to achieve the minimum target level through minimization of negative deviation from the target as the objective.

4.2.7.2.1 Problem formulation and modeling of dairy farming systems

The mathematical formulation of the model was constructed considering the whole farm household, interactions within and between enterprises, in terms of labour availability, resources availability, cash needs and cash availability at regular points of time, the home consumption needs, the need for leisure, the requirement and availability of temporary labour, and non farm employment.

The resources considered were land, water availability, and family labour. The cash needs at regular points of time for meeting buying farm inputs, hiring labour, home consumption needs and repayment of loans were also considered in the model.

The source of income for the farm household depended on the crop and dairy activities, non-farm employment activities and selling of surplus fodder. Keeping in view the variations in cost or returns parameters of inputs and outputs for the various activities / processes in the different dairy farming systems, separate models were fitted for the various dairy farming systems. The constraint parameters also varied from system to system such as availability of land, labour at regular intervals and loan amounts, meeting home consumption needs, meeting leisure needs, risk-bearing ability, etc.

Unlike conventional programming approaches wherein the objective is to maximize profits or minimize costs, here the intended objective was to minimize the deviations from the preferred multiple targets or goals which were fixed as per the farmers' preferences or understanding. Hence, the model may not be optimal in all cases, if the farmers' preferences are to be satisfied. Besides, it may always be borne in mind and also been confirmed in many studies (Soon, 1983; Pertiwi *et al.* 1992; Bulatovic 1997; Aromolaran and Olayemi 1999) that it is not profitability alone that guides farmers' decision making in selection of activities / processes or enterprises for fulfillment of their needs.

4.2.7.2.2 Lexicographic goal programming model

Faced with a multiple objective decision making problem, traditional single objective approaches give priority to one of the objectives at the expense of others, which due to the methodological limitations, are essentially ignored. In contrast, lexicographic goal programming tries to optimize by achieving the absolute goals of the top priority objective and for the non-absolute goals of the other objectives and tries to bring a solution that comes as close as possible to the satisfaction of all of these goals. That is a solution is found which minimizes the deviation from the specified goals rather than their absolute satisfaction.

The general form of the linear goal program (priority based) is given as,

Find $X = (x_1, x_2, x_3 \dots x_n)$ so as to

$$\text{Minimize } Z = [p_1 r_1(\bar{d}^-, \bar{d}^+), p_2 r_2(\bar{d}^-, \bar{d}^+), p_3 r_3(\bar{d}^-, \bar{d}^+), \dots, p_q r_q(\bar{d}^-, \bar{d}^+)] \quad (20)$$

Subject to :

$$\sum_{j=1}^n g_{kj} x_j + \bar{d}_k^- - \bar{d}_k^+ = G_k, k = 1, 2, \dots, z \quad (21)$$

$$\sum_{j=1}^n b_{ij} x_j + \bar{d}_i^- - \bar{d}_i^+ = B_i, i = 1, 2, \dots, m \quad (22)$$

$$X, \bar{d}^-, \bar{d}^+ \geq 0 \quad (23)$$

Where X = n dimensional decision variable vector

Z = q dimensional deviation function vector whose dimension represents the number of pre-emptive priority levels among the objectives³

' p_q ' = pre-emptive priority associated with $r_q(d^-, d^+)$

' $r_q(d^-, d^+)$ ' = linear function of the goal deviation variables, i.e., achievement function of the goal with q^{th} ranked priority.

' g_{kj} ' = the coefficient of the j^{th} decision variable for the k^{th} goal constraint

' b_{ij} ' = the technical requirements of the j^{th} decision variable for i^{th} resource or constraint

G_k = the predetermined goal of the k^{th} goal constraint

B_i = the i^{th} absolute constraint level

' d_k^- ' and ' d_k^+ ' = goal deviation variables which denote, respectively, under- and overachievement of the k^{th} goal

' d_i^- ' and ' d_i^+ ' = absolute constraint deviation variables which denote, respectively, under- and over utilization of the i^{th} absolute constraint

Under such formulation, given any type of goal, the non-achievement of that goal is minimized by minimizing specific deviation variables. That is, the objective is to select 'x' so as to:

(1) Minimize d_k^+ , if the goal constraint is denoted as

$$\sum_{j=1}^n g_{kj} x_j \leq G_k, \quad (24)$$

(2) Minimize d_k^- , if the goal constraint is denoted as

$$\sum_{j=1}^n g_{kj} x_j \geq G_k, \quad (25)$$

(3) Minimize $d_k^- + d_k^+$, if the goal constraint is denoted as

$$\sum_{j=1}^n g_{kj} x_j = G_k \quad (26)$$

³ The notation $p_q r_q(d^-, d^+)$ should not be interpreted as either the product of P_q and $r_q(d^-, d^+)$ or a function of $r_q(d^-, d^+)$.

Thereafter, the deviation variables at each priority level are included in the achievement function ' $r_q(d^-, d^+)$ ' and ordered in the achievement vector Z according to their respective priority.

Different models were fitted for different dairy farming systems and the derived farm plans satisfying multiple goals were compared with the existing farm plans in different systems.

4.2.7.2.3 Formulation of absolute constraints

In general, absolute constraints comprise of production capacities, institutional, structural and functional limitations or restrictions, as well as other assumptions. The assumptions on which the absolute constraints are based are regional specific depending on a set pattern of socio-economic and infrastructural situation.

The objective ensuring farm family survival with specified extent of probability may be interpreted in two ways. It may mean that total monetary income should cover total money-value requirements for survival. It may also be interpreted that the commodities for the families own consumption should be produced on their own farms. However, these interpretations may reflect the extreme cases which are not strictly relevant to the attitudes of farmers in the study area, whose money value requirements are proportionally increasing for meeting family's own consumption needs from the farm. In Haryana, farmers generally prefer to meet only the basic food items from their own farm, and meet other needs from the market. With increasing provisions of access to markets and with the availability of variety of both food and non-food goods, the trend is slowly changing from self-dependence for food to market dependence. But still certain basic food commodities such as cereals, pulses and milk are met from the farm. These products are not only essential for daily consumption; but are also characterized by serious price fluctuations. Hence, most farmers prefer not to be dependent on the fluctuating market for these products. Hygienic problems concerning these products also play a significant role. Consequently it is natural that the conditions to cover these

requirements of these products should be considered as absolute constraints instead of relative goal constraints.

The absolute constraints comprising of all the items mentioned above, i.e., production capacities, limitations or restrictions, and other assumptions, can be expressed in the mathematical form as under:

$$\sum_{j=1}^n b_{ij} x_j + d_i^- - d_i^+ = B_i, i = 1, 2, \dots, m \quad (27)$$

Depending upon the constraint type the final formulation of absolute constraint was decided.

$$\sum_{j=1}^n b_{ij} x_j \geq B_i, \text{ if } d_i^- \text{ should be zero} \quad (28)$$

$$\sum_{j=1}^n b_{ij} x_j \leq B_i, \text{ if } d_i^+ \text{ should be zero} \quad (29)$$

4.2.7.2.4 Formulation of achievement functions

a) Goal achievement function: Expected total gross margin

The gross margin of an enterprise is its value of enterprise output less the variable costs attributable to it. The criteria for variable costs in the gross margin sense, is that they must be specific to a single enterprise, and they must vary approximately in proportional to the size of the enterprise. For crop production, the proportional specific variable costs consisted primarily of seed, fertilizer, sprays, part of fuel and repair costs and hired / contract labour specially for that enterprise. For livestock production, concentrate feed, veterinary and medicinal expenses, seed and fertilizer for fodder, and some miscellaneous expenses, were regarded as variable costs.

Gross margins though can be calculated without much great difficulty. The problem lies in selecting the gross margin from a cross-section of farm households belonging to a specific system. Keeping in view the limitations associated with a static model as techniques and prices change constantly, it was assumed that within a short period the variations within the enterprise will be within the intra farm variations of the same system. Hence with the

limitations of non-availability of dynamic data for a period of years due to resource and time restrictions, the mean of the margin within the system was taken as the gross margin for the enterprise. To set the goal of total gross margin, the logic of inexhaustibility of this goal was applied. The goal will be infinite, but an arbitrarily high level was chosen depending on the system in question, which is hardly attainable. With the enterprise gross margins and the arbitrarily established goal, the goal achievement function for expected total gross margin can be formulated as follows:

$$\text{Min } r_y(d^-, d^+) = d_y^- \quad (30)$$

Subject to,

$$\sum_{j=1}^n g_{yj} x_j + d_y^- - d_y^+ = G_y \quad (31)$$

Where, d_y^- and d_y^+ denote, respectively, under- and over achievement of expected gross margin goal, g_{yj} represents the sample mean gross margin per unit of the j^{th} enterprise, and G_y is the goal of total gross margin. The goal achievement function is here represented by one variable, d_y^- .

b) Goal achievement function: Survival

The difference between the objectives of maximizing expected total gross margin and of ensuring survival lies in the assumption of risk and uncertainty associated with it. Without risk and uncertainty, the two objectives may no longer be in conflict. The goal level of survival of the farm family depends primarily on the average living standard of the farm category and number of family members. The tradition, customs and habit persistence of the society also tend to affect the level. Food, clothing, fuel, light and housing costs among others are generally regarded as inevitable living expenditures. Besides social expenses, customs, rituals, marriages, traditions, festivals and children's education etc. are inevitable. Consequently all the items mentioned above were included in the survival goal. Hence their recent real living expenditure data about above-mentioned items were used to set the survival goal for each of the dairy farming system.

With the established goal, G_s , the survival goal achievement function can be formulated as:

$$\text{Min } r_s (d^-, d^+) = d_s^- \quad (32)$$

$$\text{s.t. } \sum_{j=1}^n \hat{g}_{yj} x_j - 2 \phi \Omega w^{-1} \cdot \sum_{h=1}^w y_h^- + d_s^- - d_s^+ = G_s \quad (33)$$

$$\text{s.t. } \sum_{j=1}^n (g_{yjh} - \hat{g}_{yj}) x_j + y_h^- \geq 0, \quad h = 1, 2, \dots, w \quad (34)$$

Where, 'w' shows the sample size,

g_{yjh} denotes the gross margin observed for the j^{th} enterprise in the year 'h',

$\hat{g}_{yj}$ is the sample mean gross margin per unit of the j^{th} enterprise.

d_s^- and d_s^+ denote, respectively, under- and over- achievement of the Survival goal.

y_h^- shows the absolute value of the negative total gross margin deviation in year 'h' around the expected return based on sample mean gross margin and is defined by

$$y_h^- = \left| \min \left\{ \sum_{j=1}^n (g_{yjh} - \hat{g}_{yj}) x_j, 0 \right\} \right| \quad (35)$$

' ϕ ' refers to a risk parameter with the admissible probability to risk or uncertainty when the population is normally or approximately normally distributed. In other words, under the assumption of normal distribution of population, the level of ϕ can be derived by making use of the tables for the t – distribution provided the admissible probability to risk or uncertainty⁴ if the sample size is known. For small samples it is desirable to use student's t distribution rather than the standard normal distribution.

c) **Goal achievement function: Financial self-support**

The preferences to borrow money varied for different dairy farming systems. Generally the farm family households, which were marginal and

⁴ The subjective limits which individual farmers are willing to permit.

landless farms, in general, don't like to borrow money from others unless it is absolutely necessary. For the dairy farming systems with small farms, credit availability was limited in terms of time and amount depending on land availability. Hence it is natural to consider financial self-support to be regarded as one of the important objectives in farm planning for landless and marginal dairy farming systems.

Types of credit available to the farms can be broadly classified into two categories: production credit from the public sector including agricultural cooperatives credit societies and grameen banks and general credit from the private sector such as the money lenders, commission agents, arahitas, friends and relatives including private sector banks. The public production credit is mainly made to encourage or stimulate production of specific goods and for specific agri-enterprises. Interest rates tend to be relatively low. On the other hand private credit is not directly linked with any specific production activities, and interest rates are relatively high.

In order to incorporate these different types of credit into one achievement function, the most commensurable unit is the interest rates for different types of credit. Thus the objective of financial self-support was replaced by the objective of no or limited interest payments depending upon the dairy farming system. The achievement function can be mathematically formulated as follows:

$$\text{Min } r_r (d^-, d^+) = d_r^+ \quad (36)$$

$$\text{s.t. } \sum_{j=1}^n \hat{g}_{rj} x_j + d_r^- - d_r^+ = G_r \quad (37)$$

Where, g_{rj} denotes the interest rate of credit j

d_r^- and d_r^+ are, respectively, under- and over achievement variables for the total interest payment goal or the financial self support goal.

G_r indicates the total interest payment goal whose value depends upon the type of dairy farming system.

d) Goal achievement function: Leisure

The Haryana farm structure has three peak labour demand seasons: the second half of march to April, the second half of may to the first half of July and September to October in the irrigated zone and two in partially rainfed zone, March to April and September to October. During the off-season, ample idle labour time is available, but during the peak season most of family farms face labour scarcity. This problem is compounding due to the rapid out-flow of young rural labour to urban industrial cities in the last two decades and due to inadequate rent – in mechanized agricultural operations and the high degree of seasonality in the use of farm equipment and machinery. Hence most of the farm households are overworked during their peak seasons and desire to curtail their labour during this period and achieve minimum amount of leisure during the year.

How much the family farms desire to reduce their labour demand may differ from farm to farm, but it is was assumed that the desired labour supply after meeting the leisure needs is zero. The goal achievement function of leisure can then be formulated as follows:

$$\text{Min } r_l (d^-, d^+) = d^+_l \quad (38)$$

$$\text{s.t. } \sum_{j=1}^n g_{lj} x_j + d^-_l - d^+_l = G_l \quad (39)$$

Where g_{lj} denotes the required labor of enterprise j for the year and d^-_l and d^+_l represent, respectively, under- and overachievement of the goal of total labour supply, G_l .

4.2.7.2.5 The farm planning model for dairy farming systems

The comprehensive farm planning model for the dairy farming systems with the goal achievement function vector, the absolute constraints, the goal constraints, and the non-negative and zero constraints is given as follows:

$$\text{Find } X = (x_1, x_2, x_3, \dots, x_n) \text{ so as to minimize} \quad (40)$$

$$Z = (P_1 d_s^-, P_2 d_y^-, P_3 d_r^+, P_4 d_l^+) \text{ subject to }^5 \quad (41)$$

$$\sum_{j=1}^n \hat{g}_{yj} x_j - 2 \phi \Omega w^{-1} \cdot \sum_{h=1}^w y_h^- + d_s^- - d_s^+ = G_s \quad (42)$$

$$\sum_{j=1}^n g_{yj} x_j + d_y^- - d_y^+ = G_y \quad (43)$$

$$\sum_{j=1}^n \hat{g}_{rj} x_j + d_r^- - d_r^+ = G_r \quad (44)$$

$$\sum_{j=1}^n g_{lj} x_j + d_l^- - d_l^+ = G_l \quad (45)$$

$$\sum_{j=1}^n (g_{yjh} - \hat{g}_{yj}) x_j + y_h^- \geq 0, \quad h = 1, 2, \dots, w \quad (46)$$

$$\sum_{j=1}^n b_{ij} x_j \geq B_i, \text{ if } d_i^- \text{ should be zero} \quad (47)$$

$$\sum_{j=1}^n b_{ij} x_j \leq B_i, \text{ if } d_i^+ \text{ should be zero, } i = 1, 2, \dots, m \quad (48)$$

$$X, d^-, d^+ \geq 0 \quad (49)$$

where, X refers to the vector of 'n' activities in the model

d_y^- and d_y^+ denote, respectively, under- and over achievement of expected gross margin goal,

d_s^- and d_s^+ denote, respectively, under- and over- achievement of the Survival goal.

d_r^- and d_r^+ are, respectively, under- and over achievement variables for the total interest payment goal or the financial self support goal.

d_l^+ represent, respectively, under- and over achievement of the leisure goal G_l

g_{yj} represents the sample mean gross margin per unit of the j^{th} enterprise,

⁵ the order of the priorities of goals will vary depending upon the dairy farming system

g_{yjh} denotes the gross margin observed for the j^{th} enterprise in the year h ,

$\hat{g}_{yj}$ is the sample mean gross margin per unit of the j^{th} enterprise.

g_{rj} denotes the interest rate of credit j

g_{lj} denotes the required labor of enterprise j for the year and $d_1 G_1$ refers to the goal of total labour supply.

G_y is the goal of total gross margin. The goal achievement function is here represented by one variable, d_y .

G_r indicates the total interest payment goal whose value depends upon the type of dairy farming system.

w shows the sample size,

y_h shows the absolute value of the negative total gross margin deviation in year h around the expected return based on sample mean gross margins

' ϕ ' refers to a risk parameter with the admissible probability to risk or uncertainty

Thus, a lexicographic goal-programming model was developed for developing need based farm plans of dairy farming systems of Haryana. The model's goal achievement vector was minimized subject to the various constraints such as goals, absolute, stochastic, non-negative and zero constraints.

4.2.7.2.6 Algorithm development of the models

The algorithm available for solving general lineal programming models in GAMS are many but since the problem involved both crop and dairy enterprises, the MIP (Mixed Integer Programming) was selected as the solver for the model with the dairy enterprises as integer variables (Lee and Morris, 1977). The program was written in GAMS model for lexicographic goal programming model separately for each of the identified dairy farming systems (Annexure-X). Thus the problem of returns to scale was overcome as

different models were fitted for the different systems. The iterative algorithm for the lexicographic goal program model is as follows:

Step 1: Set $q = 1$ (priority goal in order) and proceed to step 2

Step 2: Minimize the achievement function, $r_q(d^-, d^+)$, subject to the related goal constraint and the other constraints using mixed integer programming

Step 3: Examine the feasibility of the constraint set. If it is feasible, proceed to step 4. If not, the matrix must be adjusted. Go to step 6.

Step 4: Check if there is any other lower ranked achievable function. If it exists, the solution is intermediate. Proceed to step 5. If not the solution becomes global. Go to step 6.

Step 5: Set $q = q + 1$ and turn to step 2.

Step 6: Check if the efficient yield set is empty, if not proceed to step 7, otherwise to step 9.

Step 7: Increase potential yield of dairy enterprises to the most efficient dairy farming system in each of the system

Step 8: go to step 1

Step 9: stop

4.2.7.2.7 The multi-criteria farm model structure

The model of lexicographic goal program was developed using GAMS (General Algebraic Modelling Structure). There were in total 8 models developed for each of the goal program for the 8 identified dairy farming systems. The basic structure of the model comprised of 15 sets namely crop enterprises, fodder crop enterprises, dairy enterprises, months, cropping activities, dairy activities, land types, crop lands, livestock feeding alternatives, year, family consumption bundle alternatives, technology characteristics, process land possibilities, transfer cash, non farm income. The sets referred to various groups of variables of similar characteristics that were used in the model.

a) Crop enterprises

There were five crop enterprises namely, bajra, wheat, mustard, gram and cotton in the models of the partially rainfed zone and four crop enterprises namely paddy, wheat, sugarcane and mustard in the irrigated zone. Though there are a number of other enterprises such as sesamum, arhar, barley, sugarcane, paddy, vegetables, potato and fruits such as mangoes grown in the partially rainfed zone, but were insignificant in terms of area under cultivation, hence have not been considered. Nevertheless, they can be considered as possible crop enterprises under certain conditions of water availability, soil characteristics and specific location. Similarly in the irrigated zone, crops like mango, poplar, fodder crops like bazra, maize, potato, other vegetables, pulse crops like moong, masaar, Arhar were also grown but were not considered in the model due to their insignificant presence. However, the reason for not considering green fodder in the crop enterprises is fodder is grown primarily to meet the requirements of the milch animals owned by the farm household.

b) Fodder crop enterprises

The fodder crops considered in the model were berseem, jowar and maize. Crop residues such as, wheat straw, paddy straw and sugarcane tops used as fodder were also considered in the model as fodder crop enterprises with the linkages with their respective main crop enterprises.

b) Dairy enterprises

The dairy enterprises in both the zones were buffalo, crossbred and indigenous cattle. These three species have different parameters of input and output, besides the preference of the farm households for these species varied from systems to system. Though there were also other milk producing enterprises such as goat, camel, etc. but were not considered due to their dual nature. Besides, milk is one of the most significant outputs in case of cows and buffaloes only, hence considered as dairy enterprises. Since the model dealt with dairy farming systems, hence other livestock such as poultry and pigs found in the irrigated zone, goats and camels in the partially rainfed zone were not considered.

c) Months

The twelve months have been taken in this set. Months are important variables as dimensions to form matrix of various parameters such as informal credit rates, land, labour and working capital requirement for crop and dairy activities, and cash flow from crop and dairy activities. The set of months was also used to form matrix for other variables such as transfer cash within the farm in case of surplus, family labour use, temporary labour use, informal credit requirements, and non-farm income hours. The main reason for taking information or modeling at monthly intervals in labour use and credit variables was the inter-farm variations in family labour use and credit availability. Information on monthly parameters on labour, land requirement, working capital parameter and cash flow from enterprises enabled to give an adequate representation of decision making due to short interval and the frequency of decision making related with agricultural operations. Moreover data availability was more feasible at monthly level than at shorter intervals such as daily or weekly or fortnightly, keeping in view the resource constraint for a detailed data collection.

d) Cropping activities

Cropping activities or processes refers to the crop with a particular technology (variety, intensity of machinery use, inputs etc.) or under different growth conditions such as location, topography, water availability, soil structure, etc. Thus the same crop may have one or more cropping activities. In this model, the number of cropping activities was the same as the crops, assuming that each of the crops was grown with one technology only. Thus the cropping activities considered in the present study were bajra, wheat, mustard, gram and cotton in the models of the partially rainfed zone and four crop enterprises namely paddy, wheat, sugarcane and mustard in the irrigated zone.

e) Dairy activities

Dairy activities or processes refer to the dairy enterprise with a particular technology (management factor, breed, intensity of machinery use,

feeds and fodder inputs, etc.) or under different growth conditions such as location, topography, water availability, soil structure, etc. Thus, the same dairy enterprise may have one or more dairy activities. In this model, the numbers of dairy activities were the same as the dairy, assuming that each of the dairy enterprises was managed with one technology only.

Thus, the dairy activities considered in this study were buffalo, crossbred and local cattle in the models of the irrigated and partially rainfed zone.

f) Land types

Generally a farmer has a multitude of land types suitable for different crop types such as upland, lowland, shallow land depending on the topography; saline soil, alkaline soil, normal soil depending on electrical conductivity and salt content; irrigated, rainfed and partially rainfed depending upon irrigation intensity and irrigation source availability; fertile, infertile soil depending on nutrient status; clayey, sandy, loamy or other grades depending on the soil structure. Thus based on all these parameters, different cropping or dairy activities can be practiced on different land types. In this model, it has been assumed that the farmer holds only one type of land suitable for all the crops.

g) Crop lands

Not all types of land available with the farmer may be suitable for crops. In some cases, these lands, which are not suitable for crops, are considered as wastelands, and may be used for grazing of livestock. Here in this model all land held by farmer has been assumed to be suitable for cropping.

h) Livestock feeding alternatives

The feed management of livestock may vary depending on the resource availability and the location of the farm. Since different feeding alternatives would give different input and output parameters, they were considered as separate variables. In this model one way of producing and

utilizing feed for livestock has been assumed. In the landless dairy farming systems, perennial grasses, weeds, wild grasses, fodder leaves of trees, etc. were collected and fed as green fodder. Wild grasses gathered by farmers consisted of various species of grass. The ratios of each kind of grass to total gathered grasses differed from case to case. Due to lack of relevant data on feed combination and forage crops by these systems, it has been assumed that the feed combination and forage ratios in these systems generally follow the accepted practice.

i) Year

The year refers to the years for which variations in crop revenue is considered for the goal of farm survival using MOTAD model. Here the last ten years were considered in the model from the year 1990 to 1999.

j) Family consumption bundle alternatives

The consumption of food produced in the farm depends on the preferences for different food items and the relative share of different products in the diet and the income elasticity. Thus different bundles of food consumption can be fixed. Here only possible food consumption bundle of meeting home consumption needs was considered for each model.

k) Technology characteristics

The technology for crop enterprises is the various inputs such as seeds, fertilizers, irrigation intensity, pesticides, equipment, etc. In the present study, seeds, fertilizers, pesticides, equipment and fuel were considered.

l) Process land possibilities

The cropping activities possibilities are a matrix of cropping activities and the land type. However, since only one land type has been considered here, the process land possibilities were the same as cropping activities.

m) Transfer cash

There are variations in working capital availability. The working capital for the farm comes from sale of farm products, savings, credit, non-farm

income etc. Hence the availability of working capital was considered to be varying at different points of time. The surplus capital if any, after meeting cash needs, was transferred to the next month. This transfer was accounted by twelve such variables, one for each month.

n) Non-farm income

The income accruing to the farm household, coming from sources other than the farm, was referred to as non-farm income. Only one source of non-farm income for each of the dairy farming system has been assumed.

o) Parameters

Sixteen parameters of the models namely, the technological coefficients such as prices, costs and constraint limits of the sets have been considered in the present study. These were target, deviation from goals and weights of goals; price, average crop revenue, and price deviation for crops; crop limits, technology costs, dry fodder production and cropping constant of cropping activities; ration of feeding alternatives; monthly household expenditure and land availability for different types of land.

There were 12 scalar parameters, which were the fixed parameters, for a particular model at a point of time and place. These were family wage rate, temporary labour wage rate, permanent labour wage rate, value of self-consumption, working capital, family labour, livestock price, veterinary service cost, man days per man month, risk factor and prices of dry fodder such as wheat and bazra straw.

The technological coefficients were depicted in the form of tables due to their variation with respect to two dimensions thus forming a matrix, e.g., crop and month. Thus there were 18 tables, for each of the models. These were based on month-wise land occupation by crop and fodder crops month wise; feed requirement for livestock and feed alternatives; labour requirement for cropping and livestock feed; consumption bundles of crop and dairy; yield of dairy and crop activities, for different grades of land; cropping technology and working capital requirements for crop and dairy activities, crop revenue

time series; monthly cash flow from crop and dairy activities, transfer of cash within each month, and dry fodder requirement for dairy activities according to type of fodder and land downgrading possibilities under land resource of various types or grades constraint.

The decision variables or real activities were cropping activities; fodder cropping activities; livestock activity defined on feed techniques; total livestock for milk production; crop wise crop production; species wise milk production; family consumption of farm produced food; monthly labour use; month-wise informal credit; monthly non-farm income and cash transfer within each of the successive months. Besides there were variables for summation figures based on activity selection such as farm income, farm revenue, crop cost, cost of credit, labour cost, veterinary cost, and deviations from goal objective. In all 28 variables were considered in the optimization model.

To consider the positive integer nature of certain variables such as livestock for milk production; total number of milch animals for milk production were considered as positive integer variables. Remaining decision variables were considered as positive.

The model constraints (absolute and goal) were formulated in form of equations. A total number of thirty-one equations were formulated. There were seven constraints of restrictive nature relating to land availability; yield, sale and consumption (crops / dairy) balance; on farm consumption needs; family labour availability; working capital restrictions and non-farm hired labour availability constraint. There were four goal constraints and one target goal constraint namely of maximization of gross margin; ensuring family survival; financial self-support and meeting minimum leisure needs. The objective was that of minimizing the goal deviations. The remaining constraints numbering nineteen were equations representing the various relationships and grouping of variables under different heads relating to livestock feed requirement; crop production; milk production; on farm consumption; crop price deviation; net farm income; cost of crop activities;

labour cost; veterinary cost; cost of credit; farm income; meeting working capital requirements monthly; dry fodder requirement; total cost of dairy activities; total cost of crop activities; average revenue over time period and price deviation for MOTAD modeling (Annexure-IX).

p) Available resources

i) Land

Though a variety of land classification can be done based on the type of soil, irrigation provisions, problematic soils (water logging, alkaline, saline), crop suitability, topography, etc., it has been assumed that the average farmer for each of the dairy farming system has land of uniform quality.

ii) Labour

There are three main seasons in terms of agricultural activities, rainy, winter and summer. The best way to classify them is on the basis of months. To decide the length of months for data collection, a course has to be steered between over-restriction and excessive flexibility as to when work can be performed. If very short periods are taken within which labor coefficients for each job are rigidly specified, the choice of farm plan may be unnecessarily limited. On the other hand, if very long periods are taken, the selection may become wide unrealistically. Generally natural crop cycles and specified periods of time range when certain operations are to be performed is the basis of selection of time period of data collection. Since agriculture in Haryana generally has a range of 15 days to 45 days for various operations, it was decided to collect data at monthly interval. Hence monthly general labour requirements for different crop and dairy activities were collected. In calculating the availability of man labour, man-hours were used as standard work units. A man-hour has been defined as one hour of activity performed by an average worker. Total family labour available in standard manhours was calculated by weighting the differences in age and sex of the family members (1 man = 1.5 women = 2 children). It is assumed that a farmer can work for 8

hours per day and 25 days for a month⁶. Housewives, middle or high school boy or girl is assumed to be able to provide 26 manhours in one normal month and 50 manhours in the peak season (months of June, September and April). The model allows for expanding the labour size by hiring temporary or permanent labour.

iii) Production facilities

The production facilities for the different dairy farming systems were assumed to be status quo, and hence provisions for expansion or contraction of production facilities and hence cost considerations are not considered in the model.

iv) Capital

The source of capital for the farm family households is generally through sale of farm products and through other income and borrowing. On the other hand it is consumed in the process of meeting farm inputs demand such as seed, fertilizer and pesticides, and fixed costs, such as wages, rents, overheads, interest payments and repayment of capital. Since meeting working capital needs is an important consideration of farm planning for family farm households in Haryana especially the small, marginal and landless farm households, certain assumptions have been made to simplify the total working capital requirements keeping in view the difficulties in obtaining relevant data about the level of cash flows. Hence it has been assumed that half of total working capital requirements should be at hand, in cash or in kind at the beginning of farm planning. As a result, total capital available at the beginning of the farm planning has been defined as the amount of cash at hand such as money deposited in banks, loans, installments, investments in fixed deposits, livestock, and the value of inventory of production inputs and farm produce for sale or for seeds.

⁶ The five days a month are allowed for weather effects and unforeseen contingencies. It is assumed that the farmers take holidays in the off-season and hence the working standards refers to potential labour force.

q) **Constraints**

i) **Goal constraints**

Four goal constraints namely, expected total gross margin maximization; farm survival with degree of probability; financial self-support and leisure, were derived in formulating the goal achievement functions. Every goal constraint has been accompanied on the left hand side, by negative and positive deviation variables (d_k^- and d_k^+ , respectively). The value of d_k^- for any choice of x , decision variable, reflects the under achievement of the k^{th} goal, while the value of d_k^+ represents over achievement. Hence each goal constraint is of the form:

$$F_k(x) + d_k^- - d_k^+ = G_k, \quad k = 1, 2, \dots, 4 \quad (50)$$

ii) **Stochastic constraints**

In the model, farmers' risk aversion behaviour was handled stochastically by making use of a MOTAD model. On the assumption that variations in price and yield are widely represented over a period of ten years, ten stochastic constraints are considered in the model. Every stochastic constraint was accompanied by the mean absolute value of negative deviation, y_h^- . Mathematically it could be represented as:

$$\sum_{j=1}^n (g_{yjh} - \hat{g}_{yj}) x_j + y_h^- \geq 0, \quad h = 1, 2, \dots, 10. \quad (51)$$

iii) **Other absolute constraints**

Borrowed capital : Credit available to farmers can be broadly classified into production credit from the public sector and general credit from the private sector. The former is available to encourage or stimulate production of specific goods and is consequently linked with specific enterprises. Generally the credit availability of public sector in Haryana is from the rural banks on the basis of land holdings size and / or membership of the cooperative society bank. Under normal conditions with no default of past records, an average farmer gets a credit of Rs.5000 per acre of paddy or wheat of seasonal loan of six months and Rs.9000 per acre of sugarcane of one year. Besides term loan for purchase of livestock and machinery is also available depending upon the

fulfillment of banks conditions of loan sanction. Generally based on government schemes, and evaluation of the parameters of risk bearing ability, assets owned, gross returns and repayment capacity besides past records of no default determines loan sanction. However, these loans are very specific to crop or the asset for which it is meant and hence the farmer has to produce the specific good. Hence such loans are indirectly for promoting more production of agri-goods. In contrast, private credit is not directly linked to any specific production activities. Thus its availability generally depends on the ability and willing to pay at specified rate of interest, which is determined by the lender. Hence it is assumed that the farmers can borrow money from the private sector at prevailing interest rates, of 22 percent⁷, to as much as one quarter of their present total gross margins.

Constraints on individual enterprises : Generally under family farm conditions, which are not commercially oriented, certain limitations are bounded by the farmer based on the nature of production activities, the farmer's preferences and the need for crop rotation. Though crop rotation constraints can only be incorporated in a dynamic model framework, the limitations due to nature of production activities can be fitted in static models. Under existing technology of raising livestock for milk and other outputs such as cow dung, heifers, calves, draught, the requirement of dry fodder was mostly met from the crop production within the farm. Hence the number of livestock to be reared was decided by the availability of dry fodder from the farm. Similarly certain enterprises such as sugarcane were not practiced by the marginal farmers in the irrigated zone, due to the long gestation period and the need for surplus working capital.

Limitations on hiring and leasing labor : In Haryana, the availability of temporary or contractual labour at the right time of agricultural operations in the peak season of sowing, harvesting etc. was constrained. Hence the peak availability of labour was incorporated in the model⁸.

⁷ With annual inflation rate of 8 percent during the same period, the real interest rate is about 14 percent.

⁸ Based on observed data covering the past five years in the region.

4.2.7.2.9 Decision variables

a) Production activities

i) Crop production

A total of five most important crops were included in the models for the partially rainfed zone and four crops in the models for the irrigated zone. They comprised of bazra, wheat, rapeseed, gram and cotton in the partially rainfed zone and paddy, wheat, sugarcane and rapeseed in the irrigated zone. The relevant primary data for the crop production were collected during the period from July 2000 – June 2001.

ii) Livestock

Various livestock enterprises such as goats, camels, poultry, sheep, etc are prevailing in the area. But only milch livestock, i.e., cattle and buffaloes have taken into consideration, due to the specific nature of the modeling with dairy farming systems in mind and the predominance of these livestock in comparison to other livestock in Haryana. Two types of cattle namely, indigenous non-descript milch adult cattle and crossbred milch adult cattle were considered.

iii) Money borrowing activities

To make the model flexible to working capital needs at different times of the year, the model allows the farmer to borrow money from the market. As discussed above, the types of credit available are public production credit and private general credit. The public production credit is made available in cash or in the form of specific supplies and equipment needed. Hence it is closely related to specific enterprises. Interest rates being relatively lower, farmers prefer public credit to private credit due to relatively lower interest rates. However, this credit is generally insufficient to meet their capital requirements. Hence, the remaining credit needs are to be borrowed from the private sector. In Haryana, generally the commission agents, the arahitas, the wealthy ones provide such credit at an average interest rate of 22 to 36 percent per year. Part of the high interest rate was due to the scarcity of capital and due to the

high risk in repayment, as some of the credit is also for non-production or consumption purposes by some farmers. In the present model, the interest rates for public credit have been taken as 12 to 14 percent per year regardless of the type of the credit and for private credit varying from 12 to 36 percent per year on month basis.

iv) Hiring labour activities

To ensure flexibility in supply of farm labour at peak periods, the model incorporated provision to hire casual labour or contractual labour at the prevailing wage rate of Rs.80 per manday of labour.

v) Non farm employment activities

Considering the high prevalence of non farm employment among farmers in Haryana, the provision of non farm employment in off season has been incorporated in the model at varying wage rate for different farming systems, looking into the type of work that can be done by the farmer in each of the dairy farming systems. For the landless systems, the minimum wage rate has been fixed at Rs.80 per day but in case of skilled operations such as tractor ploughing on contract performed by the small farmers, an average wage rate of Rs.100 per day has been taken. This also adds flexibility to the working capital availability to the farm to meet its farm and consumption needs. However, the extent of availability is constrained in terms of mandays available per year in the study area based on the general enquiry from the sample households.

4.2.7.2.10 Deviation variables

a) Stochastic deviation variables

In order to take into account the stochastic nature of gross margin of crop enterprise in whole farm planning, a MOTAD model was incorporated in the model. The MOTAD model takes care of inter year absolute value of the negative total gross margin deviations, which is defined by the formulation (36). The crop enterprises gross margin incorporated in the matrix was based on the secondary data on crop yield and price of ten years (1990-1999) from

secondary sources such as Statistical Abstract of Haryana for different years (Annexure-XVII). Therefore, the model included ten stochastic deviation variables.

b) Goal deviation variables

In a goal-programming model, each goal constraint is generally accompanied by negative and a positive goal deviation variable, which represents, respectively, under- and over- achievement of the goal. Since the model here includes four goal constraints, eight goal deviation variables were incorporated in the model. However, in lexicographic model, the number of goal deviation variables at the first stage of iteration decreased with every iteration and only five variables remained at the final iteration.

4.2.7.2.11 The risk aversion parameter

Risk and uncertainty is an integral part of farming. Hence the decisions taken by the farmers are accounted greatly by this factor. However, the degree of risk averse behaviour varies from farm to farm. Generally the small and marginal farms are more risk averse since a disastrous error in farming tends to be disastrous to the participating family as well. That is, their risk behaviour is mainly concerned with the anxiety of not being able to meet the requirements for their family's survival. To handle the problem surrounding risk and uncertainty, the MOTAD model was developed to fit into the Goal programming model. The MOTAD model was included in the survival achievement function of the model in order to take into account the stochastic nature of the crop enterprise gross margins.

However, a MOTAD model is generally based on a parametric constraint either on expected total gross margin or the sum of negative deviation as well as it was subjected to the absolute technical constraints. The MOTAD model developed for the Linear Goal Programming model in the present study included a risk aversion parameter (ϕ). The qualitative evaluation of the farmers' risk bearing ability or his assessment of potential consequences of risk was reflected by this parameter. It corresponded to the admissible probability of risk determined by the farmer by making use of the

tables for the t-distribution under the assumption of normal distribution of population for each of the concerned dairy farming systems. The admissible probability was defined as the subjective limit to which the farmer is willing to submit. Therefore, the value will change with his personal evaluation of the potential consequences of risk.

Thus, different levels of admissible probability or risk result in different solutions to MOTAD model and thus different linear goal programming solutions. More is the admissible probability, less is the subjective probability and more is the risk-proneness. Four levels of admissible probability have been assumed, viz., 5, 10, 15 and 20 percent with the smaller range for the marginal and small farms and higher range for the large farms.

4.2.7.3 Effect of raising milk and concentrate prices

To study the impact of varying milk prices on the farm plans, various simulations with rise in prices at 5 percent interval of the existing price were tried. Based on the analysis of time series data on milk prices paid to farmers for the past five years, it was found that milk prices increase by 5 to 10 percent every year. Besides, the time series data on milk prices revealed a 5 to 10 percent rise in milk prices every year. Hence, two alternatives of raising the price by 5 and 10 percent were considered in the present study.

Concentrate is one of the important feed purchased for feeding dairy animals in Haryana in all the dairy systems. Thus it is essential to know the effect of changes in concentrate prices on the farm plan. Here also, as in milk prices simulation, a change by 5 to 10 percent found significant changes in parameters. Hence two alternatives of 5 and 10 percent increase in concentrate prices were considered for the farm plans of each of the dairy farming systems. It has been assumed in the present study that the price of other inputs would remain the same with the rise in milk or concentrate prices.

4.2.7.4 Effect of adoption of frontier milk yield

The analysis of frontier analysis has shown high variations in efficiencies of the dairy farming systems, which implies that there are large variations in milk yield across different dairy farming systems. To study their

effect on farm plan if the representative farm is the most technically efficient farm in terms of frontier yield, simulation of farm plans to changes in milk production or yield for each of the milch species has been considered. The milk yield of each of the dairy activities of the most efficient farm was taken to study the effect on the optimal farm plan model of each of the dairy farming systems.

4.3 LIMITATIONS OF THE STUDY

The social science investigations are not free from the limitations which are beyond the control of lone researcher. This is more so with the research scholars who have limited time and resources at their disposal. The present study also had some limitations which are given as under:

1. The data collection was season-wise based on survey method for one year from the sampled households. Since the respondents generally do not keep any records, hence relying on memory of informants has its own limitations. However, under present circumstances, this was the best possible way to collect the required information with limited time and resources.
2. It was not possible to evaluate the varying opportunity costs of labour and capital for the dairy farming systems considered in the economic efficiency model due to lack of sufficient information.
3. The herd management and socio-economic parameters of the farm households in the study area could not be considered in identification of dairy farming systems of the study area due to the complexities involved in the analysis obtained with increase in the number of variables used in cluster analysis. The present developed systems of classification of dairy farming systems has its lacunae of non-inclusion of agro-climatic characteristics, feeding pattern components in the methodology of cluster analysis to identify the dairy farming systems spatially due to lack of data.
4. The efficiency effects model to understand the factors affecting efficiency of milk production could not be studied, as it was beyond the scope of the present study;

5. It was not possible to consider risk in milk production activities in optimal farm plans due to lack of information on milk yield and returns of different milch animals over the years in the study area;
6. The dairy farming systems in the urban and peri-urban region have been excluded as the focus in the present study was mainly on the dairy farming systems in rural areas;
7. The frontier analysis is stochastic static and, therefore, the dynamic effects of dairying couldn't be considered in the analysis;
8. The technical and economic efficiency measures are based on the assumption that the random error component (v_i) due to inefficiency effects (u_i) has half normal distributional form. Hence, the resulting efficiency measures may still be sensitive to distributional assumptions.
9. The optimum farm plans are deterministic static and representative of the identified dairy farming systems based on positive existing situations only.
10. It was not possible to consider multiple outputs of dairy farming and the indirect effects of dairy farming such as environmental pollution in the efficiency determination model due to lack of information and was beyond the scope of the present study.
11. The analysis was done only at the farm level and as such constraints at the regional level have not been considered in the present study.
12. It was assumed that all the crop and dairy enterprise activities in the model can be purchased or sold without any restrictions when required.
13. Constant returns to scale was assumed in this functional analysis mainly due to lack of sufficient number of observations with larger herd size responsible for economies in scale due to size.

Results and Discussion

5. RESULTS AND DISCUSSION

Commensurate with the objectives of the study, the data collected from the sampled households in the study area were analyzed and interpreted. The important results and discussion of the findings in the light of previous studies have been presented in the following five sections:

1. Identification of dairy farming systems
2. Cost components of dairying farming systems
3. Family returns of the dairy farming systems
4. Efficiencies of the dairy farming systems
5. Optimal farm plans of the dairy farming systems

5.1 IDENTIFICATION OF DAIRY FARMING SYSTEMS

The hierarchical complete linkage method of cluster analysis was used to classify all the farm households after removing the outliers based on the complete enumeration data obtained from the sampled villages in the selected districts of Yamunanagar representing the irrigated zone, and the rainfed zone represented by Gurgaon and Bhiwani. There were 322 outliers in the sampled households. Out of the 322 outliers in the group, 280 households were in the no milch category. In the irrigated zone, it accounted for 8.4 percent of the farm households and in the rainfed zone, it accounted for 18.7 percent of the farm households. Most of the farm households in this outlier category belonged to the landless households (77% in irrigated zone and 71.6% in rainfed zone). This clearly suggested that the landless households who did not adopt dairying were relatively more in the rainfed zone than the irrigated zone. There were another 42 households in the outlier group with extreme values in terms of land holdings and herd size, 20 of which were from the irrigated zone and 22 from the rainfed zone. In the irrigated semi-arid zone, five households possessed land holdings above 30 acres, while in the rainfed

zone three households had land holdings above 30 acres. Similarly there were 4 households with more than 14 milch buffaloes and 1 household with 50 crossbred cows in the rainfed region.

After removing the outliers, the data on variables from the farm households in Yamunanagar district were classified using cluster analysis to represent the dairy farming systems in the irrigated zone. Similarly cluster analysis of all the households after eliminating the outliers from the sampled villages in Gurgaon and Bhiwani districts was used to represent the dairy farming systems in the partially rainfed zone of Haryana. Due to similarity in irrigation intensity, ground water status, the cropping pattern and rainfall in the selected villages in Gurgaon and Bhiwani, the data on the farm households from these villages were pooled to identify the dairy farming systems in the partially rainfed zone which were represented by these districts. The variables used for cluster analysis were milk production per day, the composition of milch livestock, operational land holdings, and area under fodder crops. Previous studies have classified the farm households on the basis of land size (Ram and Singh, 1974; Pandey, 1988; Keshari *et al.*, 1998; Rajender *et al.*, 1998; Yadav and Yadav, 1998); type of milch animal (Singh *et al.*, 1975); number of milch animals (Rai *et al.*, 1997; Dixit and Laharia, 1998; Shukla and Brahmanekar, 1999). Thus, the present study has used all these variables together in classifying the farm households. The linkages between some of the variables such as land size and herd size have been reported by Singh *et al.* (1986) and Sirohi and Sirohi (1997).

The results of cluster analysis of the sampled farm households are shown in Table 5.1. The selection of the stage of selection of clusters is based on the optimality criterion value. The optimality criterion value is the closest proximity value among the groups at that stage of the process as determined by complete linkage method. A perusal of Table 5.1 revealed that, on the basis of point of maximum jump of Euclidean distance between cluster groups, the five clusters identified in the irrigated zone were formed at optimal

criterion values of 0.5, 1.2, 6.5, 12.0 and 14.0, respectively, as obtained using the software SPSS. Similarly five clusters were identified in the rainfed zone at optimal criterion values of 0.3, 2.4, 6.0, 8.0 and 11.0, respectively.

Table 5.1 Classification of farm households in the study area using cluster analysis.

Irrigated zone			Rainfed zone		
Cluster	Number of households	Criterion value	Cluster	Number of households	Criterion value
1	165	0.5	1	190	0.3
2	36	1.2	2	312	2.4
3	59	6.5	3	428	6.0
4	24	12.0	4	75	8.0
5	24	14.0	5	62	11.0

The Kruskal walis test of significance revealed milch livestock composition and mean operational land holdings as significant variables at 5 percent level of significance.

Of the 10 clusters identified from both the zones, 8 clusters were selected for naming due to their being in sufficient numbers and uniform distinguishable features with respect to dairying to qualify for being represented as dairy farming systems in the study area. They comprised of first four from each of the irrigated and partially rainfed zones. The fifth cluster from each of the two zones was the intermediate cluster.

There were 24 households belonging to the intermediate fifth cluster in irrigated zone and accounted for 6.7 percent of the 358 households in the irrigated region. It consisted of 14 households with only crossbred cows, 9 households with only indigenous cows and 1 household with crossbred and local cow. Twenty-one households in this cluster belonged to the landless category.

There were 62 households belonging to the intermediate fifth cluster in the rainfed zone and accounted for 4.6 percent of the 1339 households in the rainfed region. These composed of 12 households with only crossbred cows,

48 households with only local cows and only 2 households with both crossbred and local cows. 36 households were of the landless type from this group, 13 households of the marginal category and 11 households of the small category and only 2 households of the large category.

The clusters identified from the irrigated and rainfed zones and the outliers have been presented in figures 5.1 and 5.2, respectively. As can be seen from Figures 5.1 and 5.2, maximum number of households belonged to the landless households in the irrigated zone and the small farmers' category in the rainfed zone.

5.1.1 Naming of the Dairy Farming Systems

The naming of the identified eight clusters relevant to dairying were made on the basis of most important and significant variables characterizing the clusters namely, type of milch animal, number of milch animals and operational land holdings. Previous studies conducted by Kumar (1998) and Dhaka and Jain (1999) have identified and named the systems on the basis of enterprise giving thrust on income and milch animal composition, respectively. All the systems identified were buffalo based dairy farming systems. Therefore, the naming of the dairy farming systems was done accordingly in relation with agro climatic zone (location specificity), number of milch animals and land holdings.

These systems were named as follows:

- Irrigated landless dairy farming system (ILL-2)
- Irrigated marginal dairy farming system (IM-2)
- Irrigated small dairy farming system (IS-3)
- Irrigated large dairy farming system (IL-4)
- Rainfed landless dairy farming system (RLL-2)
- Rainfed marginal dairy farming system (RM-2)
- Rainfed small dairy farming system (RS-3)
- Rainfed large dairy farming system (RL-3)

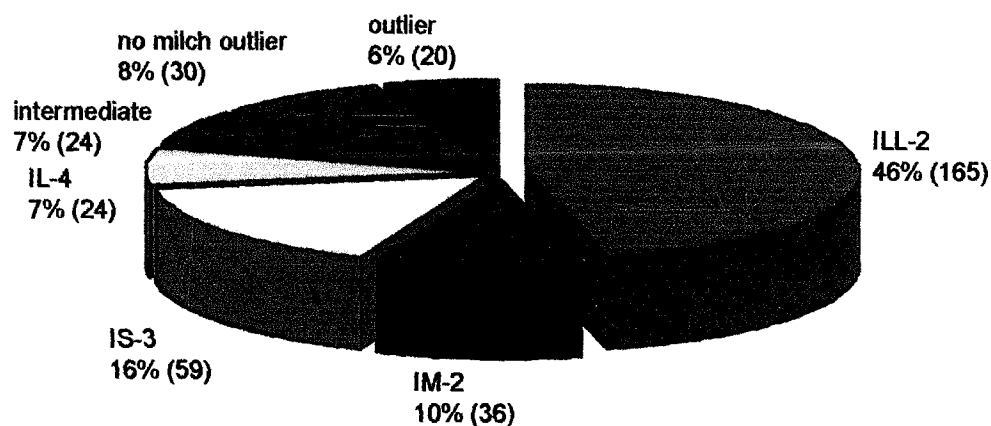


Figure 5.1 Classification of households according to different identified clusters in the irrigated zone of Haryana

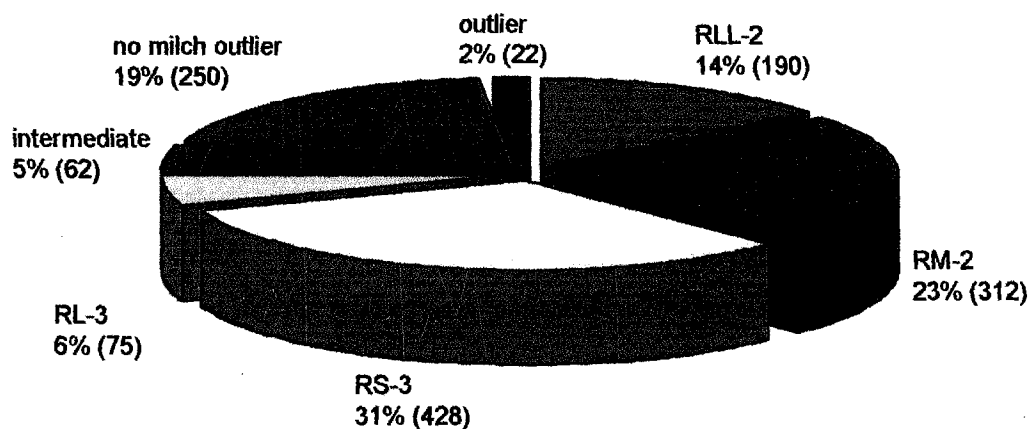


Figure 5.2 Classification of households according to different identified clusters in the rainfed zone of Haryana

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems. Figures in parentheses indicate number of households belonging to the system identified.

The figure in parenthesis refers to the number of milch animals. All the systems were buffalo based. As can be seen from Figure 5.1, the Irrigated landless dairy farming system (ILL-2) was the most prominent system in the irrigated zone of Haryana comprising of 46 percent of the sampled farm households in this zone. The least prominent system in the irrigated zone was the Irrigated large dairy farming system with only 7 percent of the households. Similarly from Figure 5.2, in the rainfed zone, rainfed small dairy farming system (RS-3) was the most prominent system accounting for 31 percent of the households belonging to this system and the least prominent was the rainfed large dairy farming system with only 6 percent households in the rainfed zone.

5.1.2 General Characteristics of the Identified Dairy Farming Systems

The dairy farming systems in Haryana were represented and identified by their specific features (Figs. 5.3 and 5.4). The family size, labour utilization and availability are some of the important criteria, which were unique for each of the dairy farming systems. The dairy farming features considered were herd size, number of milch animals and its composition, their productive and reproductive characteristics such as milk yield per day in different seasons, intercalving period, dry period, breed of animals and management features such as labour management, housing, breeding, management, feeding, milking, economics of milk marketing, and source of income of the household. The ensuing section provides an insight into the specific features of the identified dairy farming systems in Haryana.

The maximum numbers of households in the identified systems in the irrigated zone were found in the landless dairy farming systems (46%) followed by small (16%), marginal (10%) and large (7%) systems (Fig. 5.1). In the rainfed zone, majority of households belonged to the small dairy farming systems (31%) followed by marginal (23%), landless (14%), and large (6%) systems (Fig. 5.2).

A perusal of Table 5.2 revealed that the average family size was lower in the rainfed zone as compared to the irrigated zone. In the irrigated as well

as rainfed zones, the average family size was the highest in the dairy farming systems of the large farm households. However, the sex ratio of the females to males was relatively lower in the dairy farming systems of the large farm households (RL-3) in both the zones. The major occupation of the small and large dairy farming systems in both the zones was crop farming while it was off-farm labour in the case of the landless and marginal dairy farming systems.

Table 5.2 Family size and composition across different dairy farming systems in Haryana.

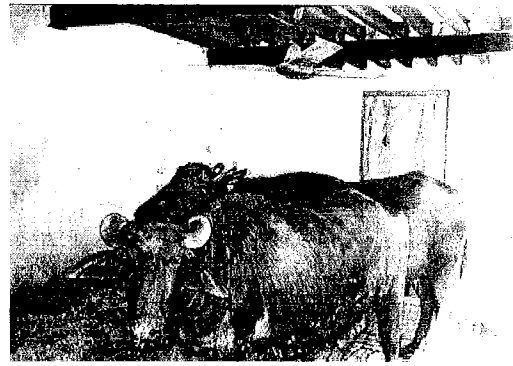
Characteristics	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Number of households	165	36	59	24	190	312	428	75
Average family size	9.2	8.1	10.2	12.7	6.9	7.2	7.4	8.8
Average adult males	3.1	2.7	3.7	4.3	1.8	2.1	2.3	3.0
Average adult females	2.7	2.5	3.2	3.4	1.5	1.8	1.8	2.3
Average children	3.4	2.9	3.3	5.0	3.6	3.3	3.3	3.5
Sex ratio (females : 1000 males)	939	995	892	865	842	868	804	791
Major occupation	Labour	Labour	Farmer	Farmer	Labour	Labour	Farmer	Farmer

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

In view of labour being an important resource component in family households, it was felt necessary to analyze the availability and utilization of labour for carrying out farm operations. Hence, labour utilization and availability in mandays per year has been presented across dairy farming systems in Table 5.3. A perusal of Table 5.3 revealed that the labour availability and leisure was relatively more on large farm households in both the irrigated as well as rainfed zone.



Irrigated landless dairy farming system (ILL-2)



Irrigated marginal dairy farming system (IM-2)



Irrigated small dairy farming system (IS-3)



Irrigated large dairy farming system (IL-4)

Figure 5.3 Description of irrigated dairy farming systems identified in Haryana state using cluster analysis.



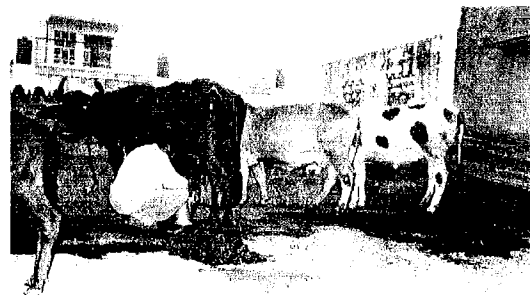
Rainfed landless dairy farming system (RLL-2)



Rainfed marginal dairy farming system (RM-2)



Rainfed small dairy farming system (RS-3)



Rainfed large dairy farming system (RL-3)

Figure 5.4 Description of rainfed dairy farming systems identified in Haryana state using cluster analysis.

Table 5.3 Labour availability and utilization by dairy farming systems.

(In mandays/year)

Characteristics	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Available	1378	872	1343	1886	1081	1020	998	1098
Crops	0	58	152	274	3	83	130	253
Dairy	295	151	157	233	248	259	219	189
Farm	295	209	309	507	251	342	349	442
Non-farm	215	215	149	0	187	208	45	0
Leisure	868	448	885	1379	643	470	604	656

All the households across various dairy farming systems had significant amount of unutilized available labour for farm or non-farm operations. Maximum amount of labour time available for leisure activities was in the large farm households in the irrigated zone and the minimum in the marginal farm households in the irrigated zone.

The ILL-2 and IM-2 systems were wholly managed by the family members with a significant work contribution from the female members of the household. The labour utilization for the milch animals (species-wise) across dairy farming systems have been presented in Table 5.4.

Table 5.4 Labour utilization across dairy farming systems species-wise in the study area.

(In manhours/year/milch animal)

Milch species	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Buffalo	1595	679	707	523	1513	1166	1034	540
Crossbred cow	1459	804	658	630	1388	1074	954	710
Local cow	1235	695	524	535	1046	913	864	552

A perusal of Table 5.4 revealed that labour used per milch animal was relatively more in the landless systems in both the zones. This could be explained partially on the basis of the practice of feeding green fodder depending on labour intensive green fodder collection of grasses, weeds, etc from open fields. The labour hours used were 1595, 1459 and 1235 manhours per buffalo, crossbred and local cow per year, respectively, in the ILL-2

system. In the IM-2 system, the labour hours used was 679, 804 and manhours per buffalo, crossbred and local cow per year, respectively. Working as a farm labourer and in non-farm labour for 215 mandays were main source of family income for ILL-2 and IM-2 systems.

The IS-3 system was also mostly managed by the family members with the female members of the household managing the cleaning and feeding by the male members. The labour hours used were 707, 658 and 524 manhours per buffalo, crossbred and local cow per year, respectively.

The IL-4 system was partly managed by the male adult family members and partly by hired labour. The labour hours used were 523, 630 and 535 manhours per buffalo, crossbred and local cow per year, respectively.

In the RLL-2 system, the labour hours used were 1513, 1388 and 1046 manhours per buffalo, crossbred and local cow per year, respectively. Working as a farm labourer and in non-farm labour for 187 mandays were main source of family income for this system.

In the RM-2 system, the labour hours used were 1166, 1074 and 913 manhours per buffalo, crossbred and local cow per year, respectively. Working as a farm labourer and in non-farm labour for 208 mandays was main source of family income for this system. Besides some crop such as bazra, mustard, gram, wheat, berseem and jowar was also grown to meet home consumption and animal feed needs.

The RS-3 system was also mostly managed by the family members with the female members of the household managing the cleaning and feeding and milking being done by the male members. The labour hours used was 1034, 954 and 864 manhours per buffalo, crossbred and local cow per year, respectively.

Limited job in off-farm or farm jobs in others fields were also carried out at an average rate of 45 mandays per year. The RL-3 system was partly managed by the male family members and partly by hired labour. The labour hours used were 540, 710 and 552 manhours per buffalo, crossbred and local cow per year, respectively.

In the overall, it could be seen that the landless and the marginal farms in the irrigated and rainfed zones were more labour intensive in dairying than the small or large systems. The marginal systems in the rainfed zone were more labour intensive than the marginal systems in the irrigated zone.

5.1.3 Herd Characteristics of the Identified Dairy Farming Systems

The herd characteristics in terms of number and composition of milch animals have been presented in Table 5.5. The dairy farming systems were predominantly landless buffalo based type (ILL-2) in the irrigated zone while these were small (RS-3) and marginal (RM-2) buffalo based type in the rainfed zone. Unlike the irrigated zone, the landless category was not the most prominent in the rainfed zone as more households possessed land and those without land also preferred to quit dairying as is evident from the cluster analysis results with no milch cluster comprising of maximum number of landless households with no milch animals (179).

Table 5.5 Characteristics of identified dairy farming systems in the study area.

Characteristics	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Number of households	165	36	59	24	190	312	428	75
Percent of households sampled in each zone	46	10	16	7	14	23	31	6
Average Buffaloes	1.3	1.5	2.3	3.0	1.3	1.5	1.7	2.1
Average Crossbred cows	0.3	0.2	0.4	0.8	0.0	0.0	0.0	0.1
Average local cows	0.2	0.1	0.3	0.3	0.1	0.1	0.2	0.2
Average herd size	3.0	3.2	5.5	8.3	2.3	2.9	3.8	5.1
Buffalo based (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Crossbred based (%)	20.6	16.7	33.9	54.2	2.1	2.9	3.7	8.0
Local cattle based (%)	18.8	5.6	32.2	29.2	7.4	11.9	15.0	14.7

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

The buffaloes in the study area possessed Murrah and Nili-Ravi characteristics. The local cows were mostly of non-descript type, while crossbred cows were mostly Holstein or Jersey crosses. Buffaloes were highly seasonal breeders with calving season ranging from September to March.

A further perusal of Table 5.5 revealed that the herd size varied from 3 to 8 animals in the irrigated zone and from 2 to 5 animals in the rainfed zone. There was a general trend of increase in herd size with the increase in land holdings size. The dairy farming systems were predominantly buffalo based as could be seen from the Table 5.5 that all households possessed buffaloes across various dairy farming systems in both the zones. Crossbred cows were found to be relatively more in the irrigated zone in the small and large farms. Local cows were more predominant in the irrigated small and large systems.

In the ILL-2 system, the median composition of the milch bovines was two adult milch animals (two buffaloes or one buffalo with one crossbred cow or local cow). The median herd size was 3 animals. The reproductive characteristics of the milch animals viz. intercalving period and dry period are presented in Table 5.6

Table 5.6 Mean calving interval and dry period of different milch bovines across dairy farming systems in the study area.

(In number of days)

Milch species	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Intercalving period								
Buffalo	475	480	436	445	467	479	439	433
Crossbred cow	483	503	437	448	486	475	437	405
Local cow	498	538	528	499	505	529	494	457
Dry period								
Buffalo	176	189	135	140	168	175	130	135
Crossbred cow	158	170	125	132	160	169	140	129
Local cow	173	214	215	204	209	220	195	149

A perusal of Table 5.6 revealed that in the ILL-2 system, the mean intercalving period was much higher at 475, 483 and 498 days for buffalo, crossbred and local cow, respectively. The mean dry period of the buffalo, crossbred and local cow was 176, 158 and 173 days, respectively.

In IM-2 system, the median composition of the milch livestock was two adult milch animals (two buffaloes or one buffalo with one crossbred cow or local cow). The median herd size was 3 animals. The mean intercalving period was much higher at 480, 503 and 538 days for buffalo, crossbred and local cow, respectively. The mean dry period of the buffalo, crossbred and local cow were 189, 170 and 214 days, respectively.

In IS-3 system, the median composition of the milch livestock was three adult milch animals (two buffaloes with one crossbred cow or local cow). The median herd size was 6 animals. The mean intercalving period was comparatively lesser than other systems at 436, 437 and 528 days for buffalo, crossbred and local cow, respectively. The mean dry period of the buffalo, crossbred and local cow was 135, 125 and 215 days, respectively.

In IL-4 system, the median composition of the milch livestock was four adult milch animals (three buffaloes with one crossbred cow or local cow). The median herd size was 8. The mean intercalving period was 445, 448 and 499 days for buffalo, crossbred and local cow, respectively. The mean dry period of the buffalo, crossbred and local cow was 140, 132 and 204 days, respectively.

In the RLL-2 system, the median composition of the milch livestock was two adult milch animals (two buffaloes or one buffalo with one crossbred cow or local cow). The median herd size was 3 animals. The mean intercalving period was much higher at 467, 486 and 505 days for buffalo, crossbred and local cow, respectively. The mean dry period of the buffalo, crossbred and local cow was 168, 160 and 209 days, respectively.

In the RM-2 system, the median composition of the milch livestock was two adult milch animals (two buffaloes or one buffalo with one crossbred cow or local cow). The median herd size was 3 animals. The mean intercalving

period was 479, 475 and 529 days for buffalo, crossbred and local cow, respectively. The mean dry period of the buffalo, crossbred and local cow were 175, 169 and 220 days, respectively.

In RS-3 system, the median composition of the milch livestock was three adult milch animals (two buffaloes with one crossbred cow or local cow). The median herd size was 4 animals. The mean intercalving period was at 439, 437 and 494 days for buffalo, crossbred and local cow, respectively. So the crossbred and local cows were not in milk in every year. Reproductive disorders were one of the reasons for non-adoption of the crossbred cow by this category of system. The mean dry period of the buffalo, crossbred and local cow were 130, 140 and 195 days, respectively.

In RL-3 system, the median composition of the milch livestock was three adult milch animals (three buffaloes or two buffaloes with one crossbred cow or local cow). The median herd size was 5 animals. The mean intercalving period were 433, 405 and 457 days for buffalo, crossbred and local cow, respectively. The mean dry period of the buffalo, crossbred and local cow were 135, 129 and 149 days, respectively.

It can be seen from the Table 5.7 that the mean proportion of milch animals in milk across dairy farming systems in one year varied from a high of 71.4 percent in crossbred cows in case of small systems in irrigated zone to as low as 58.4 in local cows in marginal systems in rainfed zone. More proportion of buffaloes were in milk in rainfed zone while proportion of crossbred cows in milk were more in irrigated zone.

Table 5.7 Mean proportion of milch animals species-wise in milk per year across dairy farming systems in the study area.

(%)

Milch species	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Buffalo	63.0	60.6	69.0	68.5	64.0	63.5	70.4	68.8
Crossbred cow	67.3	66.2	71.4	70.5	67.1	64.4	68.0	68.2
Local cow	65.3	60.2	59.3	59.1	58.6	58.4	60.5	67.4

Thus, it could be summarized that the average number of buffaloes across dairy farming systems increased with increase in land holdings size in the irrigated zone from 1.3 to 3.0 ha and in the rainfed zone from 1.3 to 2.1 ha. However, the average numbers of crossbred or Indigenous cows were less than one across all the systems signifying their insignificant presence in the across all the systems identified in the study area. However, crossbred cows were significantly higher than other systems in the irrigated small and large systems. It is also clear from the description that longer dry periods of milch animals is a problem across all dairy farming systems with lower proportion of milch animals in milk in a year. The proportion of milch animals in milk was comparatively better in buffaloes and crossbred cows in the irrigated small systems and in buffaloes in the rainfed small systems. Overall, the proportions of animals in milk were better in the rainfed large systems across all species.

5.1.4 Milk Yield Characteristics of the Identified Dairy Farming Systems

The mean daily milk yield of different species across various dairy farming systems in the irrigated and rainfed zone, respectively, are presented in Tables 5.8 and 5.9.

A perusal of Table 5.8 revealed that in the ILL-2 system, the overall mean milk yield per day for buffalo, crossbred and local cow was 2.8, 2.7 and 2.0 kg, respectively. In the IM-2 system, the overall mean yield per day of buffalo, crossbred and local cow was 2.3, 2.3 and 1.4 kg, respectively. In the IS-3 system, the overall mean yield per day of buffalo, crossbred and local cow was 3.5, 3.5 and 2.3 kg, respectively. In the IL-4 system, the mean yield per day of buffalo, crossbred and local cow was 3.1, 3.7 and 2.3 kg, respectively.

A perusal of Table 5.9 revealed that in the RLL-2 system, the mean yield per day per buffalo, crossbred and local cow was 2.4, 3.0 and 1.7 kg, respectively. In the RM-2 system, the mean yield per day per buffalo, crossbred and local cow was 2.6, 2.3 and 2.1 kg, respectively. In the RS-3 system, the mean yield per day per buffalo, crossbred and local cow was 3.2,

Table 5.8 Average daily milk yield of milch animals across dairy farming systems in the irrigated zone.

(In kg)

Seasons	Dairy farming systems											
	ILL-2			IM-2			IS-3			IL-4		
	B	CB	LC	B	CB	LC	B	CB	LC	B	CB	LC
Rainy	3.2	3.3	2.1	2.4	3.0	1.0	4.0	3.6	2.0	3.0	4.2	2.0
Winter	3.7	3.1	2.9	3.5	2.5	2.0	4.6	3.9	2.8	3.8	4.8	3.0
Summer	1.4	1.6	0.9	1.0	1.5	1.3	1.9	3.0	2.1	2.6	2.2	2.0
Overall	2.8	2.7	2.0	2.3	2.3	1.4	3.5	3.5	2.3	3.1	3.7	2.3

B = Buffalo; CB = Crossbred; LC = Local cow.

Table 5.9 Average daily milk yield of milch animals across dairy farming systems in the rainfed zone.

(In kg)

Seasons	Dairy Farming Systems											
	RLL-2			RM-2			RS-3			RL-3		
	B	CB	LC	B	CB	LC	B	CB	LC	B	CB	LC
Rainy	2.9	3.0	2.0	3.0	3.0	2.5	3.5	3.0	2.6	3.5	7.0	3.0
Winter	3.2	4.0	2.0	3.3	2.5	2.4	4.3	4.5	2.5	3.9	5.0	3.0
Summer	1.1	2.0	1.0	1.4	1.5	1.5	1.9	3.0	1.8	2.4	4.0	2.0
Overall	2.4	3.0	1.7	2.6	2.3	2.1	3.2	3.5	2.3	3.3	5.4	2.7

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems. B = Buffalo; CB = Crossbred; LC = Local cow.

3.5 and 2.3 kg, respectively. In the RL-3 system, the mean yield per day per buffalo, crossbred and local cow was 3.3, 5.4 and 2.7 kg, respectively.

In order to compare the milk yield across systems in an uniform pattern, the milk yield was standardized on the basis of fat content and the number and type of milch animals to standard milch units (SMU). The mean milk yield per standard animal unit per year was found to be 890 kg in the ILL-2 system, 630 kg in the IM-2 system, 1064 kg in the IS-3 system, and 1035 kg in the IL-4 system. The mean milk yield per standard animal unit per annum was 739 kg in the RLL-2 system, 732 kg in the RM-2 system, 1016 kg in the RS-3 system, and 1191 kg in the RL-3 system. Thus, mean FCM¹ milk yield per year per SMU was observed to vary from 630 kg in the marginal irrigated systems to 1191 kg in the large rainfed systems. Crossbred cows were found to be more productive in terms of milk yield in the large land sized farms of rainfed zone.

The average daily milk yield was comparatively more in the large category in the rainfed system than in the irrigated system. In the other systems, it was more or less similar to the irrigated zone systems.

In general, the average daily milk yield was observed to be relatively more in the partially rainfed zone than the irrigated zone. The plausible reason for this observation could be partly due to better feeding practices of concentrates such as cotton seed cake, mustard cake, bazra seed etc. and comparatively better nutritive dry fodders such as bajra / jowar straw on account of its easy availability being grown in this area. It could also be due to the higher adaptability of the cattle and buffalo breeds to the arid climatic condition due to the origin and evolution of most of Indian cattle and buffalo breeds in the arid zone.

5.1.5 Feeding Pattern of the Dairy Farming Systems

Green fodder, dry fodder and concentrates are the sources of feed for milch animals to supply the required roughages, nutrients and minerals across all dairy farming systems identified in Haryana. However, the proportion,

¹ $FCM\ milk = (milk\ production * fat\ in\ % * 0.15) + (milk\ production * 0.4)$

quality, quantity and type varies from system to system depending upon the availability, accessibility, cost, etc. The feeding system was mostly stall based with limited grazing being practiced only if community owned grazing lands were available in the village.

The following section describes each of the type of feed viz. green, dry fodder and concentrates to shed light on the nutritional status of the dairy farming systems.

5.1.5.1 Feeding of green fodder

The average quantity of green fodder fed to the animals per day in the irrigated zone are presented in Table 5.10. The major source of green fodder was of perennial grasses, weeds and sugarcane tops in the irrigated zone by the landless dairy farming systems while sugarcane tops, berseem, jowar and maize were fed to all the other systems in irrigated zone. Sugarcane tops was mostly fed in the late winters and early summer. Berseem was fed in the winter season and jowar and maize in the summer and rainy season, respectively.

Table 5.10 Average quantity of green fodder fed to milch animals across various dairy farming systems in the irrigated zone.

(kg/day/milch animal)

Green fodder	Dairy farming systems											
	ILL-2			IM-2			IS-3			IL-4		
	B	CB	LC	B	CB	LC	B	CB	LC	B	CB	LC
Perennial weeds	12.1	16.5	11.8	4.5	5.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Sugarcane tops	13.9	16.8	15.7	9.9	15.4	11.2	9.3	14.7	10.4	6.5	10.4	9.9
Berseem	0.0	0.0	0.0	8.5	15.4	5.5	9.2	20.7	6.3	22.7	25.7	19.4
Jowar	0.0	0.0	0.0	12.3	12.0	10.3	13.8	14.8	10.1	25.7	25.6	25.6
Maize	0.0	0.0	0.0	5.6	5.4	4.0	5.0	4.6	3.8	13.6	13.3	15.2

In the ILL-2 system, the feeding was of perennial weeds, grasses, weeds collected from the crop fields and sometimes roadside grazing throughout the year. Sugarcane tops was also fed during the harvest season

of sugarcane in the late winters and early summer season. The availability of grasses, weeds is almost six months a year except during the hot summer and early monsoon months of May-August and the colder months of January-February. Generally the conventional green fodder such as berseem, jowar and maize are not used to feed the animals due to their high costs and lack of land to grow them. The mean quantity of perennial grasses, weeds collected fed was found to be 12.1, 16.5, 11.8 kg per day per milch animal for buffalo, crossbred cow and local cow, respectively. The mean quantity of sugarcane tops fed during the harvest season of sugarcane was found to be 13.9, 16.8 and 15.7 kg per day per milch animal.

In IM-2 system, the green fodders used to feed the animals were berseem in December to March, sugarcane tops in April to May, maize in July and jowar in August to September. So there were some periods of green fodder scarcity in months of June, October, and November. This system is able to grow green fodder to meet its requirement but sometimes it purchases green fodder to meet the scarcity of fodder in certain months. Sugarcane tops is generally available to this system in kind against farm labour in harvesting sugarcane in other farms. The mean quantity of berseem fed was found to be 8.5, 15.4, 5.5 kg per milch animal per day in buffalo, crossbred cow and local cow, respectively. The mean quantity of jowar fed was found to be 12.3, 12.0 and 10.3 kg per milch animal per day while that of maize 5.6, 5.4 and 4.0 in buffalo, crossbred cow and local cow, respectively. The mean quantity of sugarcane tops fed was found to be 9.9, 15.4 and 11.2 kg per milch animal per day in buffalo, crossbred cow and local cow, respectively, in this system.

In the IS-3 system, the green fodder used to feed the animals were similar to the IM-2 system with berseem in December to March, sugarcane tops in April to May, maize in July and jowar in August to September. So there were some periods of green fodder scarcity in months of June, October, and November. This system is able to grow all the green fodder to meet its requirement and also sell surplus fodder. Sugarcane tops is generally available to this system from its own farm. The mean quantity of berseem fed

was found to be 9.2, 20.7, 6.3 kg per milch animal per day in buffalo crossbred cow and local cow, respectively. The mean quantity of jowar fed was found to be 13.8, 14.8, 10.1 kg per milch animal per day while that of maize 5.0, 4.6, 3.8 kg in buffalo, crossbred cow and local cow, respectively. The mean quantity of sugarcane tops fed was found to be 9.3, 14.7, 10.4 kg per milch animal per day in buffalo, crossbred cow and local cow, respectively, in this system. Thus, crossbred cow was given more of green fodder in this system.

In the IL-4 system, the green fodder used to feed the animals were similar to the IM-2 and IS-3 system with berseem in December to March, sugarcane tops in April to May, maize in July and jowar in August to September. So there were some periods of green fodder scarcity in months of June, October, and November. This system is able to grow all the green fodder to meet its requirement and also sell surplus fodder. Sugarcane tops is available to this system from its own farm. The mean quantity of berseem fed was found to be 22.7, 25.7 and 19.4 kg per milch animal per day in buffalo, crossbred cow and local cow, respectively. The mean quantity of jowar fed was found to be 25.7, 25.6, and 25.6 kg per milch animal per day while that of maize 13.6, 13.3 and 15.2 kg in buffalo, crossbred cow and local cow, respectively. The mean quantity of sugarcane tops fed was found to be 6.5, 10.4 and 9.9 kg per milch animal per day in buffalo, crossbred cow and local cow, respectively in this system. Thus, green fodder feeding especially berseem in *rabi* season and jowar in *kharif* season were given more weightage in this system.

Thus, It could be observed from Table 5.10 that the irrigated large buffalo based dairy farming systems were mostly green fodder based with significant quantities of berseem and jowar fodder being fed to milch animals. Green fodder was fed liberally to the crossbred cows rather than buffaloes or local cows in the small dairy farming systems.

The average quantity of green fodder fed to the milch animals in the rainfed zone are presented in Table 5.11.

Table 5.11 Average quantity of green fodder fed to milch animals across various dairy farming systems in the rainfed zone.

(kg/day/milch animal)

Green fodder	Dairy Farming Systems											
	RLL-2			RM-2			RS-3			RL-3		
	B	CB	LC	B	CB	LC	B	CB	LC	B	CB	LC
Perennial weeds	7.3	8.5	6.5	4.8	4.0	6.2	0.0	0.0	0.0	0.0	0.0	0.0
Berseem	7.7	8.5	9.2	8.6	16.6	8.1	12.3	17.1	9.4	12.1	17.8	8.7
Jowar	9.0	9.5	5.1	10.4	18.2	14.0	19.7	23.4	15.8	19.9	23.7	15.1
Maize	3.8	5.6	5.7	4.3	9.6	5.3	7.0	9.9	5.8	7.0	10.4	5.5

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

In the RLL-2 system, the feeding was of perennial weeds, grasses, weeds collected from the crop fields and sometimes roadside grazing throughout the year. Sugarcane tops was also fed during the harvest season of sugarcane in the late winters and early summer season. The availability of grasses, weeds is almost six months a year except during the hot summer and early monsoon months of May-August and the colder months of January-February. Generally, the conventional green fodder such as berseem, jowar and maize are also used to feed the animals during their period of availability, mostly purchased in cash or kind against farm labour. A perusal of Table 5.11 revealed that the mean quantity of perennial grasses, weeds collected fed were 7.3, 8.5 and 6.5 kg per day per milch animal for buffalo, crossbred cow and local cow, respectively. The mean quantity of berseem fed was found to be 7.7, 8.5 and 9.2 kg; jowar at 9.0, 9.5 and 5.1 kg and maize at 3.8, 5.6 and 5.7 kg per milch animal per day for buffalo, crossbred cow and local cow, respectively.

In RM-2 system, the green fodder used to feed the animals were berseem in December to March, maize in July and jowar in August to September. So, there were some periods of green fodder scarcity in months of June, October, and November. This system is able to grow green fodder to meet its requirement but sometimes it collects grasses, weeds to feed up to

4.8, 4.0 and 6.2 kg per day per buffalo, crossbred cow and local cow, respectively. The mean quantity of berseem fed was found to be 8.6, 16.6, 8.1 kg per milch animal per day in buffalo, crossbred cow and local cow, respectively. The mean quantity of jowar fed was found to be 10.4, 18.2, 14.0 kg per milch animal per day while that of maize 4.3, 9.6 and 5.3 kg in buffalo, crossbred cow and local cow, respectively.

In the RS-3 system, the green fodder used to feed the animals were similar to the IM-2 system with berseem in December to March, maize in July and jowar in August to September. So there were some periods of green fodder scarcity in months of June, October, and November. This system is able to grow all the green fodder to meet its requirement and also sell surplus fodder. The mean quantity of berseem fed was found to be 12.3, 17.1 and 9.4 kg per milch animal per day in buffalo, crossbred cow and local cow, respectively. The mean quantity of jowar fed was found to be 19.7, 23.4 and 15.8 kg per milch animal per day while that of maize 7.0, 9.9 and 5.8 kg in buffalo, crossbred cow and local cow, respectively. The mean quantity of sugarcane tops fed was found to be 9.3, 14.7, 10.4 kg per milch animal per day in buffalo, crossbred cow and local cow, respectively, in this system. Thus, crossbred cow was given more of green fodder in this system.

In the RL-3 system, the green fodder used to feed the animals were similar to the RS-3 system with berseem in December to March, maize in July and jowar in August to September. So there were some periods of green fodder scarcity in months of June, October, and November. This system is able to grow all the green fodder to meet its requirement and also sell surplus fodder. The mean quantity of berseem fed was found to be 12.1, 17.8 and 8.7 kg per milch animal per day in buffalo, crossbred cow and local cow, respectively. The mean quantity of jowar fed was found to be 19.9, 23.7 and 15.1 kg per milch animal per day while that of maize 7.0, 10.4, 5.5 kg in buffalo, crossbred cow and local cow, respectively. Thus, green fodder feeding especially berseem in *rabi* season and jowar in *kharif* season were given more weightage in this system.

Thus, in overall, it could be observed that Berseem, Jowar and maize were the main green fodder crops in both the zones. Liberal quantities of feeding of these green fodder crops were practiced by the large systems of the irrigated and rainfed zones with comparatively more quantities per milch animal per day in the irrigated zone.

5.1.5.2 Feeding of dry fodder

Majority of the systems were dry fodder crop-residue based with concentrates. The dry fodder was fed to milch animals throughout the year in all the systems. The dry fodder fed was mainly wheat straw and paddy straw in the irrigated zone and wheat straw, bajra / jowar straw in the rainfed zone. The dry fodder fed to the milch animals in the irrigated zone has been presented in Table 5.12.

Table 5.12 Average quantity of dry fodder fed to milch animals across various dairy farming systems in the irrigated zone.

(kg/day/milch animal)

Dry fodder	Dairy farming systems											
	ILL-2			IM-2			IS-3			IL-4		
	B	CB	LC	B	CB	LC	B	CB	LC	B	CB	LC
Wheat straw	5.9	5.5	4.7	8.9	7.8	7.6	8.9	8.0	7.2	4.9	5.3	4.7
Paddy straw	2.6	3.0	3.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

In the ILL-2 system, Wheat and paddy straw was the dry fodder, which was used throughout the year to feed the animals. Wheat straw was generally purchased in cash or in kind in return for farm work in others' fields. A perusal of Table 5.12 revealed that the mean quantity of wheat straw fed was 5.9, 5.5 and 4.7 kg per buffalo, crossbred cow and local cow, respectively, in this landless system in irrigated zone. Paddy straw was fed at 2.6, 3.0 and 3.6 kg per buffalo, crossbred cow and local cow, respectively.

In IM-2 system, Wheat and paddy straw was the dry fodder, which was used throughout the year to feed the animals. Wheat straw was generally purchased in cash or in kind in return for farm work in others' fields. The mean

quantity of wheat straw fed was 8.9, 7.8 and 7.6 kg per buffalo, crossbred cow and local cow, respectively. Paddy straw was fed at 1.8 kg per day per buffalo.

In the IS-3 system, Wheat straw was the dry fodder, which was used throughout the year to feed the animals. Wheat straw was generally home-produced. The mean quantity of wheat straw fed was 8.9, 8.0, 7.2 kg per buffalo, crossbred cow and local cow, respectively.

In the IL-4 system, Wheat straw was the dry fodder, which was used throughout the year to feed the animals. Wheat straw was generally home-produced. The mean quantity of wheat straw fed was 4.9, 5.3, 4.7 kg per buffalo, crossbred cow and local cow, respectively.

The amount of dry fodder fed to the milch animals in the rainfed zone have been presented in Table 5.13.

Table 5.13 Average quantity of dry fodder fed to milch animals across various dairy-farming systems in the rainfed zone.

(kg/day/milch animal)

Dry fodder	Dairy Farming Systems											
	RLL-2			RM-2			RS-3			RL-3		
	B	CB	LC	B	CB	LC	B	CB	LC	B	CB	LC
Wheat straw	4.9	4.7	4.9	5.7	5.9	5.7	6.4	5.9	5.9	7.2	6.0	5.5
Bazra / jowar straw	3.9	4.0	3.6	4.3	2.7	3.6	2.6	2.6	3.2	3.5	2.4	3.9

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems. B = Buffalo; CB = Crossbred; LC = Local cow.

A close scrutiny of Table 5.13 revealed that in the RLL-2 system, Wheat and bazra straw was the dry fodder, which was used throughout the year to feed the animals. Wheat and bajra straw was generally purchased in cash or in kind in return for farm work in others' fields. The mean quantity of wheat straw fed was 4.9, 4.7 and 4.9 kg per buffalo, crossbred cow and local cow, respectively. Bajra / jowar straw was fed at 3.9, 4.0 and 3.6 kg per buffalo, crossbred cow and local cow, respectively.

In RM-2 system, wheat and bajra straw was the dry fodder, which was used throughout the year to feed the animals. Wheat straw was generally purchased in cash or in kind in return for farm work in others' fields. The mean quantity of wheat straw fed was 5.7, 5.9 and 5.7 kg per buffalo, crossbred cow and local cow, respectively. Bajra / jowar straw was fed at 4.3, 2.7 and 3.6 kg per day per buffalo, crossbred cow and local cow, respectively.

In the RS-3 system, wheat and bajra straw was the dry fodder, which was used throughout the year to feed the animals. Wheat straw was generally home-produced. The mean quantity of wheat straw fed was 6.4, 5.9 and 5.9 kg per buffalo, crossbred cow and local cow, respectively, and bajra / jowar straw was fed at 2.6, 2.6 and 3.2 kg per day per buffalo, crossbred cow and local cow, respectively.

In the RL-3 system, wheat and bajra straw was the dry fodder, which was used throughout the year to feed the animals. Wheat and bajra straw were generally home-produced. The mean quantity of wheat straw fed was 7.2, 6.0, 5.5 and of bajra / jowar straw at 3.5, 2.4 and 3.9 kg per buffalo, crossbred cow and local cow, respectively. In RL-3 system, dry fodder was available in surplus to feed the animals and was used liberally. Excess was often sold by the farmer in the local market.

Wheat straw was the predominant dry fodder in the irrigated and rainfed zone while paddy straw was only fed by the landless and marginal buffalo based dairy farming systems. However, bajra / jowar straw was fed in all the dairy farming systems of the rainfed zone. Maximum amount of wheat straw was fed in the irrigated small buffalo based dairy farming systems. Maximum bajra / jowar straw was fed in the marginal buffalo based dairy farming systems in the rainfed zone.

5.1.5.3 Feeding of concentrates

Concentrates used were mostly from locally made ingredients derived from crop-residues in both the zones. Mustard seed cake and cotton seed cake and wheat meal are the three major concentrates which are widely used throughout the irrigated and rainfed zone. Gram meal is also used in the rainfed zone significantly.

The amount of concentrate ingredients fed to the milch animals in the irrigated zone have been presented in Table 5.14.

Table 5.14 Average quantity of concentrates fed to milch animals across various dairy farming systems in the irrigated zone.

(kg/day/milch animal)

Concentrate ingredients	Dairy farming systems											
	ILL-2			IM-2			IS-3			IL-4		
	B	CB	LC	B	CB	LC	B	CB	LC	B	CB	LC
Mustard seed cake	0.3	0.3	0.2	0.2	0.2	0.1	0.3	0.5	0.2	0.5	0.5	0.3
Rice bran	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.0
Cotton seed cake	0.3	0.4	0.2	0.3	0.3	0.1	0.5	0.6	0.4	0.7	1.0	0.8
Wheat meal	0.3	0.2	0.2	0.2	0.1	0	0.4	0.6	0.7	0.5	0.8	0.2
Compound feed	0.0	0.0	0.0	0.1	0.2	0.1	0.2	0.2	0.1	0.3	0.1	0.1
Taramira	0.0	0.0	0.0	0.2	0.3	0	0.3	0.2	0.1	0.3	0.2	0.1
Wheat	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.0	0.0
Jaggery	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
Gram meal	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.0

Dairy farming system codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems. B = Buffalo; CB = Crossbred; LC = Local cow.

In the ILL-2 system, Concentrates such as mustard seed cake, cotton seed cake and wheat meal were also used to feed the animals and was used when the animal is in lactation or is advanced pregnant. A perusal of Table 5.14 revealed that in the ILL-2 system, the mean quantities of feed fed were 0.3 kg each of mustard seed cake, cotton seed cake and wheat meal per buffalo per annum; 0.3, 0.4 and 0.2 kg per crossbred cow per day and 0.2 kg of each of the ingredients per local cow per annum, respectively.

In IM-2 system, the mean quantities of feed fed were 0.2, 0.3, 0.2, 0.2, 0.1, 0.12 and 0.0 kg of mustard seed cake, rice meal, cotton seed cake, wheat meal, taramira, wheat, compound feed, respectively, per buffalo per annum; 0.2, 0.3, 0.1, 0.3, 0.2, 0.09 kg per crossbred cow per annum 0.1, 0.1, 0.0, 0.0, 0.2, 0.09 kg per local cow per day, respectively.

In the IS-3 system, jaggery and methi was also used to feed the buffaloes especially in the advanced stages of pregnancy and early lactation. The mean quantities of feed fed were 0.3, 0.5, 0.5, 0.4, 0.3, 0.1, 0.178 and 0.1 kg of mustard seed cake, rice meal, cotton seed cake, wheat meal, taramira, wheat, compound feed and gram meal, respectively, per buffalo per day; 0.5, 0.03, 0.6, 0.6, 0.2, 0.2, 0.21 and 0.1 kg per crossbred cow per day and in case of local cow, the quantities of mustard seed cake, rice meal, cotton seed cake, wheat meal, taramira, wheat, compound feed used to feed were 0.2, 0.0, 0.4, 0.7, 0.1, 0.2, 0.05 kg per local cow per day, respectively. Jaggery and methi used was 0.1 and 0.02 kg, respectively, per buffalo per day.

In the IL-4 system, the mean quantities of feed fed were 0.5, 0.05, 0.7, 0.5, 0.3, 0.2, 0.315 and 0.1 kg of mustard seed cake, rice meal, cotton seed cake, wheat meal, taramira, wheat, compound feed and gram meal, respectively, per buffalo per annum; 0.5, 0.05, 1, 0.8, 0.2 0.0, 0.08 and 0.1 kg per crossbred cow per annum and 0.3, 0.0, 0.8, 0.2, 0.1, 0.0, 0.0 and 0.0 quintal per local cow per annum, respectively. Jaggery and methi used were 0.1 and 0.03 kg, respectively, per buffalo per day.

The amount of concentrates fed to the milch animals in the rainfed zone have been presented in Table 5.15.

Table 5.15 Average quantity of concentrates fed to milch animals across various dairy farming systems in the rainfed zone.

(kg/day/milch animal)

Concentrate ingredients	Dairy Farming Systems											
	RLL-2			RM-2			RS-3			RL-3		
	B	CB	LC	B	CB	LC	B	CB	LC	B	CB	LC
Mustard seed cake	0.2	0.2	0.2	0.2	0.2	0.1	0.6	0.8	0.3	1.0	1.2	0.5
Cotton seed cake	0.2	0.2	0.1	0.3	0.3	0.1	0.5	0.5	0.3	0.7	0.8	0.5
Wheat meal	0.0	0.0	0.0	0.2	0.1	0.0	0.3	0.2	0.1	0.2	0.3	0.1
Taramira	0.0	0.0	0.0	0.2	0.3	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Compound feed	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1
Wheat	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bajra	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Gram meal	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.2	0.0

Dairy Farming System codes RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: RLL2: 2 represent the mean number of milch animals representing the systems.

A perusal of the Table 5.15 revealed that in RLL-2 system, the main concentrate ingredients used to feed the animals were mustard seed cake, cotton seed cake and compound feed. The quantity of mustard seed cake and cotton seed cake used was higher than the amount of compound feed used per day. The quantity used per day was almost similar for buffaloes and crossbred cow but lower in case of local cow. This signified that the amount of concentrates fed was proportional to the milk yield of the animal in this system.

In RM-2 system, the mean quantities of feed fed were 0.8, 0.1, 0.6, 0.1, 0.1, 0.1, 0.2 quintal of mustard seed cake, gram meal, cotton seed cake, wheat meal, mustard, compound feed and wheat, respectively per buffalo per annum; 0.2, 0.3, 0.2, 0.2, 0.1, 0.03, 0.1 kg per crossbred cow per day and 0.2, 0.3, 0.1, 0.3, 0.1, 0.1 and 0.1 kg per local cow per annum, respectively.

In RS-3 system, the mean quantities of feed fed were 0.6, 0.5, 0.3, 0.1, 0.1, 0.1, 0.1 and 0.1 kg of mustard seed cake, gram meal, cotton seed cake, wheat meal, mustard, compound feed, and gram meal, respectively, per buffalo per annum; 0.8, 0.5, 0.2, 0.1, 0.1, 0.1, 0.1, 0.3 quintal per crossbred cow per annum and 1.2, 0.1, 0.6, 0.2, 0.3, 0.2, 0.3 quintal per local cow per annum, respectively.

In RL-3 system, the mean quantities of feed fed were 1, 0.7, 0.2, 0.1, 0.1, 0.02, 0.1, 0.04, 0.1 kg of mustard seed cake, cotton seed cake, wheat meal, taramira, wheat, bajra, and gram meal, respectively, per buffalo per day; 1.2, 0.8, 0.3, 0.1, 0.1, 0.1, 0.2 kg per crossbred cow per day and 0.5, 0.5, 0.1, 0.1, 0.1, 0.1, 0.1, 0.0 kg per local cow per day, respectively.

The concentrate fed to the milch animals was comparatively higher in the small and large systems in the rainfed zone than in the irrigated zone. The amount of concentrate fed in the landless and marginal systems were almost similar in both the zones.

5.1.6 Management Characteristics of the Dairy Farming Systems

There was generally a separate cattle shed of mud and / or bricks with thatched or asbestos roofing in all the dairy farming systems. But in many

cases, the animals were kept in the same house of the owner and tied outside the house during the daytime. In the IS-3 and RS-3 systems, the cattle shed was generally located adjoining the residence but some open space also existed to tie the animals during the daytime in the open generally under a perennial tree that provides shade or temporary shed with thatched roof to protect from sun. In the IL-4 and RL-3 systems, the cattle shed was generally located a little away from the residence with lot of space to tie the animals during the daytime in the open.

Generally two or more relative families keep the animals together in one place to take advantage of labour use and space in the IL-4 and RL-3 systems. This system had a lot of open space to keep the animals. Paddy straw was mostly used as bedding material for the animal. The cow dung was used for multipurpose uses by the household such as making cow dung cakes for use as cooking fuel, for floor and wall plastering and excess was sometimes sold as farm yard manure (FYM) or in form of cow dung cakes. The machinery use consisted of a manual chaff or driven by a motor. The rest of the dairy operations were done manually. Milking was done by hand once or twice depending on stage of lactation of animal and type of animal. Generally it was done only once a day for local cows. Weaning of calf was generally not practiced and one teat of cow was left for the calf after milking. The surplus milk after the home consumption was sold to the local milkman on a daily basis who used to collect the milk from doorsteps of the house. Sometimes such as in Antawa village, the farm households belonging to this system, sold milk to the private operators such as Nestle on a contract basis for loan provided for purchase of milch animals. Bendi village had a milk collection centre of the dairy cooperatives in the village itself where sometimes the farmer sold their milk. In the selected villages of Bhiwani region, the farm households generally did not prefer to sell liquid milk, rather surplus milk was converted to ghee, which was then sold locally. This was mainly due to lack of proper marketing infrastructure available for sale of milk. In the IL-4 and RL-3 systems, sometimes the hired labour or the owner himself supplied the milk directly to the nearby town.

5.1.7 Cropping Pattern of the Dairy Farming Systems

The cropping pattern and area under different crops across dairy farming systems is presented in Table 5.16.

Table 5.16 Area under different crops in the identified dairy farming systems of the study area.

(In ha)

Land holdings and crops	Dairy farming systems					
	IM-2	IS-3	IL-4	RM-2	RS-3	RL-3
Land holdings	0.60	2.10	6.30	0.60	2.10	6.00
Paddy	0.26	0.96	2.79	0.01	0.02	0.06
Sugarcane	0.31	1.03	3.19	0.00	0.00	0.00
Wheat	0.27	1.00	2.88	0.27	0.77	1.73
Bajra	0.00	0.00	0.00	0.29	1.70	3.54
Mustard	0.00	0.00	0.00	0.21	1.03	3.06
Gram	0.00	0.00	0.00	0.19	0.63	1.80
Cotton	0.00	0.00	0.00	0.03	0.11	0.29
Berseem	0.02	0.07	0.23	0.05	0.16	0.51
Maize	0.00	0.10	0.20	0.00	0.00	0.00
Jowar	0.03	0.10	0.32	0.05	0.13	0.34

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

A perusal of the Table 5.16 revealed that the land holdings size varied from 0 to 6.30 hectares across various dairy-farming systems in the study area. Crop farming was the main economic activity in the irrigated and rainfed small and large dairy farming systems (IS-3, IL-4, RS-3, RL-3).

The cropping pattern followed was that of paddy, sugarcane, and wheat in the irrigated zone and of mustard, wheat, bazra, gram, and cotton in the rainfed zone. Berseem and jowar were the two main fodder crops found to be grown in both the zones. Berseem was the main fodder in the *rabi* season while it was jowar in the *kharif* season. The area under berseem crop varied

from 0.02 hectares in marginal irrigated systems to 0.51 hectares in large rainfed systems. Area under jowar also varied from 0.03 to 0.34 hectares in the large rainfed systems.

Sugarcane was found to be the main crop in the entire identified dairy farming systems in the irrigated zone while it was wheat in small farm households and mustard in large farm households in the rainfed zone.

It may be concluded from the above discussion that the classification of farm households in selected villages of Haryana using cluster analysis of selected variables revealed land holdings, composition and number of milch animals as the most important and significant criteria determining the dairy farming systems of Haryana for the irrigated and rainfed zones separately. Though efforts to identify livestock systems in the world have been carried out at a macro level by Steinfeld and Maki-Hokkonen (1999), but identifying dairy farming systems at micro household level has not been attempted under Indian conditions. Therefore, in the present study, a system of classifying dairy farmers of Haryana using the multivariate cluster analysis technique was attempted in order to come up with a uniform classification criteria. The present classification of dairy farming systems overcame the dilemma of whether classification should be based on landholdings, area under fodder crops, herd size, number or composition of milch animals per household. Majority of researchers in India in the past have used these variables individually in order to classify the farm households but could not come up with a uniform criteria of identifying dairy farming systems. The above study showed significant variations in herd characteristics, feeding pattern and management, and cropping pattern across the dairy farming systems.

5.2 COST OF MAINTENANCE OF MILCH ANIMAL

Cost of maintenance involves the total costs incurred in maintaining a milch animal in a household for one year for milk production and other returns viz. cow dung. Though, there may be many other returns from milch animal in a year such as calves, heifers, transport, traction, etc. only cow dung is considered for simplicity.

Costs were grouped by cost items like variable and fixed costs. Depreciation on fixed assets such as machinery and buildings and interest on fixed assets was considered as fixed costs. Expenses on feed and fodder, labour costs (family and hired), veterinary costs, miscellaneous costs were considered as variable costs. Cost of maintenance of milch animal across dairy farming systems is very important for making various policies at the micro and macro level related to marketing, finance, production and consumption. In the present study cost analysis was useful for fulfilling the objectives of determining the efficiencies and developing the optimal plans of the identified dairy farming systems. Besides, it enabled to characterize the dairy farming systems on the basis of cost of maintenance of milch animal and milk production. Hence, this analysis was carried out for each of the three milch species namely, buffalo, crossbred cow and local cow separately.

5.2.1 Maintenance Cost of Buffalo

The mean costs of maintaining a buffalo across dairy farming systems have been presented in Table 5.17. On scrutinizing the tabular results, it was observed that the fixed costs varied from Rs.1078 in the ILL-2 system to Rs.3282 in the IL-4 system in the irrigated zone. Similarly in the rainfed zone, the fixed costs varied from Rs.1536 in the RLL-2 system to Rs.2891 in the RL-3 system. Thus, in general, the fixed costs increased with increase in land holdings in both the zones in the study area.

The variable costs, on the other hand, varied from Rs.11796 in the IS-3 system to Rs.14238 in the IL-4 system. In the rainfed zone, the variable costs varied from Rs.11033 in the RL-3 system to Rs.13768 in the RLL-2 system. Thus, it could be observed that the variable costs did not follow any set pattern with land holdings as is the case with fixed costs. The systems with large land holdings in irrigated zone had highest mean variable costs while in the rainfed zone, the system with large land holding had the least mean variable costs. A major component of the variable costs in both the zones were the feed and fodder costs followed by the labour costs.

Table 5.17 Analysis of buffalo maintenance costs across dairy farming systems.

(In Rs./animal)

Items	Dairy Farming Systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Depreciation (1)	702	1135	1731	2428	876	2010	2089	2279
Interest on fixed assets (2)	376	492	538	854	660	502	527	611
Total Fixed costs (3) = (1) + (2)	1078	1627	2269	3282	1536	2512	2616	2891
feed and fodder costs (4)	7161	8122	7888	9917	7591	6249	6715	6591
Labour costs (5)	5107	2750	2856	3211	4640	3816	3857	3048
Veterinary costs (6)	316	319	239	92	369	327	380	403
Miscellaneous costs (7)	584	714	813	1018	1168	752	1394	991
Total variable costs (8)=(3)+ (4) + (5) + (6)	13168	11906	11796	14238	13768	11144	12346	11033
Total costs (9)=(3)+(8)	14247	13533	14065	17520	15304	13656	14962	13924
Opportunity costs(10)	9278	5851	4011	3327	9209	6308	5396	3818
Cash costs (11)= (9)-(10)-(1)	4266	6547	8323	11766	5219	5338	7477	7826
Milk returns (12)	9658	8420	14155	12967	8497	8845	12463	13045
Cow dung returns (13)	628	699	714	630	689	474	484	529
Net income (14)=(12)+(13)-(9)	-3961	-4413	803	-3923	-6118	-4338	-2015	-351
Family farm income (14)+(10)	5317	1438	4814	-596	3091	1971	3381	3467

Dairy farming system codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

Feed and fodder costs consisted of the homegrown as well as the purchased components. The percentage composition of homegrown and purchased feed costs have been presented in Table 5.18.

Table 5.18 Percentage composition of different feeds and fodder fed across dairy farming systems in the study area.

(%)

Feed cost	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Homegrown feed costs	51	45	35	47	50	50	36	58
Purchased green fodder costs	0	11	1	0	3	24	17	2
Purchased dry fodder costs	35	30	17	0	33	20	7	0
Purchased concentrates costs	14	15	47	53	14	6	40	40

In this section, an attempt has been made to compare the cost proportion of homegrown fodder with that of purchased feed and fodder across different dairy farming systems. The components of costs for feed and fodder considered were homegrown green fodder, purchased green fodder, homegrown and purchased dry fodder, home grown and purchased concentrate costs. A perusal of Table 5.18 revealed the share of homegrown green fodder costs varied from 35 percent in Irrigated small (IS-3) to 58 percent in rainfed large (RL-3) systems of total feed and fodder costs.

The share of purchased green fodder and dry fodder costs decreased with increase in landholdings size. Purchased green fodder costs varied from zero percent in the irrigated landless system and irrigated large systems to 24 percent of feed costs in rainfed marginal systems (RM-2). Purchased dry fodder costs varied from zero percent in Irrigated large and rainfed large systems to 36 percent in the Irrigated landless (ILL-2) system. Thus, it can be seen that the landless and marginal systems were purchasing dry fodder significantly.

The share of purchased concentrate ingredient costs increased with increase in land holdings size. It varied from 6 percent in marginal rainfed systems to 53 percent in large irrigated systems. Relatively higher share of

feed costs in the irrigated zone than the rainfed zone can be attributed to higher share of purchased concentrate costs in the irrigated zone than the rainfed zone.

In ILL-2 system, approximately mean purchased feed costs per buffalo, crossbred cow and local cow were Rs.4881, Rs.2533 and Rs.1763, respectively. In IM-2 system, approximately mean purchased feed costs per buffalo, crossbred cow and local cow were Rs.5684, Rs.6295 and Rs.3371, respectively. In IS-3 system, approximately mean purchased feed costs per buffalo, crossbred cow and local cow were Rs.7948, Rs.5768 and Rs.4896, respectively. In IL-4 system, approximately mean purchased feed costs per buffalo, crossbred cow and local cow are Rs.14304, Rs.10648 and Rs.6078, respectively.

In the rainfed zone, in RLL-2 system, approximately mean purchased feed costs per buffalo, crossbred cow and local cow were Rs.3557, Rs.4868 and Rs.2379, respectively. In RM-2 system, approximately mean purchased feed costs per buffalo, crossbred cow and local cow were Rs.4700, Rs.3743 and Rs.2154, respectively. In RS-3 system, approximately mean purchased feed costs per buffalo, crossbred cow and local cow were Rs.3905, Rs.3314 and Rs.2528, respectively. In RL-3 system, approximately mean purchased feed costs per buffalo, crossbred cow and local cow were Rs.4738, Rs.1056 and Rs.1258, respectively.

The total cost of buffalo maintenance for milk production per year varied significantly across the systems ranging from Rs.13533 in the irrigated marginal systems (IM-2) to Rs.17520 in the irrigated large systems (IL-4) in the irrigated zone and from Rs.13656 in the rainfed marginal systems (RM-2) to Rs.15304 in the rainfed landless systems (RLL-2) in the rainfed zone. Thus, the range of costs of buffalo rearing per annum was higher in the irrigated zone than the rainfed zone. With returns from buffalo milk ranging from Rs.8420 in IM-2 to Rs.14155 in IS-3 per year, only IS-3 (irrigated small) systems were able to cover full economic costs.

However, the cash costs² of buffalo milk production were covered by all the systems signifying the sustainability of buffalo milk production in the study area. The cash cost of dairying varied from Rs.4266 in the irrigated landless systems (ILL-2) to Rs.11766 in the irrigated large systems (IL-4). Thus, the per day full economic cost of buffalo rearing in the study area across the systems ranged from Rs.37 in the marginal systems to Rs.48 in the irrigated large systems. The per day cash costs of buffalo rearing ranged from Rs.11.7 in the irrigated landless systems (ILL-2) to Rs.32.2 in the irrigated large systems (IL-4). The per day maintenance costs in buffalo has been reported by Sharma and Singh (1984) at Rs.8.77; Singh *et al.* (1990) at Rs.25.4 in Haryana; Ram *et al.* (1993) at Rs.15.81 per day in Saharanpur; Kalra *et al.* (1995) at Rs.19.11 per day in Haryana and Gupta and Aggarwal at Rs.24.25 in Himachal pradesh. Sukhla and Brahmanekar (1999) reported similar results with the costs per buffalo per day across various land holdings to vary from Rs.20.20 in the landless households to Rs.30.39 in the semi-medium households in the north zone of operation flood milk shed areas in India. The farm family income of buffalo milk production ranged from Rs.-596 in the irrigated large systems (IL-4) to Rs.5317 in the Irrigated landless systems (ILL-2). This suggests that though the full economic costs are not covered by the systems except the IS-3, the dairying would be practiced unless there are other suitable opportunities for the farmers to utilize their resources.

5.2.2 Maintenance Cost of Crossbred Cow

The mean costs of maintaining a crossbred cow across dairy farming systems have been presented in Table 5.19. On traversing the tabular results, it was observed that the fixed costs varied from Rs.1074 in the ILL-2 system to Rs.2716 in the IL-4 system in the irrigated zone. Similarly in the rainfed zone, the fixed costs varied from Rs.1251 in the RLL-2 system to Rs.4117 in the RL-3 system. Thus, in general, the fixed costs increased with increase in land holdings in both the zones in the study area. The proportion of fixed

² Total costs –(opportunity costs + depreciation)

costs in RL-3 System was found to be higher than rest of the systems considerably. This could be accounted for better building, machinery used by this system.

Table 5.19 Analysis of crossbred cow maintenance costs across dairy farming systems in the study area.

(Rs./year)

Cost items	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Depreciation (1)	708	818	1364	2161	551	931	1694	3385
Interest on fixed assets (2)	366	425	467	555	700	355	660	732
Total Fixed costs (3) = (1) + (2)	1074	1242	1831	2716	1251	1286	2354	4117
Feed and fodder costs (4)	5880	4538	6316	7718	5205	3552	4746	5383
Labour costs (5)	2818	1819	2980	2527	3145	2503	2586	3752
Veterinary costs (6)	277	182	221	162	406	276	401	717
Miscellaneous costs (7)	485	816	822	1231	1381	688	1459	1626
Total variable costs (8)=(3) + (4) + (5) + (6)	9460	7355	10338	11637	10138	7019	9193	11478
Total costs (9)=(3)+(8)	10534	8597	12169	14353	11389	8305	11547	15595
Opportunity costs (10)	5385	2661	3322	2512	6204	2670	2772	4080
Cash costs (11) = (9) - (10) - (1)	4440	5119	7484	9680	4634	4704	7080	8130
Milk returns (12)	8199	7001	10642	11331	9012	6985	10514	16359
Cow dung returns (13)	641	714	767	837	854	462	575	946
Net income (14) = (12)+(13)-(9)	-1694	-882	-761	-2185	-1523	-859	-458	1710
Family farm income (14)+(10)	3692	1779	2561	327	4681	1811	2314	5790

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

The variable costs, on the other hand, varied from Rs.7355 in the IM-2 system to Rs.11637 in the IL-4 system. In the rainfed zone, the variable costs varied from Rs.7019 in the RM-2 system to Rs.11478 in the RL-3 system. Thus, it could be observed that the variable costs increased with increase in land holdings in irrigated zone but not so in the rainfed zone. A major component of the variable costs in both the zones were the feed and fodder costs followed by the labour costs.

The total cost of crossbred cow maintenance for milk production per year varied significantly across the systems ranging from Rs.8597 in the irrigated marginal systems (IM-2) to Rs.14353 in the irrigated large systems (IL-4) in the irrigated zone and from Rs.8305 in the rainfed marginal systems (RM-2) to Rs.15595 in the rainfed large systems (RLL-2) in the rainfed zone. Thus, the range of costs of crossbred cow rearing per annum was higher in the rainfed zone than the irrigated zone while it was just the reverse in case of buffaloes. With returns from crossbred cow milk ranging from Rs.6985 in RM-2 to Rs.16359 in RL-3 per year, only RL-3 (Rainfed large) system was able to cover full economic costs.

However, the cash costs of crossbred cow milk production were covered by all the systems signifying the sustainability of crossbred cow milk production in the study area. The cash cost of dairying varied from Rs.4440 in the irrigated landless systems (ILL-2) to Rs.9680 in the irrigated large systems (IL-4). Thus, the per day full economic cost of crossbred cow rearing in the study area across the systems ranged from Rs.23.5 in the rainfed marginal systems to Rs.42.7 in the rainfed large systems. The per day cash costs of crossbred cow rearing ranged from Rs.12 in the irrigated landless systems (ILL-2) to Rs.27 in the irrigated large systems (IL-4). Studies conducted by Reddy *et al.* (1972) found maintenance cost of crossbred cow per day at Rs.5.38; Sharma and Singh (1984) at Rs.3460 per annum per crossbred cow in Haryana; Singh *et al.* (1990) at Rs.26692 for three cows per year in Haryana (HAU); Kalra *et al.* (1995) at Rs.20.25 per day per crossbred cow in Haryana; Gupta and Aggarwal (1996) at Rs.26.39 per day per crossbred cow; Sukhla and Brahmanekar (1999) at Rs.25.03 to Rs.32.40 across landless to large farm households in 1996 in the Operation flood milk shed areas in north zone. The differences in the costs observed in the present study as compared to past studies may be due to specific location of the study, methodology employed, reference year of study, etc. The farm family income of crossbred cow maintenance ranged from Rs.327 in the irrigated large systems (IL-4) to Rs.5790 in the rainfed large systems (RL-3). This suggests that though the full

economic costs are not covered by the systems except the RL-3, the dairying would be practiced unless there are other suitable opportunities for the farmers to utilize their resources.

5.2.3 Maintenance Cost of Local Cow

The mean costs of maintaining a local cow across dairy farming systems have been presented in Table 5.20. On scrutinizing the tabular results, it was observed that the fixed costs varied from Rs.830 in the IM-2 system to Rs.1735 in the IS-3 system in the irrigated zone. Similarly in the rainfed zone, the fixed costs varied from Rs.910 in the RLL-2 system to Rs.1933 in the RL-3 system. Thus, in general, the fixed cost was lower in the irrigated zone than the rainfed zone in the study area.

Table 5.20 Analysis of local cow maintenance costs across dairy farming systems in the study area.

(Rs./animal unit/year)

Items of Cost	Dairy Farming Systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Depreciation (1)	504	513	982	637	615	1212	1272	1228
Interest on fixed assets (2)	404	317	753	608	295	334	658	705
Total Fixed costs (3) = (1) + (2)	908	830	1735	1245	910	1546	1929	1933
Feed and fodder costs (4)	3708	3097	5591	5526	3233	3561	3690	4158
Labour costs (5)	3127	2658	3205	2349	2642	3471	2517	2081
Veterinary costs (6)	127	115	115	15	230	211	305	275
Miscellaneous costs (7)	414	460	521	773	542	630	627	799
Total variable costs (8)=(3)+(4)+(5)+(6)	7376	6330	9433	8663	6647	7872	7139	7313
Total costs (9)=(3)+(8)	8284	7160	11173	9904	7558	9418	9069	9244
Opportunity costs (10)	4753	3357	3568	1813	3703	3304	3005	2474
Cash costs (11)=(9)-(10)-(1)	3027	3289	6617	7457	3239	4903	4792	5544
Milk returns (12)	6052	4252	7043	7027	5094	6377	7018	8190
Cow dung returns (13)	548	460	588	630	527	498	470	690
Net income (14)=(12)+(13)-(9)	-1685	-2448	-3542	-2248	-1936	-2543	-1580	-365
Family farm income (14)+(10)	3068	909	32	-438	1767	761	1425	2107

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

The variable costs, on the other hand, varied from Rs.6330 in the IM-2 system to Rs.9433 in the IL-4 system. In the rainfed zone, the variable costs varied from Rs.6647 in the RLL-2 system to Rs.7872 in the RM-2 system. Thus, it could be observed that the variation in variable costs were not accounted by land size holdings in both the zones. A major component of the variable costs in both the zones were the feed and fodder costs followed by the labour costs. The total cost of local cow maintenance for milk production per year varied significantly across the systems ranging from Rs.7160 in the irrigated marginal systems (IM-2) to Rs.11173 in the irrigated small systems (IS-3) in the irrigated zone and from Rs.7558 in the rainfed landless systems (RLL-2) to Rs.9418 in the rainfed marginal systems (RM-2) in the rainfed zone. The irrigated large systems can easily afford to keep local cows even it is a loss giving venture with even negative farm family income due to its ability to bear the loss from high income from crop enterprises.

Thus, the range of costs of local cow rearing per annum was higher in the irrigated zone than the rainfed zone while it was just the reverse in case of crossbred cows. With returns from local cow milk ranging from Rs.4252 in RM-2 to Rs.8190 in RL-3 per year, none of the systems were able to cover full economic costs.

However, the cash costs of local cow milk production were covered by all the systems signifying the sustainability of local cow milk production in the study area. The cash cost of dairying varied from Rs.3239 in the rainfed landless systems (RLL-2) to Rs.7457 in the irrigated large systems (IL-4). Thus, the per day full economic cost of local cow rearing in the study area across the systems ranged from Rs.20 in the irrigated marginal systems to Rs.31 in the irrigated small systems. The per day cash costs of local cow rearing ranged from Rs.8 in the irrigated landless systems (ILL-2) to Rs.20 in the irrigated large systems (IL-4).

Studies conducted by Reddy *et al.* (1972) found maintenance cost of local cow per day at Rs.4.88; Sharma and Singh (1984) at Rs.1847 to Rs.2219 per annum per local cow in Haryana; Kalra *et al.* (1995) at Rs.14.22 per day per local cow in Haryana; Gupta and Aggarwal (1996) at Rs.13.04 per

day per local cow; Sukhla and Brahmankar (1999) at Rs.14 to Rs.19.06 across landless to large farm households in 1996 in the operation flood milk shed areas in north zone. This suggests that though the full economic costs are not covered by any of the systems, the dairying of local cow would be practiced unless there are other suitable opportunities for the farmers to utilize their resources.

5.3 COST OF MILK PRODUCTION

Milk production is one of the most important objectives of dairy farming. Hence, analysis of cost of milk production is very much necessary to aid in policy decision making and in further analysis of objectives. In the present section cost of milk production has been worked out per kg of milk production for different species, viz. buffalo, crossbred cow and local cow separately.

5.3.1 Cost of Buffalo Milk Production

The cost components of per kilogram of buffalo milk production have been presented in Table 5.21. A close examination of the results revealed that cost of buffalo milk production varied significantly across the systems ranging from Rs.11.01 per kg in the irrigated small systems to Rs.16.12 per kg in the irrigated marginal systems in the irrigated zone and from 11.56 per kg in the large rainfed systems to 17.47 in the rainfed landless systems in the rainfed zone. With price of buffalo milk ranging from Rs.9.32 to Rs.11.46 per kg, none of the systems except the irrigated small systems were able to cover the full economic costs. However, the cash costs of buffalo milk production were covered by all the systems. The cash cost of dairying varied from Rs.4.23 per kg in the irrigated landless systems to Rs.10.58 per kg in the large irrigated systems. The cash returns per kg of buffalo milk production ranged from Rs.1.43 in the large irrigated systems to Rs.5.83 in the irrigated landless systems. The cash return in the rainfed systems was more uniform across the dairy farming systems. Only Irrigated small (IS-3) system was making positive profits. But in terms of family farm income, the landless dairy farming systems (ILL-2 and RLL-2) in both the zones were doing better with family farm income being highest across various dairy farming systems. The share of feed

Table 5.21 Component-wise cost of buffalo milk production across dairy farming systems in the study area.

(Rs./kg)

Items of Cost	Dairy Farming Systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Depreciation (1)	0.52 (3.7)	1.11 (6.9)	1.30 (11.8)	1.96 (12.7)	0.86 (4.9)	2.06 (14.3)	1.75 (13.7)	1.80 (15.6)
Interest on fixed assets (2)	0.26 (1.8)	0.47 (2.9)	0.38 (3.4)	0.60 (3.9)	0.60 (3.4)	0.44 (3.1)	0.40 (3.1)	0.44 (3.8)
Total fixed costs (3) = (1) + (2)	0.78 (5.6)	1.58 (9.8)	1.68 (15.2)	2.56 (16.5)	1.46 (8.3)	2.50 (17.4)	2.15 (16.8)	2.24 (19.4)
Feed and fodder costs (4)	7.34 (52.7)	9.92 (61.5)	6.24 (56.7)	8.89 (57.4)	8.93 (51.1)	6.76 (47.0)	5.88 (45.9)	5.63 (48.7)
Labour costs (5)	5.22 (37.5)	3.50 (21.7)	2.32 (21.1)	3.02 (19.5)	5.61 (32.1)	4.18 (29.1)	3.49 (27.3)	2.70 (23.4)
Veterinary costs (6)	0.20 (1.4)	0.23 (1.5)	0.15 (1.4)	0.24 (1.5)	0.25 (1.4)	0.23 (1.6)	0.20 (1.5)	0.22 (1.9)
Miscellaneous costs (7)	0.40 (2.9)	0.88 (5.5)	0.61 (5.6)	0.78 (5.0)	1.23 (7.0)	0.72 (5.0)	1.09 (8.5)	0.77 (6.6)
Total variable costs (8)=(3)+(4)+(5)+(6)	13.16 (94.4)	14.54 (90.2)	9.33 (84.8)	12.92 (83.5)	16.01 (91.7)	11.89 (82.6)	10.66 (83.2)	9.32 (80.6)
Total costs (9)=(3)+(8)	13.94 (100.0)	16.12 (100.0)	11.01 (100.0)	15.48 (100.0)	17.47 (100.0)	14.39 (100.0)	12.81 (100.0)	11.56 (100.0)
Opportunity costs (10)	9.19 (65.9)	6.97 (43.2)	3.14 (28.5)	2.94 (19.0)	10.67 (61.1)	6.65 (46.2)	4.62 (36.1)	3.17 (27.4)
Cash costs (11)=(9)-(10)-(1)	4.23	8.04	6.57	10.58	5.94	5.68	6.44	6.59
Milk returns (12)	9.45 (67.8)	10.03 (62.2)	11.08 (100.6)	11.46 (74.0)	9.70 (55.5)	9.32 (64.8)	10.67 (83.3)	10.83 (93.7)
Cow dung returns (13)	0.61 (4.4)	0.83 (5.2)	0.56 (5.1)	0.56 (3.6)	0.79 (4.5)	0.50 (3.5)	0.41 (3.2)	0.44 (3.8)
Net income (14)=(12)+(13)-(9)	-3.88 (-27.8)	-5.26 (-32.6)	0.63 (5.7)	-3.47 (-22.4)	-6.98 (-40.0)	-4.57 (-31.8)	-1.73 (-13.5)	-0.29 (-2.5)
Family farm income (14)+(10)	5.31 (38.1)	1.71 (10.6)	3.77 (34.2)	-0.53 (-3.4)	3.69 (21.1)	2.08 (14.4)	2.89 (22.6)	2.88 (24.9)

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems. Figures in parenthesis are percentage of total costs.

and fodder costs were the maximum across all the systems followed by labour costs which were observed to be the main components of milk production. Feed and fodder costs varied from 45.9 percent in the RS-3 systems to 61.5 percent in IM-2 systems. The labour costs varied from 19.5 percent in IL-4 systems to 37.5 percent in ILL-2 systems. Evidently the opportunity costs comprising of the family labour, interest on owned capital and family component of feeds and fodder were the maximum in the landless and marginal systems in both the zones. This signified the family labour intensive nature of dairy farming systems in the landless and marginal systems in the study area.

5.3.2 Cost of Crossbred Cow Milk Production

The cost of crossbred cow milk production component-wise have been presented in Table 5.22. On perusal of the Table 5.22, it was found that cost of crossbred cow milk production also varied significantly across the various dairy farming systems ranging from Rs.9.53 per kg in the irrigated small systems (IS-3) to Rs.10.69 per kg in the irrigated landless systems (ILL-2) in the irrigated zone and from Rs.7.91 per kg in the large rainfed systems (RL-3) to Rs.10.40 per kg in the rainfed landless systems (RLL-2) in the rainfed zone. With price of crossbred cow milk ranging from Rs.8.23 to Rs.8.39 per kg, none of the systems except the rainfed large systems (RL-3) were able to cover the full economic costs. However, the cash costs of crossbred cow milk production were covered by all the systems. The cash cost of dairying varied from Rs.4.17 per kg in the rainfed large systems (RL-3) to Rs.7.34 per kg in the irrigated large systems (IL-4). The per kg cash returns from crossbred cow milk production ranged from Rs.1.67 in the large irrigated systems to Rs.4.80 in the rainfed landless systems. The cash returns in the rainfed systems were relatively higher and more uniform across different dairy farming systems. Only rainfed large (RL-3) system was making positive profits. But in terms of family farm income, the landless dairy farming systems (ILL-2 and RLL-2) performed relatively better in both the zones. The share of feeds and fodder in the total costs were the maximum across all the systems followed by labour costs, which were the main components in milk production. Feed and fodder

costs varied from 36.0 percent in the RL-3 system to 57.8 percent in ILL-2 systems. The labour costs varied from 19.0 percent in IL-4 system to 31.2 percent in RM-2 system. Evidently the opportunity costs comprising of the family labour, interest on owned capital and family component of home grown feeds and fodder were the maximum in the landless and marginal systems in both the zones.

Table 5.22 Component wise costing of milk production by crossbred cow across dairy farming systems in the study area.

(Rs./kg)

Items of cost	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Depreciation (1)	0.59 (5.5)	0.81 (7.9)	1.02 (10.7)	1.43 (13.5)	0.42 (4.0)	1.06 (10.7)	1.29 (14.3)	1.67 (21.1)
Interest on fixed assets (2)	0.30 (2.8)	0.41 (4.0)	0.33 (3.4)	0.33 (3.1)	0.55 (5.3)	0.36 (3.7)	0.48 (5.3)	0.31 (3.9)
Total Fixed costs (3) = (1) + (2)	0.89 (8.3)	1.22 (12.0)	1.35 (14.1)	1.76 (16.5)	0.97 (9.3)	1.42 (14.4)	1.77 (19.6)	1.98 (25.0)
Feed and fodder costs (4)	6.18 (57.8)	5.61 (54.8)	5.02 (52.7)	5.80 (54.6)	4.92 (47.3)	4.38 (44.3)	3.86 (42.7)	2.85 (36.0)
Labour costs (5)	3.02 (28.3)	2.29 (22.4)	2.39 (25.1)	2.02 (19.0)	3.07 (29.5)	3.09 (31.2)	2.16 (23.9)	2.03 (25.7)
Veterinary costs (6)	0.24 (2.2)	0.11 (1.1)	0.14 (1.5)	0.23 (2.1)	0.25 (2.4)	0.24 (2.4)	0.19 (2.1)	0.27 (3.4)
Miscellaneous costs (7)	0.36 (3.4)	1.00 (9.8)	0.62 (6.6)	0.83 (7.8)	1.20 (11.5)	0.76 (7.7)	1.06 (11.7)	0.79 (9.9)
Total variable costs (8)=(3)+(4)+(5)+(6)	9.80 (91.7)	9.02 (88.1)	8.18 (85.9)	8.87 (83.5)	9.44 (90.7)	8.47 (85.6)	7.27 (80.4)	5.93 (75.0)
Total costs (9)=(3)+(8)	10.69 (100.0)	10.24 (100.0)	9.53 (100.0)	10.63 (100.0)	10.40 (100.0)	9.89 (100.0)	9.04 (100.0)	7.91 (100.0)
Opportunity costs (10)	5.55 (51.9)	3.17 (31.0)	2.60 (27.3)	1.86 (17.5)	5.77 (55.5)	3.18 (32.2)	2.17 (24.0)	2.07 (26.2)
Cash costs (11)=(9)-(10)-(1)	4.55	6.26	5.91	7.34	4.21	5.65	5.58	4.17
Milk returns (12)	8.32 (77.8)	8.34 (81.4)	8.33 (87.5)	8.39 (78.9)	8.23 (79.1)	8.32 (84.1)	8.23 (91.1)	8.30 (104.9)
Cow dung returns (13)	0.65 (6.1)	0.85 (8.3)	0.60 (6.3)	0.62 (5.8)	0.78 (7.5)	0.55 (5.6)	0.45 (5.0)	0.48 (6.1)
Net income (14)=(12)+(13)-(9)	-1.72 (-16.1)	-1.05 (-10.3)	-0.60 (-6.3)	-1.62 (-15.2)	-1.39 (-13.4)	-1.02 (-10.3)	-0.36 (-4.0)	0.87 (11.0)
Family farm income (14)+(10)	3.83 (35.9)	2.12 (20.7)	2.00 (21.0)	0.24 (2.3)	4.38 (42.1)	2.16 (21.8)	1.81 (20.0)	2.94 (37.1)

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

Figures in parenthesis are percentage of total costs

This clearly indicated the family labour intensive nature of dairy farming systems in the landless and marginal systems in the study area. Crossbred cows were found to yield higher returns by Singh *et al.* (1990); Kumar *et al.* (1994); Kalra *et al.* (1995); Gupta and Aggarwal (1996); Saxena *et al.* (1998). In this study crossbred cows were found to yield better in rainfed zone and small and large systems in the irrigated zone, whereas in landless and marginal systems in irrigated zone, the buffalo and local cow performed better in terms of family farm returns.

5.3.3 Cost of Local Cow Milk Production

The results of per kilogram cost of local cow milk production have been presented in Table 5.23. A close perusal of the table revealed that the cost of local cow milk production also varied significantly across the systems ranging from Rs.11.35 per kg in the irrigated landless systems (ILL-2) to Rs.14.01 per kg in the irrigated marginal systems (IM-2) in the irrigated zone while it ranged from Rs.9.38 per kg in the large rainfed systems to Rs.12.29 per kg in the rainfed marginal systems in the rainfed zone. With price of local cow milk ranging from Rs.8.21 to Rs.8.39 per kg, none of the systems were able to cover the full economic costs. However, the cash costs of local cow milk production were covered by all the systems. The cash cost of dairying varied from Rs.4.16 per kg in the irrigated landless systems to Rs.9.07 per kg in the large irrigated systems. The cash returns per kg of local cow milk production ranged from Re. 0.05 in the large irrigated systems (IL-4) to Rs.4.88 in the irrigated landless systems (ILL-2). The cash returns in the rainfed systems were more uniform across the dairy farming systems. Though, none of the systems made positive profits in local cow milk production, in terms of family farm income, the landless dairy farming systems (ILL-2 and RLL-2) performed relatively better in both the zones.

The share of feeds and fodder costs in total costs were the maximum across all the systems followed by labour costs, which were the main components in milk production. The share of feed and fodder costs varied

Table 5.23 Component wise costing of milk production by local cow across dairy farming systems in the study area.

(Rs./kg)

Items of Cost	Dairy Farming Systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Depreciation (1)	0.60 (5.3)	0.78 (5.6)	1.13 (8.3)	0.60 (4.8)	0.87 (7.1)	1.52 (12.4)	1.49 (13.4)	1.23 (12.7)
Interest on fixed assets (2)	0.50 (4.4)	0.49 (3.5)	0.80 (6.2)	0.60 (5.3)	0.37 (3.0)	0.31 (2.5)	0.70 (6.9)	0.60 (6.8)
Total Fixed costs (3) = (1) + (2)	1.10 (9.7)	1.27 (9.1)	1.93 (14.5)	1.20 (10.1)	1.24 (10.2)	1.83 (14.9)	2.19 (20.3)	1.83 (19.5)
Feed and fodder costs (4)	5.25 (46.3)	6.27 (44.8)	6.82 (51.2)	6.70 (56.8)	5.43 (44.6)	4.83 (39.3)	4.59 (42.5)	4.36 (46.5)
Labour costs (5)	4.42 (38.9)	5.37 (38.3)	3.92 (29.5)	2.94 (24.9)	4.49 (36.9)	4.70 (38.2)	3.16 (29.3)	2.28 (24.3)
Veterinary costs (6)	0.13 (1.1)	0.15 (1.1)	0.08 (0.6)	0.14 (1.2)	0.22 (1.8)	0.16 (1.3)	0.21 (2.0)	0.17 (1.8)
Miscellaneous costs (7)	0.45 (4.0)	0.94 (6.7)	0.55 (4.2)	0.83 (7.0)	0.80 (6.6)	0.76 (6.2)	0.65 (6.0)	0.75 (7.9)
Total variable costs (8)=(3)+(4)+(5)+(6)	10.25 (90.3)	12.74 (90.9)	11.38 (85.5)	10.60 (89.9)	10.94 (89.9)	10.45 (85.1)	8.61 (79.7)	7.55 (80.5)
Total costs (9)=(3)+(8)	11.35 (100.0)	14.01 (100.0)	13.31 (100.0)	11.80 (100.0)	12.18 (100.0)	12.29 (100.0)	10.80 (100.0)	9.38 (100.0)
Opportunity costs (10)	6.59 (58.1)	6.57 (46.9)	4.25 (31.9)	2.16 (18.3)	6.09 (50.0)	4.31 (35.1)	3.58 (33.1)	2.51 (26.8)
Cash costs (11) =(9)-(10)-(1)	4.16	6.66	7.96	9.07	5.22	6.46	5.77	5.68
Milk returns (12)	8.29 (73.1)	8.32 (59.4)	8.39 (63.0)	8.37 (70.9)	8.21 (67.4)	8.32 (67.7)	8.36 (77.4)	8.31 (88.6)
Cow dung returns (13)	0.75 (6.6)	0.90 (6.4)	0.70 (5.3)	0.75 (6.4)	0.85 (7.0)	0.65 (5.3)	0.56 (5.2)	0.70 (7.5)
Net income (14) =(12)+(13)-(9)	-2.31 (-20.3)	-4.79 (-34.2)	-4.22 (-31.7)	-2.68 (-22.7)	-3.12 (-25.6)	-3.32 (-27.0)	-1.88 (-17.4)	-0.37 (-4.0)
Family farm income (14)+(10)	4.28 (37.7)	1.78 (12.7)	0.03 (0.23)	-0.52 (-4.4)	2.97 (24.4)	0.99 (8.1)	1.70 (15.7)	2.14 (22.8)

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems. Figures in parenthesis are percentage of total costs.

from 39.3 percent in the RM-2 systems to 56.8 percent in IL-4 systems. The share of labour costs varied from 24.9 percent in IL-4 systems to 38.9 percent in ILL-2 systems. The opportunity costs comprising of the family labour, interest on owned capital and family labour component of feeds and fodder were the maximum in the landless and marginal systems in both the zones. This showed the family labour intensive nature of dairy farming systems in the landless and marginal systems in the study area. Thus, none of the systems were making positive net profits in local cow milk production in the study area whereas irrigated small (IS-3) was making positive net profits in buffalo milk production while rainfed large system (RL-3) was making positive profits in crossbred cow milk production.

The share of veterinary costs across all systems and species varied from 1.1 to 3.4 percent of total costs. The share of miscellaneous costs ranged from 2.9 to 11.7 percent of total costs.

The differences in cost components were mainly due to the type of production system and access to resources by each of the dairy farming system. Reddy *et al.* (1972) made a comparative study on costs of milk production with 56 crossbred and 157 purebreds (Tharparkar, Sahiwal, Red Sindhi) cows in 1969. Of the total cost of milk production, feeds accounted for 55 percent for crossbred and 43 percent for purebred cows. Sastry *et al.* (1979) studied the economics of milk production data for 1971-72 to 1975-76 from a 2-ha dairy farm with 5-8 buffaloes. Feed costs accounted for 47-57 percent of total, and labour component made up 14 to 21 percent of total cost with the bulk of the remaining costs being attributed to depreciation and interest. Gangwar and Sastry (1988) in a review on the economics of buffalo performance studies concluded that feed constitutes the main cost of maintenance. Kumar and Gupta (1988) in a study on cost of milk production in the Muzaffar Nagar district of Uttar Pradesh also observed feed and fodder costs accounting for the main part of maintenance costs of all 3 types of animal. Thus, reducing the cost of animal feed and fodder production would have a significant effect in reducing the cost of milk production. Ram *et al.*

(1993) in their study on the costs and returns of milk production from buffaloes in Saharanpur district of western Uttar Pradesh, India for 1987 from a sample of 195 landless labour, marginal and small farm households found feed and fodder to be the major components of total costs (64%), followed by labour (15%). Kumar *et al.* (1994) in a seven year study on various farming systems in Haryana observed that expenditure incurred on feed were higher (more than 40%) followed by expenditure on labour (more than 30%) among all the items in both the units. The expenditure pattern in the two systems indicated that expenditure on feed was higher in the cow unit than the buffalo unit and more expenditure was recorded on labour in the buffalo unit as compared with the cow unit. Sukhla and Brahmankar (1999) in their survey of farm households in 1996 in flush season found the feed cost to be the major share of 70 percent of all costs followed by labour at 22.9 percent of total costs. In case of landless labour, the labour cost accounted for higher share at 35.3 percent and feed at 56 percent. The share of home produced feed cost increased with increase in size of land holding while the share of labour decreased. The share of purchased feed decreased with land size with highest in landless category but was higher in large than small land holding category.

In the present study, the cash costs were found to be maximum in the irrigated large systems while the minimum in the landless systems. The maximum opportunity costs were observed in the irrigated landless systems while it was minimum in the irrigated large systems. Thus, it can be concluded that feed constituted the major component of costs across various dairy farming systems. The share of labour cost decreased with increase in landholding size. Differences in feed costs were also observed due to differences in methodology applied in various studies. In the present study the green fodder which was of perennial grasses and weeds collected from crop and open fields, road side, etc. by landless and marginal systems was considered as home grown with its value imputed on the basis of market value of grasses.

5.4 INCOME STRUCTURE OF THE DAIRY FARMING SYSTEMS

5.4.1 Gross Family Returns

The gross family returns refer to the mean gross returns of the crop and dairy enterprises and off farm activities engaged in by the family members of the households belonging to different dairy farming systems. The mean gross family returns of the households selected belonging to the dairy farming systems identified are shown in Table 5.24.

Table 5.24 Analysis of mean gross family returns of dairy farming systems in the study area.

(Rs./year)

Returns	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Crop returns	0 (0.0)	43413 (53.3)	211786 (78.1)	623895 (88.1)	0 (0.0)	16329 (30.0)	69979 (64.1)	204650 (75.6)
Fodder crop returns	0 (0.0)	2733 (3.4)	8971 (3.3)	27491 (3.9)	0 (0.0)	853 (1.6)	4251 (3.9)	19313 (7.1)
Milk returns	17017 (46.6)	16459 (20.2)	35484 (13.1)	53722 (7.6)	13497 (43.8)	18182 (33.4)	29844 (27.3)	44564 (16.5)
Other dairy returns	1417 (3.9)	1800 (2.2)	2150 (0.8)	3120 (0.4)	1391 (4.5)	1233 (2.3)	1546 (1.4)	2200 (0.8)
Non-farm and other farm returns	18053 (49.5)	17014 (20.9)	12944 (4.8)	0 (0.0)	15908 (51.7)	17919 (33.9)	3600 (3.3)	0 (0.0)
Gross family returns	36487 (100.0)	81419 (100.0)	271335 (100.0)	708228 (100.0)	30796 (100.0)	54515 (100.0)	109220 (100.0)	270727 (100.0)

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems. Figures in parenthesis represent percentage of gross family returns.

The dairy farming systems identified and analyzed in the study area were subsistence dairy farms but in terms of gross returns to family income, a perusal of Table 5.24 showed that dairying contributed significantly in case of landless dairy farming systems in both the irrigated and rainfed zone. The annual returns from milk varied from Rs.16459 in the marginal irrigated buffalo

based dairy farming systems to Rs.53722 in the irrigated large buffalo based dairy farming systems in the irrigated zone. Similarly in the rainfed zone, the annual returns from milk varied from Rs.13497 in the rainfed landless system to Rs.44564 in the rainfed large system. The share of other dairy returns which included sale of fodder and cow dung to gross family returns varied from Rs.1417 to 3120.

Almost all the dairy farming systems except the landless dairy farming systems in both the zones were engaged in cultivation of crops. The major cash crops cultivated in the partially rainfed zone were bazra, gram, mustard and wheat while those in the irrigated zone were paddy, sugarcane, mustard and wheat. The share of returns from these crops to total farm returns varied from 30 percent in the rainfed marginal buffalo based system to 88.1 percent in the irrigated large buffalo based system. The small and large systems in both the zones are specialized in crop cultivation in terms of gross returns. The other major activity contributing to gross farm returns was off farm and other farm income. This was especially significant for the landless and marginal dairy farming systems in both the zones. The share of non farm and other farm returns to gross returns varies from zero percent in case of large farms to 51.7 percent in the rainfed landless dairy farming systems. Thus, in both the zones, the off farm income was contributing significantly to gross family returns in the landless and marginal systems by 20.9 in irrigated marginal system to 551.7 in rainfed landless system.

5.4.2 Net Family Returns

The results of net family returns of the various dairy farming systems are presented in Table 5.25. A close scrutiny of the results in Table 5.22 revealed that the highest net family income, with over Rs.300000 per farm, was found in the irrigated large buffalo based dairy farming systems. However, this income was mainly from crops contributing 88.3 percent to net family returns followed by sale of fodder that was placed at 5.5 percent, which includes sale of feeds and fodders produced in the farm.

Table 5.25 Analysis of net family returns of dairy farming systems in the study area.

(Rs./year)

Returns	Dairy farming systems							
	ILL-2	IM-2	IS-3	IL-4	RLL-2	RM-2	RS-3	RL-3
Crop returns	0 (0.0)	3943 (13.5)	66,014 (61.6)	273500 (88.3)	0 (0.0)	257 (1.0)	34843 (68.4)	119199 (81.8)
Milk returns	6970 (23.9)	2650 (9.0)	14224 (13.3)	12372 (4.0)	4520 (18.8)	4535 (17.3)	8142 (16.0)	13193 (9.0)
Cow dung returns	1417 (4.9)	1800 (6.1)	2150 (2.0)	3120 (1.0)	1391 (5.8)	1233 (4.7)	1546 (3.0)	2200 (1.5)
Sale of fodder	0 (0.0)	1025 (3.5)	8971 (8.4)	17001 (5.5)	0 (0.0)	853 (3.3)	1251 (2.5)	8167 (5.6)
Farm cash returns	8387 (28.7)	9418 (32.2)	90260 (84.2)	305993 (98.8)	5911 (24.6)	6096 (23.3)	44092 (86.6)	142759 (97.9)
Non-farm and other farm returns	18,053 (61.8)	17,014 (58.1)	12,944 (12.1)	0 (0.0)	15,908 (66.1)	17,919 (68.4)	3,600 (7.1)	0 (0.0)
Non cash farm returns	2750 (9.4)	2850 (9.7)	3950 (3.7)	3650 (1.2)	2250 (9.3)	2170 (8.3)	3250 (6.4)	3050 (2.1)
Net family returns	29190 (100.0)	29282 (100.0)	107154 (100.0)	309643 (100.0)	24069 (100.0)	26185 (100.0)	50942 (100.0)	145809 (100.0)

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

Figure in parenthesis represent percentage of net family returns

The contribution of dairying was more prominent in the rainfed zone as is evident from the higher contribution to net income from dairying in the rainfed zone than in the irrigated zone. An exception to it in the irrigated zone is the irrigated landless system in which cash returns from milk was contributing significantly up to 23.9 percent of net family income.

Other dairy returns, viz., returns from cow dung varied from 1.0 percent in the irrigated large buffalo based systems to 6.1 percent in irrigated marginal systems. The most significant contribution to family income in the landless systems was from the other farm and non-farm activities at 61.8 percent in the irrigated zone in irrigated landless system (Rs.18053) to 68.4 percent in the rainfed zone (Rs.17919) in the rainfed marginal system. Thus, non-farm and other farm income was an important component of net family returns in the case of the landless and marginal dairy farming systems in both the zones.

The net income of farming activity to gross family returns varied from 13.5 percent in the irrigated marginal systems to 88.3 percent in the irrigated large systems. The net income was found to be well above 20 percent in all systems, except the marginal systems signifying the sustainability of crop activities in this region.

The net family income across the systems, however, varied from as low as Rs.24069 in the rainfed landless system to Rs.309643 in the irrigated large systems.

5.5 EFFICIENCIES OF THE DAIRY FARMING SYSTEMS

The main objective of this section is to assess the possibilities for productivity gains by improving the efficiencies of the identified dairy farming systems in the study area. This objective has been pursued first by estimating a stochastic production frontier and stochastic cost frontier, which provides the basis for measuring farm-level technical efficiency and economic efficiency. The measurement of efficiency was carried out at four levels viz., standard animal unit (SAU), buffalo, crossbred cow and local cow unit per farm. Further, the potential gains that can be achieved by improving the efficiencies of the dairy farming systems to their frontier output level have been estimated. The results of this study has policy implications because it not only provides empirical measures of efficiency indices, but also identifies the potential of improvement in milk production across various dairy farming systems based on efficiencies. The present analysis also provides an insight into the sustainable methods of productivity improvement without any additional resources unlike productivity improvement through change in inputs or technological change, which requires additional resources.

The results have been presented in two sections: fitting of Frontier model and estimation of efficiency, which has been done separately for each of the species where after technical and economic efficiencies have been estimated.

The estimation of technical efficiency and its interpretation has been done on the basis of the estimation of the stochastic production frontier using

Cobb-Douglas and translog models as specified in methodology. In this regard it is pertinent to mention that only a few studies in agriculture have been carried out using stochastic frontier functions under Indian conditions, e.g., Kalirajan *et al.* (1984) for crop farming and Sharma and Sharma (2002) for dairying. A few deterministic frontier estimation studies have been carried out for commercial herds by Srivastava (1995) and Chand (1998). An attempt has, therefore, been made in this section to analyze efficiencies of dairy farming systems using stochastic frontier functions. Similarly the cost efficiency estimation and its interpretation has been carried out using the dual of Cobb-Douglas production frontier namely Cobb-Douglas cost frontier. The ensuing section provide the results of functional analysis followed by estimation of technical and economic efficiency according to standard animal unit and each of the species.

5.5.1 Frontier Functional Analysis for Milk Production

The objective of the present investigation was to estimate the efficiencies of the farm household in milk production; therefore, it was very important to consider the effect of various species of milch animals kept by the farm household. Thus, standard animal units of the bovine stock were derived for each of the farm households as per the methodology stated earlier. The milk production by the farm household was also standardized to fat corrected milk as per the equation (3) given in the methodology.

5.5.1.1 Standard animal unit

Based on the model discussed in methodology in section 4.3, ordinary least squares (OLS) and maximum likelihood estimation (MLE) techniques were employed to estimate the parameters of the Cobb-Douglas production function using Frontier version 4.1 software package. The results of the same have been presented in Table 5.26. The generalized likelihood ratio statistic for testing the null hypothesis for the absence of inefficiency effects in the Cobb-Douglas stochastic frontier production was estimated to be 4.81. If the null hypothesis is true, the generalized likelihood-ratio statistic has a mixed chi-square distribution with 7 degrees of freedom. Using a probability of type 1

error of 0.05, the critical value for the test statistic is 6.35, which was obtained from table of percentage points of the χ^2 distribution. The calculated value of the LR test statistic of 4.81 was not found to be statistically significant at the 5 percent level. Though tests of significance are frequently conducted at a much smaller value of a type 1 error, there is some basis for considering a higher probability level for a preliminary testing procedure. Therefore, the null hypothesis that there were no technical inefficiency effects in the Cobb-Douglas stochastic frontier production function was rejected at 10 percent probability level for the sample data in the present study. Accordingly, the Cobb-Douglas OLS model or the average response function was not considered to be an adequate representation of data.

Table 5.26 OLS and MLE estimates of stochastic Cobb-Douglas frontier milk production function of standard animal unit of farm households in the study area.

Variables	OLS Estimates	Standard Errors	MLE Estimates	Standard errors
Constant term	1.563**	0.262	1.726**	0.257
Green fodder index	0.172*	0.086	0.186*	0.081
Dry fodder index	0.127	0.095	0.106	0.093
Concentrate index	0.218**	0.076	0.193**	0.073
Hired labour	0.012	0.019	0.013	0.018
Family labour	0.103**	0.043	0.078*	0.043
Depreciation	0.039	0.053	0.047	0.050
Veterinary expenses	-0.039	0.065	-0.002	0.064
Miscellaneous costs	0.045	0.053	0.028	0.050
Variance parameter				
$\sigma^2 = s^2_v + s^2_u$	0.012		0.021**	0.004
$\gamma = s^2_u / s^2_s$			0.723**	0.113
LR test of the one-sided error			4.810	
Log likelihood function	149.203		151.608	

* Significant ($P < 0.05$) and ** Significant ($P < 0.01$)

The estimate of the gamma values of 0.723 was found to be significant at one percent level, which showed that the frontier model was significantly different from the OLS model or the deterministic frontier, in which there were no random errors in the production function. Thus, it can be inferred that there are random errors as well as inefficiency errors in the model.

The OLS function provided the estimates of the “average” production function, while the ML model provided estimates of the stochastic production frontier. The dissimilarities of the coefficient parameters across equations confirm that the frontier function does not represent a neutral upward shift of the average production function. The higher constant value in the case of MLE clearly indicated higher frontier output. The relatively lower value of the significant input parameters in case of concentrates, family labour and higher significant value of green fodder coefficients in the case of MLE may be interpreted as the increasing role of green fodder than concentrates or family labour in determining the efficiency of the farm. The coefficient for concentrates was found to be statistically significant at one percent level for both the OLS and the MLE models. The coefficients for family labour and green fodder was found to be statistically significant at 5 percent level in the MLE as well as OLS models but family labour was significant at one percent level in the OLS model. Similar OLS results were found by Chander *et al.* 1999, in a study of the major determinants of milk production in the Jaipur district of Rajasthan State, in 1994-95 who found that green fodder and concentrates were the important inputs that determined milk yield in the villages. The coefficients for veterinary expenses were found to be negative and non-significant, whereas the coefficients for miscellaneous costs were positive and non-significant indicating that such expenses do not have any significant impact on milk production.

Most of the milk production function studies for different species have concluded that feeds and fodder and their relative allocation are the most important determinants of milk production. Kumar *et al.* (1975) examined the relative importance of various inputs in milk production and the concentration in milk production according to order of lactation for the Haryana breed of cattle maintained under village management. The elasticity of production was highest for feed, which was the major factor influencing milk yield. Rai and Gangwar (1976) analyzed resource-use efficiency and cost of buffalo milk production in Haryana using data collected from 51 farms in the Hisar district of Haryana where efficiency of utilization of concentrate, roughage and labour

was studied. The concentrate feeding had the most significant effect on milk yield on all the farms in all the seasons. Pandey *et al.* (1980) developed milk production functions for understanding variations in milk yield in the Bundelkhand region of Uttar Pradesh. The input variables viz. fodder, concentrates, labour, other cash expenditure and lactation were observed to explain 40-85 percent of the total variation in milk yield. Fodder was the most significant production factor, followed by concentrates. Kairon *et al.* (1995) in a study carried out in the operational area of the Ambala-Kurukshetra Regional Rural Bank observed through regression analysis that the concentrates were the most important input affecting milk production. Saxena *et al.* (1998) analyzed the resource use efficiency of two mixed farming systems viz. mixed farming with three crossbred cows and with three Murrah buffaloes each on one ha canal irrigated land in the research farm of the Department of Agronomy, CCS Haryana Agricultural University, Hisar. The study suggested that much scope exists for increasing the profitability of these systems by optimizing the use of green and dry fodder in proportion with concentrates.

The coefficients of the input variables in the Cobb-Douglas production function provided in Table 5.26 are elasticities of milk output with respect to different inputs. A perusal of Table 5.26 indicated that the elasticity of milk production with respect to concentrate index was 0.22 and that of family labour as 0.10, which were also statistically significant. This clearly suggested that with one percent increase in concentrates input (in terms of nutrient index), the total milk production at the farm would increase by 0.22 percent whereas one percent increase in family labour input in standard manhours would entail 0.10 percent increase in milk production. Thus, it can be concluded that there was further scope for investment in concentrates and family labour in order to increase the milk production. However, these values have been obtained relative to the particular production function used at farm level, where the elasticities of production of most other variables were relatively lower as compared to past studies. This could be due to relatively lower variation in the input variables at the farm level. The plausible reason for

this could be due to aggregated nature of the production function in terms of the milk production and inputs considered for the whole year and the nearly uniform distribution of milch animals in the sample. The elasticity of the green fodder index was estimated to be positive and significant at 5 percent level with a magnitude of 0.17. This suggested that if the green fodder index in standard nutritive terms is increased by 1 percent, the average milk production per year would increase by 0.17 percent. It may be mentioned here that since the aim of the functional analysis was to determine the efficiency of milk production at the farm household level rather than predict response of inputs on milk production, therefore, the data has been considered in an aggregated manner for the whole year, assuming that the farm is homogenous with respect to order and stage of lactation of milch animals across farm households.

The elasticities of milk production for dry fodder; hired labour and depreciation were not significant in both the OLS and MLE models suggesting that these variables did not have significant impact on average or frontier levels of milk production. The elasticities of milk production with respect to concentrate and family labour were found to be positive and significant at 1 percent level of significance and green fodder at 5 percent level. Thus, it could be concluded that there is potential to increase further use of concentrates, family labour management and green fodder for increasing productivity of standard milch animal unit at the overall farm household level.

The returns to scale parameter for the Cobb-Douglas production function obtained by adding the elasticities of production of the eight input variables was found to be 0.68 which showed decreasing returns to scale. This implied that with increasing intensity of input used in dairying by one percent, milk production would increase at a decreasing rate of 0.68 percent.

It was also of interest to see whether the translog production function is an adequate representation of the data, given the specifications of the Cobb-Douglas frontier model. In order to test the null hypothesis that the coefficients of the Cobb-Douglas frontier are simultaneously zero, $H_0: \beta_j = 0$, the value of

the generalized likelihood ratio statistic for testing the null hypothesis was obtained as under:

$$LR = -2(50.76 - 151.6) = 201.68$$

The calculated value of LR statistic was compared with the tabulated value of upper five percent point for the χ^2 distribution, which was 12.02 for 7 degrees of freedom. It can, therefore, be concluded that the translog frontier is not an adequate representation of the data, given the specifications of the Cobb-Douglas frontier. The results of the translog production function are presented in Annexures XI and XII.

The results of the production function analysis for each of the milch species are presented in the ensuing sections that follow:

5.5.1.2 Buffalo

As stated earlier, two different functional forms viz. the Cobb-Douglas and the translog were fitted to the milk production data for buffalo. The OLS and the MLE estimates of the parameters of the Cobb-Douglas model have been presented in Table 5.27. The generalized likelihood ratio test statistic for testing the null hypothesis of the presence of inefficiency effects in the Cobb-Douglas stochastic frontier production was estimated to be 4.67. If this null hypothesis is true, the generalized likelihood-ratio statistic has a mixed chi-square distribution with 7 degrees of freedom. Using a probability of type 1 error of 0.25, the critical value for the test statistic is 6.35. Therefore, the value of the test statistic of 4.67 was found to be not significant at the 5 percent level. Although tests of significance are frequently conducted at a much smaller value of type 1 error, there is some basis for considering a higher level for a preliminary testing procedure. In the present study, the null hypothesis was rejected at 10 percent level suggesting that there were technical inefficiency effects in the Cobb-Douglas stochastic frontier buffalo milk production function for the dairy farmers in the sample data. Thus, the Cobb-Douglas OLS model or the average response function was not found to be an adequate representation of data.

Table 5.27 OLS and MLE estimates of stochastic Cobb-Douglas frontier buffalo milk production function of farm households in the study area.

Variables	OLS Estimates	Standard Errors	MLE Estimates	Standard errors
Constant	1.812**	0.298	2.016**	0.289
Green fodder index	0.281**	0.092	0.282**	0.086
Dry fodder index	0.061	0.103	0.039	0.100
Concentrate index	0.097*	0.068	0.086	0.062
Hired labour	-0.006	0.019	-0.008	0.019
Family labour	0.056	0.038	0.032	0.037
Depreciation	0.039	0.037	0.047	0.036
Veterinary expenses	-0.028	0.065	-0.006	0.061
Miscellaneous costs	0.022	0.057	0.005	0.053
Variance parameter				
$\sigma^2 = s^2_v + s^2_u$	0.014		0.023**	0.004
$\gamma = s^2_u / s^2_s$			0.677**	0.114
LR test of the one-sided error			4.670	
Log likelihood function	133.769		136.100	

* Significant (P < 0.05) and ** Significant (P < 0.01)

Moreover, the gamma value was found to be significant at one percent level, hence, it can be concluded that random errors as well as inefficiency errors are present in the model. Table 5.27 provides the coefficients of the input variables in the Cobb-Douglas production function, which are also the estimates of elasticities of mean output with respect to different inputs.

A perusal of Table 5.27 indicated that the constant term was significant and relatively higher for MLE model than OLS model which confirmed that the frontier function represents a neutral upward shift of the average production function. Though the coefficient for green fodder was statistically significant both for OLS and MLE models and marginally higher in MLE, indicated increasing role of green fodder in determining the efficiency of the buffalo milk production in the farm.

A perusal of Table 5.27 revealed that in case of MLE, the elasticity of milk production with respect to green fodder index was estimated to be 0.282, which was significant at one percent level. This suggested that, green fodder

index was the most important variable indicating that with one percent increase in green fodder index, the total milk production would increase by 0.282 percent. The elasticities of milk production with respect to dry fodder and concentrate indices were found to be positive and non-significant at 5 percent level indicating that there was no significant impact of these variables on milk production.

It may be mentioned that since the aim of the functional analysis was to determine the efficiency of milk production at the farm household level rather than predict response to the use of inputs on milk production, therefore, the data was considered in an aggregated manner, assuming that the farm is homogenous in terms of animal composition such as stage of lactation, wet : dry ratio, order of lactation of milch animals within farm households in the identified dairy farming systems.

The elasticities of milk production with respect to hired labour and veterinary expenses were negative and not significant. This could be due to relatively higher use of hired labour for dairy operations by the large farms. The returns to scale as estimated by the sum of the elasticities of the eight input variables was found to be 0.536 which indicated decreasing returns to scale.

A further investigation was also made with regard to adequacy of the translog frontier production function to the sample data, given the specifications of the Cobb-Douglas model. The results of the translog frontier estimates are presented in Table 5.27, which gives the value of the log-likelihood function as 26.4. The null hypothesis that the first order coefficients of the Cobb-Douglas frontier are simultaneously zero, $H_0: \beta_j = 0$, was tested through the generalized likelihood ratio statistic. The value of the test statistic was found to be:

$$LR = -2(26.4 - 136.1) = 219.4$$

This value was found to be greater than the upper five percent point for the χ^2 distribution for 7 degrees of freedom. Accordingly, the null hypothesis that the translog frontier is an adequate representation of the sample data was rejected, given the specifications of the Cobb-Douglas frontier.

Thus, it can be inferred that at the overall farm household level there is a potential to increase the use of nutrients through green fodder for increasing the productivity of buffalo. Concentrate index did not show any significant impact, which could be due to low variability in its use across farm households for buffaloes. The coefficient for veterinary expenses was non-significant indicating its insignificant role on buffalo milk productivity.

5.5.1.3 Crossbred cow

Only Cobb-Douglas form of frontier milk production function could be fitted, as the numbers of observations available for crossbred cows were only 20, which was not sufficient to run a translog frontier model. However, an attempt has been made to present the results for crossbred cow milk production function. The maximum likelihood estimates of the parameters of the Cobb-Douglas model have been presented in Table 5.28.

Table 5.28 OLS and MLE estimates of stochastic Cobb-Douglas frontier crossbred cow milk production function of farm households in the study area.

Variables	OLS Estimates	Standard Errors	MLE Estimates	Standard errors
Intercept	7.635*	3.626	7.257**	1.055
Green fodder index	-0.373	0.353	-0.078	0.260
Dry fodder index	0.356	0.604	0.164	0.210
Concentrate index	0.081	0.174	0.118	0.081
Hired labour	0.101	0.099	0.080	0.070
Family labour	-0.171	0.178	-0.033	0.157
Depreciation	0.120	0.205	0.058	0.128
Veterinary expenses	-0.016	0.476	-0.327	0.421
Miscellaneous costs	-0.134	0.379	0.062	0.250
Variance parameter				
$\sigma^2 = s^2_v + s^2_u$	0.142		0.071	2.338
$\gamma = s^2_u / s^2_s$			0.000	4075.617
LR test of the one-sided error			6.026	
Log likelihood function	-2.853		0.160	

* Significant (P < 0.05) and ** Significant (P < 0.01)

The generalized likelihood ratio statistic for testing the null hypothesis for the absence of inefficiency effects in the Cobb-Douglas stochastic frontier production was found to be 6.026, which was less than the tabulated value of chi-square at 6.35 for 7 degrees of freedom. Therefore, the value of the test statistic of 6.026 was found to be not significant at the 10 percent level implying the acceptance of the null hypothesis that there were no technical inefficiency effects in the Cobb-Douglas stochastic frontier function for crossbred cow milk production. Accordingly, the Cobb-Douglas OLS model or the average response function was found to provide an adequate representation of data. The zero gamma values showed that there are only random errors and no inefficiency errors in the model.

None of the input variables were found to be statistically significant which could be due to low variation in the sample observations with respect to the input variables as well as less number of sample observations (20) in case of crossbred cow milk production which were not adequate to fit the milk production functions.

5.5.1.4 Local cow

Only Cobb-Douglas form of frontier milk production function could be fitted in the case of with local cow, as the number of observations was only 28, which was not sufficient to run a translog frontier model. However, an attempt has been made to present the results for local cow milk production function. The maximum likelihood estimates of the parameters of the Cobb-Douglas model have been presented in Table 5.29.

The generalized likelihood ratio statistic for testing the null hypothesis, of the absence of inefficiency effects in the Cobb-Douglas stochastic frontier production could not be calculated as the log likelihood function for both the OLS and the MLE estimates of the frontier model were the same. This signified the absence of errors due to inefficiency as is evident from the very non-significant low gamma value. Therefore, the null hypothesis that there were no technical inefficiency effects in the Cobb-Douglas stochastic frontier

function for local cow milk production was accepted. Thus, the Cobb-Douglas OLS model or the average response function was found to be an adequate representation of data.

Table 5.29 OLS and MLE estimates of stochastic Cobb-Douglas frontier local cow milk production function of farm households in the study area.

Variables	OLS Estimates	Standard Errors	MLE Estimates	Standard errors
intercept	2.447*	0.837	2.450**	0.826
Green fodder index	0.126	0.246	0.126	0.194
Dry fodder index	-0.054	0.244	-0.054	0.187
Concentrate index	0.146	0.158	0.146	0.128
Hired labour	0.012	0.076	0.012	0.061
Family labour	-0.052	0.137	-0.052	0.109
Depreciation	0.159	0.125	0.159	0.102
Veterinary expenses	0.071	0.195	0.071	0.155
Miscellaneous costs	-0.141	0.183	-0.141	0.147
Variance parameter				
$\sigma^2 = s^2_v + s^2_u$	0.011		0.008**	0.003
$\gamma = s^2_u / s^2_s$			0.001	0.484
LR test of the one-sided error			NA	
Log likelihood function	28.503		28.503	

* Significant (P < 0.05); ** Significant (P < 0.01); NA = Not applicable.

None of the coefficients were found to be statistically significant, which could be attributed to the lower number of observations in the case of local cow (26), which were not adequate to fit the milk production function.

It is pertinent to state that the aim of the present study was to determine the efficiencies of the farm household in milk production irrespective of the milch species. Hence, it was not considered necessary to have sufficient number of observations species wise, as these were dependent on the number of households sampled within each of the dairy farming systems and not on the number of observations of each of the species with buffaloes being the dominant species in all the systems.

5.5.2 Estimation of Technical Efficiency

An important component of frontier production function is the estimation of the technical efficiency of individual farms (Annexure-XIII). In order to analyze how efficient are the dairy farms in the study area, technical efficiency of the farm households were determined for standard animal unit per farm to assess the efficiency of individual farms. In order to assess the variation in technical efficiency due to species of milch animal using the results of the frontier production models, the estimates of efficiencies for each of the species were also obtained. To determine the technical efficiency of the identified systems, the mean of the technical efficiency indices of the milk production for different sample farms across each dairy farming system were obtained. The indices of mean technical efficiency of farm households for different species and standard animal unit across various dairy farming systems obtained using results of the Cobb-Douglas frontier production function are presented in Table 5.30.

Table 5.30 Mean technical efficiency estimates of dairy farming systems species-wise in the study area.

Dairy Farming System	SAU	Buffalo	Crossbred cow
ILL-2	92.5±3.9	93.0±2.7	86.6±1.4
IM-2	86.8±6.2	86.5±6.1	85.3±0.0
IS-3	92.2±6.0	91.1±7.5	88.9±9.1
IL-4	86.6±6.8	87.7±7.2	87.9±9.1
RLL-2	90.5±4.8	90.8±4.4	88.3±0.0
RM-2	90.5±0.1	90.1±3.3	75.7±0.0
RS-3	91.7±4.3	91.1±4.5	92.5±7.8
RL-3	91.1±5.7	90.8±5.2	95.4±0.0
Overall	91.1±4.7	90.9±4.6	87.8±9.2

SAU = Standard animal unit.

5.5.2.1 Standard animal unit

A close perusal of Table 5.30 shows that in the irrigated zone, the mean efficiency estimates ranged from 86.6 percent in the irrigated large systems (IL-4) to 92.5 percent in the irrigated landless systems (ILL-2). The mean efficiency estimate of the landless systems was found to be better than the large systems. This could be attributed to dairying being the main source of farm income for the landless farm households, which compels them to take better care of animals to ensure higher efficiency unlike the marginal or large systems. The mean efficiency estimate of the irrigated small systems (IS-3) was found to be 92.2 percent, however, with a higher value of standard deviation of 6.0. The irrigated large systems were found to have the least technical efficiency in the irrigated zone. The mean efficiency estimate of the marginal system (IM-2) was relatively lower at 86.8 percent. On the whole, the irrigated landless system (ILL-2) was found to be the most technical efficient system with a lower value of standard deviation. The results clearly indicated that there is a relatively more scope for improvement of technical efficiency in case of the marginal and the large dairy farming systems in the irrigated zone.

In the rainfed zone, the mean technical efficiency estimates closely ranged from 90.5 percent in the rainfed landless system (RLL-2) and rainfed marginal system (RM-2) to 91.7 percent in the rainfed small systems (RS-3). The value of standard deviation associated with technical efficiency showed that technical efficiency estimates were found to vary more in the rainfed large systems than in the rainfed marginal systems. The most technically efficient dairy farming system in the rainfed zone was the rainfed small (RS-3) System while the least efficient system were the rainfed landless (RLL-2) and the rainfed marginal (RM-2).

In the nutshell, the irrigated landless systems (ILL-2) was the most technically efficient while the irrigated large system (IL-4) was the least efficient dairy farming system in the study area in terms of milk production by standard animal unit. The variation in mean efficiency estimates was found to be more in the irrigated zone than in the rainfed zone.

5.5.2.2 Buffalo

A close perusal of Table 5.30 revealed that in the irrigated zone, the mean efficiency estimates ranged from 86.5 percent in the irrigated marginal systems (IM-2) to 93.0 percent in the irrigated landless systems (ILL-2). Therefore, the mean technical efficiency estimates of buffalo milk production in case of the landless systems were found to be better than the marginal or large systems. The mean efficiency estimates of the irrigated small systems (IS-3) were found to be 91.1 percent with a higher value of standard deviation of 7.5. The irrigated marginal systems were found to have the least technical efficiency in the irrigated zone. The mean efficiency estimate of the large system (IL-4) was also lower at 87.7 percent. Therefore, it can be inferred that the irrigated landless system (ILL-2) was the most technical efficient system with a comparatively lower value of standard deviation. Further, marginal and the large systems in the irrigated zone need to improve their technical efficiency more in comparison to the landless or the small systems. Similar results were found by Bagi (1981), who found higher technical efficiency on small farms in his study on economic efficiency of irrigated, partially irrigated and dry farms in Haryana using dummy variable technique. Dixit (1999) also found higher technical efficiency on small herds as compared to their counterparts. However, the point of difference in the present study were the relatively lower efficiencies of the irrigated marginal systems.

In the rainfed zone, the mean technical efficiency estimates of buffalo milk production ranged closely from 90.06 percent in the rainfed marginal (RM-2) to 91.09 percent in the rainfed small (RS-3) systems. Variation in technical efficiency estimates of farms as revealed by the value of standard deviation was found to be more in the rainfed large systems while it was less in the rainfed marginal systems. The most technically efficient dairy farming system in the rainfed zone was the rainfed small (RS-3) System while the least efficient system was the rainfed marginal (RM-2). The efficiency estimates of the rainfed landless and rainfed large systems were similar with a magnitude of 90.8 percent in both the systems.

On the whole, the irrigated landless systems (ILL-2) was the most technically efficient while the irrigated marginal system (IM-2) was the least technically efficient dairy farming system in the study area in terms of buffalo milk production. The variation in mean efficiency indices was found to be relatively more in the irrigated zone than the rainfed zone.

5.5.2.3 Crossbred cow

A close perusal of Table 5.30 revealed that in the irrigated zone, the mean efficiency estimates ranged from 85.3 percent in the irrigated marginal system (IM-2) to 88.9 percent in the irrigated small system (ILL-2). The mean technical efficiency estimates of crossbred cow milk production for the small systems were found to be better than the marginal systems. The mean efficiency estimates of the irrigated landless systems (ILL-2) was found to be 86.6 percent, however, with a lower value of standard deviation of 1.4. The irrigated marginal systems were found to have the least technical efficiency in the irrigated zone. The mean efficiency estimate of the large system (IL-4) was found to be at 87.9 percent with a higher magnitude of standard deviation (9.1) signifying large variations in efficiency estimates across farms within the system.

On the whole, the irrigated small system (ILL-2) was found to be the most technical efficient system with comparatively lower standard deviation. The results clearly indicated that the marginal and the landless dairy farming systems in the irrigated zone need to improve their technical efficiency of crossbred cow milk production more in comparison to the small or the large systems in the irrigated zone. Thus, it can be observed that unlike the landless systems, which were most efficient in buffalo milk production, the small systems were more efficient in crossbred cow milk production in the irrigated zone. The plausible reason for this finding could be the better care and management in the small systems for crossbred cows, which demand intensive management in terms of resources. better efficiency estimates for the small systems in crossbred cow milk production could be due to comparatively better resources at their disposal than the landless systems for

the management of crossbred cows. Buffalo could do well in terms of technical efficiency in landless systems, as it is a comparatively hardy animal than crossbred cows.

In the rainfed zone, the mean technical efficiency estimates of crossbred cow milk production were found to range from 75.7 percent in the rainfed marginal (RM-2) system to 95.4 percent in the rainfed large (RL-3) system. This could be partly attributed to lesser number of sample observations for crossbred cows in each of the systems identified. The most technically efficient dairy farming system in the rainfed zone was the rainfed large (RL-3) System while the least efficient system was the rainfed marginal (RM-2). The efficiency estimates of the rainfed landless and rainfed small systems were 88.3 and 92.5 percent, respectively. Thus, the landless systems were comparatively more technically efficient than the marginal systems for crossbred cow milk production.

In the nutshell, the rainfed large systems (RL-3) was the most technically efficient while the rainfed marginal system (RM-2) was the least efficient dairy farming system for crossbred milk production. It is, however, very difficult to generalize these results, as the number of observations in each of the systems was very low. Surprisingly, though numbers of crossbred cows were more in the irrigated zone, the most technically efficient farm in crossbred cow milk production was observed in the rainfed large system (RL-3), which could possibly be due to better feeding and management care of crossbred cows in the rainfed zone. The variation in mean efficiency estimates was observed to be more in the rainfed zone than the irrigated zone.

5.5.2.4 Local cow

The mean technical efficiency of local cow milk production using Cobb-Douglas frontier model was found to be 100 percent for the sample farm households. This indicated that the average farmer in the sample was fully efficient and no further improvement in milk production was possible through technical efficiency improvement in local cows. This could be attributed to the fact that all the households were rearing local cows at their frontier level of milk production and whatever variation in the milk production was present was

due to random variations alone. The options to improve productivity of local cows can be either through technological change or change in inputs allocation in the study area, which can be possible through technical change, which was beyond the scope of the study.

5.5.3 Potential of Technical Efficiency Improvement of the Dairy Farming Systems

Productivity enhancement in milk production is one of the most important goals of Indian dairying. The present analysis of data has focused on the issues of productivity enhancement through improvement in technical efficiencies of the dairy farming systems with the existing resources and technology for standard animal unit and the three milch species, viz. buffalo, crossbred cow and local cow separately.

Based on the technical efficiency of the most efficient farm in each of the dairy farming system, the average potential to increase milk production of the dairy farming systems was determined using the following formula:

Potential for increasing milk production per milch animal = $[1 - (\text{mean technical efficiency of the system} / \text{maximum technical efficiency of the system})] * 100$.

The average potential of increasing milk production through technical efficiency improvement across various dairy farming systems are presented in Table 5.31.

Table 5.31 Mean potential increase in milk production across dairy farming systems using existing resources.

Dairy Farming System	SAU	Buffalo	Crossbred cow
ILL-2	4.6	4.2	10.7
IM-2	7.7	8.0	0.0
IS-3	4.9	7.0	9.3
IL-4	5.9	6.7	8.4
RLL-2	5.7	5.4	0.0
RM-2	5.7	5.2	0.4
RS-3	5.5	6.1	5.6
RL-3	7.0	7.3	0.0
Overall	7.1	7.3	10.4

SAU = Standard Animal Unit.

A close perusal of Table 5.31 revealed that in the irrigated zone, the potential for technical efficiency improvement of milk production of standard animal unit across systems varied from 4.6 percent in the irrigated landless system to 7.7 percent in the irrigated marginal system. In case of buffaloes it varied from 4.2 percent in the marginal system to 8.0 percent in the marginal system. In case of crossbred cows it varied from 0 to 10.7 percent in the landless system. Thus, the potential for efficiency improvement was highest for SMU and buffalo in the marginal system in irrigated zone while for crossbred cows it was found to be the highest in the landless systems.

A further perusal of Table 5.31 revealed that in the rainfed zone, the potential for technical efficiency improvement of milk production in case of standard animal unit across systems varied from 5.5 percent in the rainfed small system to 7.0 percent in the rainfed large system. In case of buffaloes it varied from 5.2 percent in the marginal system to 7.3 percent in the large system. In case of crossbred cows it varied from 0 to 5.6 percent in the small system. Thus, for an average dairy farming system in rainfed zone, the potential for efficiency improvement was maximum in the large system in case of standard animal unit and buffaloes while for it was found to be maximum in the small system for crossbred cows.

There was no scope for technical efficiency improvement in case of local cows as no inefficiency effects were found in the model in case of local cows.

The potential for improvement in technical efficiency of the least technical efficient farms in each of the dairy farming systems is presented in Table 5.32. A close perusal of Table 5.32 revealed that for the least efficient farms in the irrigated zone, the maximum potential for efficiency improvement in terms of reducing milk production costs varied from 18.1 percent in the marginal system to 22.7 percent in case of small system for standard animal unit.

Table 5.32 Potential increase in milk production of the least technically efficient farms across dairy farming systems using existing resources.

(%)

Dairy Farming System	SAU	Buffalo	Crossbred cow
ILL-2	14.4	12.4	27.8
IM-2	18.1	16.0	0.0
IS-3	22.7	28.6	18.4
IL-4	18.5	19.1	18.8
RLL-2	24.0	22.9	0.0
RM-2	18.8	15.8	0.0
RS-3	19.6	21.6	11.2
RL-3	20.4	19.4	0.0
Overall	25.5	28.6	28.6

In the rainfed zone, the potential for reducing the milk production costs for the least efficient farms varied from 18.8 percent in rainfed marginal systems to 24 percent in rainfed landless systems.

In case of buffalo, the potential for improvement in milk productivity varied from 16.0 percent in the irrigated marginal system to 28.6 percent in the irrigated small system in the irrigated zone. In case of crossbred cows, the potential was highest in the irrigated landless system at 27.8 percent in the irrigated zone and rainfed small system at 11.2 percent in the rainfed zone.

The mean technical efficiency (TE) indices for SAU in the overall category ranged from 73 to 98 percent across the farm households in the sample, with an average of 91.1 percent (Table 5.30). A perusal of Table 5.31 revealed that if the average farmer in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer would realize an 7.08 percent cost savings $[1 - (91.06/98)]$. A similar calculation for the most technically inefficient farmer revealed a cost saving of 25.5 percent $[1 - (73/98)]$ (Table 5.32).

The mean technical efficiency (TE) indices for buffalo milk production in the overall category ranged from 70 to 98 percent across the farm households in the sample, with an average of 90.9 percent (Table 5.30). This means that if the average farmer in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer would realize an 7.3 percent cost savings $[1 - (90.87/98)]$ (Table 5.31). A similar calculation for the most technically inefficient farmer revealed a cost saving of 28.6 percent $[1 - (70/98)]$ (Table 5.32).

The mean technical efficiency estimates of crossbred milk production ranged from 70 to 98 percent for the farm households in the sample, with an average of 87.8 percent for overall category (Table 5.30). This means that if the average farmer in the sample was to achieve the TE level of its most efficient counterpart, then the average farmer could realize a 10.4 percent cost savings $[1 - (87.77/98)]$ (Table 5.31). A similar calculation for the most technically inefficient farmer reveals a cost saving of 28.6 percent $[1 - ((70/98)]$ (Table 5.32).

The overall efficiencies of buffalo (90.9%) was found to be higher than that of crossbred cows (87.8%). This was, however, not in conformity with the findings of Dixit (1999) who found crossbred cow to be more efficient (79.9%) than buffaloes (69%). The difference may be accounted for due to differences in region and methodology employed as Dixit (1999) has used COLS method against MLE method used in this study. Similar studies carried out by Russel and Young (1983) in U.K. found technical efficiency of cow at 73 percent; Bravo-Ureta and Rieger (1990) of cow at 82 percent; Srivastava (1995) of cow in Delhi at 86 percent of buffalo and 82 percent of cow; Shiyani and Singh (1996) of buffalo at 79 percent and cow at 80 percent in Gujarat; Kumar (1997) of buffalo at 55 percent in U.P. and Chand (1998) at 92 percent of cow in Rajasthan. Thus, it can be seen that differences in efficiencies vary across regions and due to differences in methodology applied in the studies.

5.5.4 Frontier Functional Analysis of Cost of Milk Production

In order to study the effect on productivity of allocation of inputs along with production based on the varying prices of inputs, stochastic cost frontiers

were estimated for standard animal unit and milch species individually. The farms can reduce their average cost of milk production through improvements in economic efficiency.

5.5.4.1 Standard animal unit

The maximum likelihood estimates of the parameters of the Cobb-Douglas frontier cost function for standard animal unit are presented in Table 5.33.

A perusal of Table 5.33 revealed that the generalized likelihood ratio statistic was found to be 6.769. The calculated value of this statistic was found to be more than the tabulated chi square for 3 degrees of freedom (2.37) at 25 percent level of significance, therefore, the null hypothesis for the absence of inefficiency effects in the Cobb-Douglas stochastic frontier cost function was rejected. The Cobb-Douglas OLS model or the average response function was, therefore, not found to be an adequate representation of data. This clearly suggested that there were economic inefficiency effects in the Cobb-Douglas stochastic frontier cost function for the sample data.

Table 5.33 OLS and MLE estimates of stochastic Cobb-Douglas frontier cost function of standard animal unit across farm households in the study area.

Variables	OLS Estimates	Standard Error	MLE Estimates	Standard Error
Intercept	3.178**	0.340	3.002**	0.309
Milk production	0.241**	0.101	0.244**	0.093
Green fodder price index	-0.036	0.024	-0.050*	0.023
Dry fodder price index	0.040	0.085	0.039	0.078
Concentrate price index	0.139	0.104	0.152*	0.092
Variance parameter				
$\sigma^2 = s^2v + s^2u$	0.026		0.051**	0.010
$\gamma = s^2u / s^2s$			0.807**	0.095
LR test of the one-sided error			6.769	
Log likelihood function	76.839		80.224	

* Significant (P < 0.05) and ** Significant (P < 0.01)

The significant gamma value of 0.807 indicated that 80.7 percent of the total error was accounted for by the inefficiency error and only 19.3 percent of the total error was accounted for by random errors (Table 5.31). Thus, the MLE frontier model was found to be a better fit for the sample data than the OLS model. The input variables viz. milk production level, green fodder price index, and concentrate price index significantly influenced the cost of milk production per standard animal unit of the farm (Table 5.33). The coefficients of the input variables in the Cobb-Douglas production function can be interpreted as elasticities of mean output with respect to different inputs. The empirical results indicated that the elasticity of milk costs with respect to milk production was estimated to be 0.244, which suggested that with one percent increase in milk production, the total milk production costs per standard milch unit would increase by 0.244 percent. Further, the elasticity of the concentrate price index was estimated to be 0.152, which implied that if the price index of concentrate used in feeding of the dairy animals in the farm is increased by one percent, the total average milk production costs would also increase by 0.152 percent. The elasticity of milk production costs with respect to green fodder price index was, however, negative and significant at 5 percent level with a magnitude of -0.05 . This suggested that with one percent increase in price index of green fodder, the cost of milk production per standard animal unit would go down by 0.05 percent. This could be attributed to higher per unit cost of green fodder in nutritive value terms, which in turn lead to higher milk yield resulting in lower milk production costs per animal unit. The returns to scale parameter for the Cobb-Douglas frontier cost function obtained as the sum of the elasticities of the four input variables was found to be 0.385 which indicated decreasing returns to scale.

5.5.4.2 Buffalo

The maximum likelihood estimates of the parameters of the Cobb-Douglas model for buffalo milk production costs have been presented in Table 5.34.

Table 5.34 OLS and MLE estimates of stochastic Cobb-Douglas frontier cost function of buffalo milk production across farm households in the study area.

Variables	OLS Estimates	Standard Errors	MLE Estimates	Standard Errors
Intercept	3.618**	0.356	3.577**	0.327
Milk production	0.222*	0.106	0.194*	0.097
Green fodder price index	0.001	0.026	-0.002	0.025
Dry fodder price index	0.045	0.095	0.031	0.094
Concentrate price index	-0.090	0.115	-0.115	0.109
Variance parameter				
$\sigma^2 = s^2v + s^2u$	0.032		0.065*	0.013
$\gamma = s^2u / s^2s$			0.820*	0.096
LR test of the one-sided error			5.285	
Log likelihood function	57.962		60.604	

* Significant (P < 0.05) and ** Significant (P < 0.01)

The generalized likelihood ratio statistic for testing the null hypothesis for the absence of inefficiency effects in the Cobb-Douglas stochastic frontier production was found to be 5.285. Since the calculated value was greater than the tabulated value of chi square at 3 degrees of freedom (2.37) at 10 percent level of significance, therefore, the null hypothesis that there were no technical inefficiency effects in the Cobb-Douglas stochastic frontier buffalo milk cost function for the dairy farmers in the sample was rejected. Accordingly, the MLE frontier model was found to represent the data better than the OLS model. The gamma value of 0.820, which was statistically significant showed that there were more of inefficiency errors than random errors in the model.

The input variable viz. milk production level, significantly influenced the cost of milk production per buffalo of the farm (Table 5.34). The coefficients of the input variables in the Cobb-Douglas production function interpreted as elasticities of mean output with respect to different inputs indicated that the elasticity of milk production costs with respect to milk production was estimated to be 0.222, which was statistically significant. This indicated that, if the production of milk is increased by 1 percent, then the total milk production

costs would increase by 0.222 percent. On the other hand, the elasticities of green fodder price index; concentrate price index were found to be negative and non-significant while it was positive and non-significant for dry fodder price index.

5.5.4.3 Crossbred cow

The maximum likelihood estimates of the parameters of the Cobb-Douglas model for crossbred cow milk production costs have been presented in Table 5.35. The generalized likelihood ratio statistic for testing the null hypothesis for the absence of inefficiency effects in the Cobb-Douglas stochastic frontier production could not be computed as the log likelihood function for both the OLS and MLE estimates were found to be the same (12.634). Therefore, all the errors in the model were attributed to random component with no inefficiency component in the model.

Table 5.35 OLS and MLE estimates of stochastic Cobb-Douglas frontier cost function of crossbred cow milk production across farm households in the study area.

Variables	OLS Estimates	Standard Errors	MLE Estimates	Standard Errors
Constant	3.934**	0.742	3.933**	0.806
Milk production	0.062	0.236	0.062	0.198
Green fodder price index	0.068	0.071	0.068	0.060
Dryfodder price index	0.374	0.269	0.374	0.220
Concentrate price index	-0.422	0.284	-0.422*	0.222
Variance parameter				
$\sigma^2 = s^2v + s^2u$	0.022		0.017**	0.006
$\gamma = s^2u / s^2s$			0.000	0.121
LR test of the one-sided error			NA	
Log likelihood function	12.634		12.634	

* Significant (P < 0.05); ** Significant (P < 0.01); NA = Not applicable.

Therefore, the null hypothesis that there were no technical inefficiency effects in the Cobb-Douglas stochastic frontier buffalo milk cost function for the dairy farmers in the sample from Haryana was accepted. Hence, the MLE

frontier model was not found to be a better representation of data than the OLS model. From the gamma values of zero, it can be observed that there were only random errors in the model.

The constant term was significant in both the models. The empirical results for the MLE coefficients of Cobb-Douglas production function indicated that the elasticity of milk production costs with respect to concentrate price index was estimated to be -0.422, significant at 5 percent level for the MLE model indicated that with one percent increase in concentrate price index, the total milk production costs would decrease by 0.422 percent. The plausible reason for this behaviour could be due to feeding of good quality feed at a proportionality higher price resulting in higher milk production, thus, reducing the milk production costs.

5.5.4.4 Local cow

The maximum likelihood estimates of the parameters of the Cobb-Douglas model for local cow milk production costs have been presented in Table 5.36.

Table 5.36 OLS and MLE estimates of stochastic Cobb-Douglas frontier cost function of local cow milk production across farm households in the study area.

Variables	OLS Estimates	Standard Errors	MLE Estimates	Standard Errors
Constant	4.950**	1.004	6.077**	0.947
Milk production	-0.214	0.266	-0.644*	0.343
Green fodder price index	0.232**	0.056	0.232**	0.050
Dry fodder price index	-0.048	0.283	-0.378	0.356
Concentrate price index	-0.307	0.265	-0.067	0.311
Variance parameter				
$\sigma^2 = s^2v + s^2u$	0.020		0.042*	0.021
$\gamma = s^2u / s^2s$			0.970**	0.217
LR test of the one-sided error			2.781	
Log likelihood function	17.783		19.174	

* Significant (P < 0.05) and ** Significant (P < 0.01)

The generalized likelihood ratio statistic for testing the null hypothesis for the absence of inefficiency effects in the Cobb-Douglas stochastic frontier production was found to be 2.781. Since the calculated value was greater than the tabulated value of chi square at 3 degrees of freedom (2.37) at 10 percent level of significance, therefore, the null hypothesis that there were no technical inefficiency effects in the Cobb-Douglas stochastic frontier local cow milk cost function for the sample from households was rejected. Hence, the MLE frontier model was found to provide a better representation of data than the OLS model. From the significant gamma values of 0.970, it can be observed that there were more inefficiency errors than random errors in the model. This means that 97 percent of the total variation in cost could be due to economic inefficiency.

The input variable viz. green fodder price index, significantly influenced the cost of milk production per standard animal unit of the farm (Table 5.36). The coefficients of the input variables in the Cobb-Douglas production function termed as elasticities of mean output with respect to different inputs indicated that the elasticity of milk production costs with respect to green fodder price index was estimated to be 0.232. This implied that, with one percent increase in green fodder price index, then the total milk production costs would increase by 0.232 percent. The elasticities of milk production were estimated to be negative and significant at 5 percent level which suggested that one percent increase of milk production would decrease the milk production costs by 0.644 percent which could be attributed to lower actual milk production than their potential in case of local cows.

5.5.5 Estimation of Economic Efficiency

The economic efficiency of the farm households was determined using the parameters of cost frontier models. In order to determine the economic efficiency of the identified systems, the means of the economic efficiency estimates of the milk production for the sample households of each system were obtained (Annexure-XIII). The estimates of economic efficiency for different species and standard milch animal unit have been presented in Table 5.37.

Table 5.37 Mean economic efficiency estimates of dairy farming systems in the study area.

Dairy Farming System	SAU	Buffalo	Local cow
ILL-2	83.1±7.0	79.4±11.4	80.1±14.2
IM-2	86.1±4.4	81.9±7.1	93.1±0.0
IS-3	91.7±4.5	86.3±7.3	76.5±21.5
IL-4	88.1±5.3	73.9±6.8	91.7±0.0
RLL-2	82.3±10.4	76.3±13.7	87.0±2.5
RM-2	73.4±18.6	74.1±20.4	85.8±5.4
RS-3	80.2±11.2	79.2±14.6	85.5±12.1
RL-3	92.8±3.5	85.2±5.9	94.2±0.0
Overall	81.5±12.6	78.5±14.5	81.3±17.3

SAU = Standard animal unit.

In the ensuing sections, the economic efficiencies of milk production of standard animal unit and each of the milch species have been discussed.

5.5.5.1 Standard animal unit

A close perusal of Table 5.37 indicated that the mean economic efficiency (EE) index for SAU in overall category was found to be 81.5 percent (Table 5.37). In the irrigated zone, the mean efficiency estimates ranged from 83.1 percent in the irrigated landless systems (ILL-2) to 91.7 percent in the irrigated small systems (IS-3). The mean efficiency estimates of the small systems were found to be better than the landless systems. The mean economic efficiency estimates of the irrigated marginal systems (IM-2) was found to be 86.1 percent while it was 88.1 percent in the irrigated large systems (IL-4), next only to the most efficient small systems. The irrigated marginal systems were found to have the least economic efficiency in the irrigated zone. Thus, the irrigated small system (IS-3) was found to be the most economical efficient system with a relatively lower value of standard deviation. It can be further stated that the landless and the marginal systems in the irrigated zone need to improve their economic efficiency more in comparison to the small or the large systems.

In the rainfed zone, the mean economic efficiency estimates varied in a wide range from 73.4 percent in the rainfed marginal (RM-2) to 92.8 percent in the rainfed large (RL-3) systems. The value of standard deviation associated with mean economic efficiency indices for the rainfed systems indicated more variation in the farms across rainfed marginal systems as compared to the rainfed large systems.

On the whole, the most economically efficient dairy farming system was the rainfed large (RL-3) System while the rainfed marginal (RM-2) in the rainfed zone was the least efficient system. The variation in mean efficiency estimates was found to be more in the rainfed than the irrigated zone.

5.5.5.2 Buffalo

A close perusal of Table 5.37 revealed that in the irrigated zone, the mean efficiency estimates ranged from 73.9 percent in the irrigated large systems (IL-4) to 86.3 percent in the irrigated small systems (IS-3). Thus, the mean economic efficiency estimates of buffalo milk production for the small systems were found to be better than the large systems. The mean efficiency estimates of the irrigated landless systems (IS-3) were found to be 79.4 percent with a higher magnitude of standard deviation of 11.4. The irrigated large systems were found to have the least economical efficiency in the irrigated zone. The mean efficiency estimate of the marginal system (IM-2) was also lower at 81.9 percent. Thus, the irrigated small system (IS-3) was found to be the most economic efficient system. Further, the large and the landless systems in the irrigated zone need to improve their economic efficiency for buffalo milk production more as compared to the small systems.

In the rainfed zone, the mean economic efficiency estimates of buffalo milk production ranged from 74.1 percent in the rainfed marginal (RM-2) to 85.2 percent in the rainfed large (RL-3) systems. More variation in economic efficiency estimates was found in the rainfed marginal systems while it was least in the rainfed large systems as revealed from the value of standard deviation. The most economically efficient dairy farming system in the rainfed zone was the rainfed large (RL-3) System while the least efficient system was

the rainfed marginal (RM-2). The efficiency estimates of the rainfed landless and rainfed small systems were found to be 76.3 and 79.2 percent, respectively.

On the whole, the irrigated small systems (IS-3) was the most economically efficient while the irrigated large system (IL-4) was the least efficient dairy farming system for buffalo milk production in the study area in the irrigated zone whereas rainfed large (RL-3) was the most efficient and rainfed marginal (RM-2) was the least efficient in the rainfed zone.

5.5.5.3 Crossbred cow

The mean economic efficiency of crossbred milk production was found to be 100 percent. This means that the average farmer in the sample was fully cost efficient with no further possibility of reduction in milk production costs for crossbred cows through improvement in economic efficiency. This could be attributed to the fact that all households were rearing crossbred cows at their frontier level of milk production and all variations in milk production costs were due to random variations alone.

5.5.5.4 Local cow

A close perusal of Table 5.37 revealed that in the irrigated zone, the mean efficiency estimates of local cow milk production ranged from 76.5 percent in the irrigated small systems (IS-3) to 93.1 percent in the irrigated marginal systems (IM-2). Thus, the mean economic efficiency estimates of local cow milk production for the marginal system was found to be relatively more than the small system. The mean efficiency estimate of the irrigated landless systems (ILL-2) was found to be 80.1 percent with a standard deviation of 14.2. The irrigated marginal system was found to have the highest economic efficiency in the irrigated zone. The mean efficiency estimate of the large system (IL-4) was found to be 91.7 percent. Therefore, it can be stated that the irrigated marginal system (ILL-2) was the most economical efficient system. Further, the small and the landless systems in the irrigated zone need to improve their economic efficiency more in comparison to the marginal or the large systems. Thus, it can be observed

that unlike the small systems which were most efficient in buffalo milk production costs, the marginal systems were more efficient in local cow milk production costs in the irrigated zone. The small systems have comparatively more resources at their disposal than the marginal systems for rearing the local cow even if it is uneconomical.

In the rainfed zone, the mean economic efficiency estimates of crossbred cow milk production ranged from 85.5 percent in the rainfed small (RS-3) to 94.2 percent in the rainfed large (RL-3) systems. The most economically efficient dairy farming system in the rainfed zone was the rainfed large (RL-3) System while the least efficient system was the rainfed small (RS-3). The efficiency estimates of the rainfed marginal and rainfed landless systems were found to be 85.8 and 87.0 percent, respectively, which implied that the landless systems were comparatively more economically efficient in local cow milk production than the marginal systems.

In the nutshell, it can be stated that for the local cow the irrigated small (IS-3) was the most economic efficient while irrigated landless system (ILL-2) was the least economic efficient system in the irrigated zone while rainfed marginal (RM-2) was the least economic efficient and rainfed large (RL-3) was the most economic efficient system in the rainfed zone. The variation in mean economic efficiency estimates across farming systems was found to be more in the irrigated zone than the rainfed zone.

5.5.6 Potential of Economic Efficiency Improvement of the Dairy Farming Systems

Productivity enhancement in milk production is one of the most important goals of Indian dairying. The present analysis of data has focused on the issues of productivity enhancement through improvement in economic efficiencies of the dairy farming systems with the existing resources and technology for standard animal unit and the three milch species, viz. buffalo, crossbred cow and local cow separately. Based on the economic efficiency of the most efficient farm in each of the dairy farming system, the average potential to decrease milk production costs of the dairy farming systems was determined using the following formulae:

Potential for decreasing milk production costs per milch animal = $[1 - (\text{mean economic efficiency of the system} / \text{maximum economic efficiency of the system})] * 100$.

The average potential of improvement in economic efficiency for dairy farming systems is presented in Table 5.38. A close perusal of Table 5.38 revealed that the potential for economical efficiency improvement of milk production of standard animal unit across systems in terms of reduction of milk production costs varied from 4.5 percent in the irrigated small system (IS-3) to 12.6 percent in the irrigated landless system (ILL-2). In case of buffaloes it varied from 9.2 percent in the small system (IS-3) to 17.3 percent in the landless system (ILL-2). In case of local cows it varied from 0 to 18.6 percent in the small system (IS-3).

Table 5.38 Potential decrease in milk production costs across dairy farming systems in the study area using existing resources.

(%)

Dairy Farming System	SAU	Buffalo	Local cow
ILL-2	12.6	17.3	17.5
IM-2	6.4	10.0	0.0
IS-3	4.5	9.2	18.6
IL-4	5.2	12.1	0.0
RLL-2	13.4	17.0	2.2
RM-2	21.1	22.8	6.7
RS-3	15.6	16.7	12.8
RL-3	4.4	7.4	0.0
Overall	16	18.2	57.6

Thus, for an average dairy farming system in irrigated zone, the potential for efficiency improvement in terms of reducing milk production costs is maximum in the landless system while for rainfed zone, it was found to be maximum in the small system.

A further perusal of Table 5.38 revealed that the potential for economic efficiency improvement of milk production in terms of reducing milk production costs of standard animal unit across systems in rainfed zone varied from 4.4

percent in the rainfed large system (RL-3) to 21.1 percent in the rainfed marginal system (RM-2). In case of buffaloes it varied from 7.4 percent in the large system (RL-3) to 22.8 percent in the marginal system (RM-2). In case of local cows it varied from 0 to 12.8 percent in the small system (RS-3). Thus, for an average dairy farming system in rainfed zone, the potential for efficiency improvement is maximum in the marginal system in case of standard animal unit and buffaloes while for crossbred cows it was found to be maximum in the small system.

The potential for economic efficiency improvement for the least economic efficient farm in each of the dairy farming systems have been presented in Table 5.39.

Table 5.39 Potential decrease in percent of milk production costs of the least economically efficient farm households across dairy farming systems using existing resources.

(%)

Dairy Farming System	SAU	Buffalo	Local cow
ILL-2	24.2	46.9	40.2
IM-2	17.4	26.4	0.0
IS-3	16.7	24.2	50.0
IL-4	14.0	19.0	76.9
RLL-2	31.6	46.7	4.5
RM-2	69.9	72.9	12.0
RS-3	47.4	50.5	37.8
RL-3	12.4	16.3	0.0
Overall	71	72.9	78.6

A close perusal of Table 5.39 revealed that for the least economic efficient farms in the irrigated zone, the maximum potential for efficiency improvement in reducing milk production costs varied from 14.0 percent in the irrigated large system (IL-4) to 24.2 percent in case of irrigated landless system (ILL-2) for standard animal unit. In case of buffalo, the potential for economic efficiency improvement varied from 19.0 percent in the large system

(IL-4) to 46.9 percent in the landless system (ILL-2). In case of local cows, the potential was highest in the large system at 76.9 percent. Thus, for the least cost efficient dairy farming system in irrigated zone, the potential for efficiency improvement is also maximum in the landless system while for local cows it was found to be maximum in the large system.

There was no scope found for cost efficiency improvement in terms of reducing milk production costs in case of crossbred cows as there were no inefficiency effects found in the model in case of crossbred cows.

In nutshell, if the average farmer in the sample was to achieve the EE level of its most efficient counterpart of milk production costs by standard animal unit, then the average farmer could realize a 16 percent cost savings $[1 - (81.48/97)]$ (Table 5.38). A similar calculation for the most economically inefficient farmer reveals a cost saving of 71 percent $[1 - (28/98)]$ (Table 5.39).

The economical efficiency (EE) indices for buffalo milk production ranged from 26 to 96 percent for the farm households in the sample, with an average of 78.5 percent (Table 5.37). This suggested that if the average farmer in the sample was to achieve the efficiency level of its most efficient counterpart, then the average farmer could realize an 18.2 percent cost savings³ $[1 - (78.5/96)]$ (Table 5.38). Similarly for the most economically inefficient farmer can make a cost saving of 72.9 percent $[1 - (26/96)]$ (Table 5.39).

The mean economical efficiency (EE) estimates of milk production by local cow unit ranged from 21 to 98 percent for the farm households in the sample, with an average of 81.3 percent for overall category (Table 5.37). This means that if the average farmer in the sample was to achieve the EE level of its most efficient counterpart, then the average farmer could realize a 17.0 percent cost savings $[1 - (81.3/98)]$ (Table 5.38). A similar calculation for the most economically inefficient farmer reveals a cost saving of 78.6 percent $[1 - (21/98)]$ (Table 5.39).

³ $(1 - [\text{mean efficiency} / (\text{efficiency of most efficient farm})]) * 100$

5.5.7 Efficiencies of the Dairy Farming Systems

The ensuing section discusses the efficiencies in each of the dairy farming systems and the potential to improve the efficiencies in terms of either increasing milk production or lowering milk production costs.

5.5.7.1 Irrigated landless dairy farming system (ILL-2)

The most and the least technical efficient farm along with its efficiency and the annual milk production within the farming system has been presented in Table 5.40.

Table 5.40 Efficiency of most and least technical efficient farms in irrigated landless (ILL2) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Yield (kg/annum)	Farm No.	TE (%)	EE (%)	Yield (kg/annum)
SAU	31	97	93	1521	33	83	78	713
Buffalo	22	97	96	1595	16	85	87	675
Crossbred cow	12	97	100	1035	11	70	100	488
Local cow	17	100	97	1215	8	100	80	548

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.40 revealed that the technical efficiencies of the farm households in case of standard animal unit varied from 83 to 97 percent. In case of buffalo enterprise it varied from 85 to 97 percent while in case of crossbred cow, it varied from 70 to 97 percent.

The variation in milk yield per standard animal unit ranged from 713 kg to 1521 kg per year; in case of buffalo it ranged from 675 to 1595 kg per year and in case of crossbred cow it was from 488 to 1035 kg. Thus, there were wide variations in both yields and technical efficiency of milk production across the households within the system. A further perusal of Table 5.31 revealed that the maximum potential of technical efficiency improvement of the average system in terms of increase in milk production existed in case of

crossbred cows at 10.7 percent while it was only 4.2 percent in case of buffaloes. In case of standard animal unit the potential of improvement in this system was found to be only 4.6 percent.

A further perusal of Table 5.32 revealed that the potential of increasing milk production in the least technically efficient farm in this system was 27.8 percent in crossbred cows, 12.4 percent in buffaloes and 14.4 percent in case of standard animal unit.

The most and the least economic efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.41.

Table 5.41 Efficiency of most and least economic efficient farms in irrigated landless (ILL2) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)
SAU	22	95	97	7.56	32	72	90	23.27
Buffalo	22	96	97	7.08	32	51	90	22.88
Crossbred cow	12	100	97	6.24	33	100	70	14.77
Local cow	17	97	100	6.31	9	58	100	10.91

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.41 revealed that the economic efficiencies of the farm households in case of standard animal unit varied from 72 to 95 percent. In case of buffalo enterprise it varied from 51 to 96 percent while in case of local cow it varied from 58 to 97 percent. The variation in milk production costs per kg per standard animal unit was from Rs.7.56 to Rs.23.27 per kg; in case of buffalo from Rs.7.08 to Rs.22.88 while in case of local cow it was from Rs.6.31 to Rs.10.91. Thus, there was a wide variation in both costs and economic efficiency of milk production in the households of the systems. A further perusal of Table 5.38 revealed that the maximum potential of cost efficiency improvement of the average system in terms of decrease in milk production costs existed in case of local cows at 17.5 percent while it was 17.3 percent in case of buffaloes. In case of standard animal unit the potential

of improvement in this system was found to be 12.6 percent. A further perusal of Table 5.39 revealed that the potential for reducing milk production costs for the least efficient farm in this system was the maximum at 46.9 percent in buffaloes and 40.2 percent in case of local cows. In case of standard animal unit, the potential was found to be 24.2 percent.

5.5.7.2 Irrigated marginal dairy farming system (IM-2)

The most and the least technical efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.42.

Table 5.42 Efficiency of most and least technical efficient farms in irrigated marginal (IM2) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Yield (kg/annum)	Farm No.	TE (%)	EE (%)	Yield (kg/annum)
SAU	39	94	92	1214	42	77	76	566
Buffalo	39	94	81	1220	43	79	88	508
Crossbred cow	43	85	100	1095	43	85	100	1095
Local cow	41	100	93	530	41	100	93	530

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.42 revealed that the technical efficiencies of the farm households in case of standard animal unit varied from 77 to 94 percent. In case of buffalo enterprise it varied from 79 to 94 percent while in case of crossbred cow it was 85 percent as there was only one household in this system with crossbred cow. The variation in milk yield per standard animal unit was from 566 kg to 1214 kg per year; in case of buffalo from 508 to 1220 kg per year while in case of crossbred cow it was 1095 kg. Thus, there was a wide range of variation in both yields and technical efficiency of milk production in the households of the systems.

A further perusal of Table 5.31 revealed that the maximum potential of technical efficiency improvement of the average system in terms of increase in milk production existed in case of buffaloes at 8 percent while it was only 7.7 percent in case of standard animal unit. A further perusal of Table 5.32

revealed that the potential of increasing milk production in the least technically efficient farm in this system was 16 percent in buffaloes, and 18.1 percent in case of standard animal unit.

The most and the least economic efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.43.

Table 5.43 Efficiency of most and least economic efficient farms in irrigated marginal (IM2) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)
SAU	39	92	94	7.66	42	76	77	21.43
Buffalo	41	91	88	12.71	44	67	89	20.55
Crossbred cow	43	100	85	7.70	43	100	85	7.70
Local cow	41	93	100	18.89	41	93	100	18.89

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.43 revealed that the economic efficiencies of the farm households in case of standard animal unit varied from 76 to 92 percent. In case of buffalo enterprise it varied from 67 to 91 percent while in case of local cow it was 93 percent. The variation in milk production costs per kg per standard animal unit was from Rs.7.66 to Rs.21.43 per kg; in case of buffalo from Rs.12.71 to Rs.20.55 while in case of local cow it was Rs.18.89. Thus, there was a wide range of variation in both costs and economic efficiency of milk production in the households of the systems. A further perusal of Table 5.38 revealed that the maximum potential of cost efficiency improvement of the average system in terms of decrease in milk production costs existed in case of buffaloes at 10 percent while it was 6.4 percent in case of standard animal unit. A further perusal of Table 5.39 revealed that the potential for reducing milk production costs for the least efficient farm in this system was the maximum at 26.4 percent in buffaloes. In case of standard animal unit, the potential was found to be 17.4 percent.

5.5.7.3 Irrigated small dairy farming system (IS-3)

The most and the least technical efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.44.

Table 5.44 Efficiency of most and least technical efficient farms in irrigated small (IS3) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Yield (kg/annum)	Farm No.	TE (%)	EE (%)	Yield (kg/annum)
SAU	52	97	92	1745	47	75	89	423
Buffalo	52	98	90	2445	47	70	93	366
Crossbred cow	45	98	100	1950	54	80	100	913
Local cow	45	100	47	1340	47	100	74	730

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.44 revealed that the technical efficiencies of the farm households in case of standard animal unit varied from 75 to 97 percent.

In case of buffalo enterprise it varied from 70 to 98 percent while in case of crossbred cow, it varied from 80 to 98 percent. The variation in milk yield per standard animal unit was from 4223 kg to 1745 kg per year; in case of buffalo from 366 to 2445 kg per year while in case of crossbred cow it was from 912.5 to 1950 kg. Thus, there was a wide range of variation in both yields and technical efficiency of milk production in the households of the systems. A further perusal of Table 5.31 revealed that the maximum potential of technical efficiency improvement of the average system in terms of increase in milk production existed in case of crossbred cows at 9.3 percent while it was only 7.0 percent in case of buffaloes. In case of standard animal unit the potential of improvement in this system was found to be 4.9 percent. A further perusal of Table 5.32 revealed that the potential of increasing milk production in the least technically efficient farm in this system was 28.6 percent in buffaloes, 18.4 percent in crossbred cows and 22.7 percent in case of standard animal unit.

The most and the least economic efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.45.

Table 5.45 Efficiency of most and least economic efficient farms in irrigated small (IS3) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)
SAU	48	96	93	6.01	45	80	91	12.80
Buffalo	54	95	97	6.44	49	72	92	16.43
Crossbred cow	45	100	98	5.89	46	100	82	22.36
Local cow	53	94	100	12.91	45	47	100	12.96

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.45 revealed that the economic efficiencies of the farm households in case of standard animal unit varied from 80 to 96 percent. In case of buffalo enterprise it varied from 72 to 95 percent while in case of local cow it varied from 47 to 94 percent. The variation in milk production costs per kg per standard animal unit was from Rs.6.01 to Rs.12.80 per kg; in case of buffalo from Rs.6.44 to Rs.16.43 while in case of local cow it was Rs.12.91. Thus, there was a wide range of variation in both costs and economic efficiency of milk production in the households of the systems. A further perusal of Table 5.38 revealed that the maximum potential of cost efficiency improvement of the average system in terms of decrease in milk production costs existed in case of local cow at 18.6 percent followed by buffaloes at 9.2 percent while it was 4.5 percent in case of standard animal unit. A further perusal of Table 5.39 revealed that the potential for reducing milk production costs for the least efficient farm in this system was the maximum at 50 percent in local cows, followed by 24.2 percent in buffaloes and 16.7 percent in case of standard animal unit.

5.5.7.4 Irrigated large dairy farming system (IL-4)

The most and the least technical efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.46.

Table 5.46 Efficiency of most and least technical efficient farms in irrigated large (IL4) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Yield (kg/annum)	Farm No.	TE (%)	EE (%)	Yield (kg/annum)
SAU	57	92	90	1392	60	75	93	606
Buffalo	57	94	68	1643	60	76	77	609
Crossbred cow	57	96	100	1633	58	78	100	1210
Local cow	56	100	21	1335	56	100	21	1335

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.46 revealed that the technical efficiencies of the farm households in case of standard animal unit varied from 75 to 92 percent. In case of buffalo enterprise it varied from 76 to 94 percent while in case of crossbred cow cow it varied from 78 to 96 percent. The variation in milk yield per standard animal unit was from 606 kg to 1392 kg per year; in case of buffalo from 609 to 1643 kg per year while in case of crossbred cow it was from 1210 to 1633 kg. Thus, there was a wide range of variation in both yields and technical efficiency of milk production in the households of the systems. A further perusal of Table 5.31 revealed that the maximum potential of technical efficiency improvement of the average system in terms of increase in milk production existed in case of crossbred cows at 8.4 percent while it was only 6.7 percent in case of buffaloes. In case of standard animal unit the potential of improvement in this system was found to be 5.9 percent. A further perusal of Table 5.32 revealed that the potential of increasing milk production in the least technically efficient farm in this system was 19.1 percent in buffaloes, 18.8 percent in crossbred cows and 18.5 percent in case of standard animal unit.

The most and the least economic efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.47.

Table 5.47 Efficiency of most and least economic efficient farms in irrigated large (IL4) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)
SAU	60	93	75	12.57	56	80	86	14.13
Buffalo	59	84	89	14.44	57	68	94	15.27
Crossbred cow	57	100	96	6.68	58	100	78	6.92
Local cow	56	91	100	17.86	56	91	100	17.86

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.47 revealed that the economic efficiencies of the farm households in case of standard animal unit varied from 80 to 93 percent. In case of buffalo enterprise it varied from 68 to 84 percent while in case of local cow it was 91 percent.

The variation in milk production costs per kg per standard animal unit was from Rs.12.57 to Rs.14.13 per kg; in case of buffalo from Rs.14.44 to Rs.15.27 while in case of local cow it was from Rs.6.31 to Rs.17.86. Thus, there was a wide range of variation in both costs and economic efficiency of milk production in the households of the systems. A further perusal of Table 5.38 revealed that the maximum potential of cost efficiency improvement of the average system in terms of decrease in milk production costs existed in case of buffaloes at 12.1 percent. In case of standard animal unit the potential of improvement in this system was found to be 5.2 percent. A further perusal of Table 5.39 revealed that the potential for reducing milk production costs for the least efficient farm in this system was the maximum at 76.9 percent in local cow and 19 percent in case of buffaloes. In case of standard animal unit, the potential was found to be 14.0 percent.

5.5.7.5 Rainfed landless dairy farming system (RLL-2)

The most and the least technical efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.48.

Table 5.48 Efficiency of most and least technical efficient farms in rainfed landless (RLL2) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Yield (kg/annum)	Farm No.	TE (%)	EE (%)	Yield (kg/annum)
SAU	82	96	92	1155	69	73	79	446
Buffalo	82	96	88	1160	69	74	79	448
Crossbred cow	71	88	100	1100	71	88	100	1100
Local cow	64	100	89	610	64	100	89	610

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.48 revealed that the technical efficiencies of the farm households in case of standard animal unit varied from 73 to 96 percent.

In case of buffalo enterprise it varied from 74 to 96 percent while in case of crossbred cow it was 88 percent. The variation in milk yield per standard animal unit was from 446 kg to 1155 kg per year; in case of buffalo from 448 to 1160 kg per year while in case of crossbred cow it was 1100 kg. Thus, there was a wide range of variation in both yields and technical efficiency of milk production in the households of the systems. A further perusal of Table 5.31 revealed that the maximum potential of technical efficiency improvement of the average system in terms of increase in milk production existed in case of buffaloes at 5.4 percent. In case of standard animal unit the potential of improvement in this system was found to be 5.7 percent. A further perusal of Table 5.32 revealed that the potential of increasing milk production in the least technically efficient farm in this system was 22.9 percent in buffaloes, and 24 percent in case of standard animal unit.

The most and the least economic efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.49.

Table 5.49 Efficiency of most and least economic efficient farms in rainfed landless (RLL2) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)
SAU	70	95	93	9.29	80	65	92	23.49
Buffalo	70	92	92	12.03	75	49	91	20.53
Crossbred cow	71	100	88	7.83	71	100	88	7.83
Local cow	64	89	100	10.65	67	85	100	11.24

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.49 revealed that the economic efficiencies of the farm households in case of standard animal unit varied from 65 to 95 percent. In case of buffalo enterprise it varied from 49 to 92 percent while in case of local cow it varied from 85 to 89 percent. The variation in milk production costs per kg per standard animal unit was from Rs.9.29 to Rs.23.49 per kg; in case of buffalo from Rs.12.03 to Rs.20.53 while in case of local cow it was from Rs.10.65 to Rs.11.24. Thus, there was a wide range of variation in both costs and economic efficiency of milk production in the households of the systems. A further perusal of Table 5.38 revealed that the maximum potential of cost efficiency improvement of the average system in terms of decrease in milk production costs existed in case of buffaloes at 17.0 percent while it was only 2.2 percent in case of local cows. In case of standard animal unit the potential of improvement in this system was found to be 13.4 percent. A further perusal of Table 5.39 revealed that the potential for reducing milk production costs for the least efficient farm in this system was the maximum at 46.7 percent in buffaloes and 4.5 percent in case of local cows. In case of standard animal unit, the potential was found to be 31.6 percent.

5.5.7.6 Rainfed marginal dairy farming system (RM-2)

The most and the least technical efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.50.

Table 5.50 Efficiency of most and least technical efficient farms in rainfed marginal (RM2) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Yield (kg/annum)	Farm No.	TE (%)	EE (%)	Yield (kg/annum)
SAU	113	96	87	1217	104	78	28	607
Buffalo	110	95	77	1340	104	80	26	610
Crossbred cow	112	76	100	788	112	76	100	788
Local cow	84	100	88	970	114	100	92	730

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.50 revealed that the technical efficiencies of the farm households in case of standard animal unit varied from 78 to 96 percent. In case of buffalo enterprise it varied from 80 to 95 percent while in case of crossbred cow it was 76 percent. The variation in milk yield per standard animal unit was from 607 kg to 1217 kg per year; in case of buffalo from 610 to 1340 kg per year while in case of crossbred cow it was 787.5. Thus, there was a wide range of variation in both yields and technical efficiency of milk production in the households of the systems. A further perusal of Table 5.31 revealed that the maximum potential of technical efficiency improvement of the average system in terms of increase in milk production existed in case of buffalo at 5.2 percent while it was only 0.4 percent in case of crossbred cow. In case of standard animal unit the potential of improvement in this system was found to be 5.7 percent. A further perusal of Table 5.32 revealed that the potential of increasing milk production in the least technically efficient farm in this system was 15.8 percent in buffaloes and 18.8 percent in case of standard animal unit.

The most and the least economic efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.51.

Table 5.51 Efficiency of most and least economic efficient farms in rainfed marginal (RM2) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)
SAU	119	93	92	9.65	104	28	78	21.26
Buffalo	107	96	94	5.80	104	26	80	25.74
Crossbred cow	112	100	76	13.59	112	100	76	13.59
Local cow	85	92	100	12.77	107	81	100	16.59

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.51 revealed that the economic efficiencies of the farm households in case of standard animal unit varied from 28 to 93 percent. In case of buffalo enterprise it varied from 47 to 95 percent while in case of local cow it varied from 81 to 92 percent. The variation in milk production costs per kg per standard animal unit was from Rs.9.65 to Rs.21.26 per kg; in case of buffalo from Rs.5.80 to Rs.25.74 while in case of local cow it was from Rs.12.77 to Rs.16.59. Thus, there was a wide range of variation in both costs and economic efficiency of milk production in the households of the systems. A further perusal of Table 5.38 revealed that the maximum potential of cost efficiency improvement of the average system in terms of decrease in milk production costs existed in case of buffaloes at 22.8 percent while it was 6.7 percent in case of local cows. In case of standard animal unit the potential of improvement in this system was found to be 21.1 percent. A further perusal of Table 5.39 revealed that the potential for reducing milk production costs for the least efficient farm in this system was the maximum at 72.9 percent in buffaloes and 12.0 percent in case of local cows. In case of standard animal unit, the potential was found to be 69.9 percent.

5.5.7.7 Rainfed small dairy farming system (RS-3)

The most and the least technical efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.52.

Table 5.52 Efficiency of most and least technical efficient farms in rainfed small (RS3) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Yield (kg/annum)	Farm No.	TE (%)	EE (%)	Yield (kg/annum)
SAU	121	97	70	2190	140	78	88	579
Buffalo	121	97	61	2200	142	76	92	551
Crossbred cow	132	98	100	1465	169	87	100	1100
Local cow	137	100	77	1095	171	100	98	730

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.52 revealed that the technical efficiencies of the farm households in case of standard animal unit varied from 78 to 97 percent. In case of buffalo enterprise it varied from 76 to 97 percent while in case of crossbred cow it varied from 87 to 98 percent. The variation in milk yield per standard animal unit was from 579 kg to 2190 kg per year; in case of buffalo from 551 to 2200 kg per year while in case of crossbred cow it was from 1100 to 1465 kg. Thus, there was a wide range of variation in both yields and technical efficiency of milk production in the households of the systems. A further perusal of Table 5.31 revealed that the maximum potential of technical efficiency improvement of the average system in terms of increase in milk production existed in case of buffaloes at 6.1 percent while it was only 5.6 percent in case of crossbred cows. In case of standard animal unit the potential of improvement in this system was found to be 5.5 percent. A further perusal of Table 5.32 revealed that the potential of increasing milk production in the least technically efficient farm in this system was 21.6 percent in buffaloes, 11.2 percent in crossbred cows and 19.6 percent in case of standard animal unit.

The most and the least economic efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.53.

Table 5.53 Efficiency of most and least economic efficient farms in rainfed small (RS3) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)
SAU	142	95	79	10.50	154	50	83	22.46
Buffalo	138	95	93	6.96	154	47	85	22.57
Crossbred cow	132	100	98	5.53	169	100	87	20.77
Local cow	171	98	100	12.84	136	61	100	16.39

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.53 revealed that the economic efficiencies of the farm households in case of standard animal unit varied from 50 to 95 percent. In case of buffalo enterprise it varied from 47 to 95 percent while in case of local cow it varied from 61 to 98 percent. The variation in milk production costs per kg per standard animal unit was from Rs.10.50 to Rs.22.46 per kg; in case of buffalo from Rs.6.96 to Rs.22.57 while in case of local cow it was from Rs.12.84 to Rs.16.39.

Thus, there was a wide range of variation in both costs and economic efficiency of milk production in the households of the systems. A further perusal of Table 5.38 revealed that the maximum potential of cost efficiency improvement of the average system in terms of decrease in milk production costs existed in case of buffaloes at 16.7 percent while it was 12.8 percent in case of local cows. In case of standard animal unit the potential of improvement in this system was found to be 15.6 percent. A further perusal of Table 5.39 revealed that the potential for reducing milk production costs for the least efficient farm in this system was the maximum at 50.5 percent in buffaloes and 37.8 percent in case of local cows. In case of standard animal unit, the potential was found to be 47.4 percent.

5.5.7.8 Rainfed large dairy farming system (RL-3)

The most and the least technical efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.54.

Table 5.54 Efficiency of most and least technical efficient farms in rainfed large (RL3) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Yield (kg/annum)	Farm No.	TE (%)	EE (%)	Yield (kg/annum)
SAU	178	98	95	2546	179	78	92	582
Buffalo	178	98	81	2558	179	79	88	585
Crossbred cow	180	95	100	2065	180	95	100	2065
Local cow	172	100	94	1215	172	100	94	1215

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.54 revealed that the technical efficiencies of the farm households in case of standard animal unit varied from 78 to 98 percent. In case of buffalo enterprise it varied from 79 to 98 percent while in case of crossbred cow, it was 95 percent. The variation in milk yield per standard animal unit was from 582 kg to 2546 kg per year; in case of buffalo from 585 to 2558 kg per year while in case of crossbred cow it was 2065 kg. Thus, there was a wide range of variation in both yields and technical efficiency of milk production in the households of the systems. A further perusal of Table 5.31 revealed that the maximum potential of technical efficiency improvement of the average system in terms of increase in milk production existed in case of crossbred cows at 7.3. In case of standard animal unit the potential of improvement in this system was found to be 7.0 percent. A further perusal of Table 5.32 revealed that the potential of increasing milk production in the least technically efficient farm in this system was 19.4 percent in buffaloes and 20.4 percent in case of standard animal unit.

The most and the least economic efficient farm along with its efficiency and productivity parameters in this system is presented in Table 5.55.

Table 5.55 Efficiency of most and least economic efficient farms in rainfed large (RL3) dairy farming system.

Milch species	Most efficient farm				Least efficient farm			
	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)	Farm No.	TE (%)	EE (%)	Cost (Rs./kg)
SAU	173	97	90	5.77	172	85	91	11.38
Buffalo	180	92	93	8.69	172	77	91	16.24
Crossbred cow	180	100	95	7.30	180	100	95	7.30
Local cow	172	94	100	8.38	172	94	100	8.38

TE = Technical efficiency; EE = Economic efficiency.

A perusal of Table 5.55 revealed that the economic efficiencies of the farm households in case of standard animal unit varied from 85 to 97 percent. In case of buffalo enterprise it varied from 77 to 92 percent while in case of local cow it was 94 percent. The variation in milk production costs per kg per standard animal unit was from Rs.5.77 to Rs.11.38 per kg; in case of buffalo from Rs.8.69 to Rs.16.24 while in case of local cow it was Rs.8.38 per kg. Thus, there was a wide range of variation in both costs and economic efficiency of milk production in the households of the systems. A further perusal of Table 5.38 revealed that the maximum potential of cost efficiency improvement of the average system in terms of decrease in milk production costs existed in case of buffaloes at 7.4 percent. In case of standard animal unit the potential of improvement in this system was found to be 4.4 percent. A further perusal of Table 5.39 revealed that the potential for reducing milk production costs for the least efficient farm in this system was the maximum at 46.9 percent in buffaloes and 16.3 percent in case of buffaloes. In case of standard animal unit, the potential was found to be 12.4 percent.

Thus, it can be concluded on the basis of average technical efficiency of the respective dairy farming systems that there exists a scope to increase milk production and returns without incurring any extra expenditure across the average farm households belonging to the respective dairy farming systems ranging from 4.6 percent irrigated landless systems (ILL-2) to 7.0 percent in

irrigated marginal systems (IM-2). In case of buffalo, the potential of increasing milk productivity ranged from 4.2 to 8.0 percent while it was 0 to 10.7 in case of crossbred cow and no potential existed in case of local cow as all farms with local cows were found to be technically efficient. Similar studies carried out by Srivastava (1995) using deterministic frontier in commercial herds in and around Delhi found that technological efficiency contributed 44, 28, 11, 19 and 14 percent, respectively, on cow, buffalo, cow mix, buffalo mix and overall mix technology dairy farms. Technological efficiency included both technical efficiency and technological change factors and hence showed higher contribution to overall productivity. Similarly, Chand (1998) reported in a study of commercial herds in Bikaner that there existed a potential of 8,9 and 7 percent increase milk production and returns without incurring any extra expenditure in small, medium and large herd categories, respectively.

In case of the least technically efficient farm households in milk production, the potential for improvement in milk productivity was much higher ranging from 14.4 to 24 percent. In case of buffaloes it was still higher ranging from 0 to 28.6 percent while in case of crossbred cows it ranged from 0 to 27.8 percent.

On the basis of average economic efficiency, it may be observed that there existed a potential of 4.5 to 21.1 percent to decrease milk production costs across farm households belonging to different dairy farming systems. In case of buffalo milk production, the potential ranged from 7.4 to 22.8 percent while in case of local cow milk production it ranged from 0 to 18.6 percent. No inefficiency found in case of crossbred cow.

On the basis of least economic efficient farms in each of the dairy farming systems, it can be inferred that the potential to lower cost of milk production ranged from 12.4 to 69.9 percent across various dairy farming systems. In case of buffalo milk production, the potential was still higher ranging from 16.3 to 72.9 percent. In case of local cow milk production the potential ranged from 0 to 76.9 percent.

Thus, it could be concluded that there is a greater problem of economic efficiency than technical efficiency in the study area. Further, there was a

potential to improve the milk production and lower costs with the existing resources in the study area through proper resources allocation and their efficient utilization across the farm households belonging to the different dairy farming systems.

5.5.8 Frequency Estimates of Efficiencies Across Dairy Farming Systems

The frequency estimates of farm households belonging to different ranges of technical and economic efficiencies in the sample households are presented in Table 5.56 species-wise. A close perusal of the table revealed that most of the farm households were in the efficiency range of 80-100 percent of technical efficiency of milk production in case of standard animal unit. On the other hand, economic efficiency indices were spread over a wide range of 65-100 percent. Only 6 percent of the households with buffaloes were in the technical efficiency range of 65-80 percent while 25 percent of households with crossbred cows were in this range. The frequency estimates of efficiencies using translog frontier production function are presented in Annexure-XIV.

Table 5.56 Frequencies of efficiency estimates using stochastic Cobb-Douglas frontier production function.

Percentage range	Technical efficiency				Economic efficiency			
	SAU	B	CB	LC	SAU	B	CB	LC
< 20	0	0	0	0	0	0	0	0
20 - 35	0	0	0	0	4 (2)	4 (2)	0	1 (4)
35 - 50	0	0	0	0	2 (1)	4 (2)	0	1 (4)
50 - 65	0	0	0	0	14 (8)	23 (13)	0	2 (7)
65 - 80	9 (5)	11 (6)	5 (25)	0	49 (27)	42 (23)	0	5 (18)
80 - 95	151 (84)	153 (85)	9 (45)	0	108 (60)	105 (58)	0	15 (53)
95 - 100	20 (11)	16 (9)	6 (30)	28 (100)	3 (2)	2 (1)	20 (100)	4 (14)

SAU = Standard animal unit; B = Buffalo; CB = Crossbred; LC = Local cow.

Figures in parenthesis represent percentage of total households

Milk production with local cows were found to be 100 percent efficient in all the farms which may be due to lack of inefficiency errors in the model used to derive the technical efficiency indices. This could be interpreted that all the sample farm households in the operational area were operating with 100 percent technical efficiency and there was further scope to enhance productivity in local cows through improvement in technical efficiency.

The economic efficiency indices were found to vary in a range of 20-100 percent. About 4 percent of the farms in case of buffalo milk and 8 percent of the farms in case of local cow had economic efficiencies less than 50 percent. Maximum number of up to 58 and 53 percent households with buffalo and local cow milk production were in the economic efficiency range of 80-95 percent. However, there were significant number of farm households who were below this range as well, hence, it can be concluded that there is a higher potential for improvement of economic efficiency than technical efficiency in case of buffalo and local cow in the study area. However, all the farms were found to be economically efficient in the range of 95-100 percent in the case of crossbred cows, which could be attributed to incomplete information and inadequate representation of the costs of crossbred cow milk production using the Cobb-Douglas cost function frontier which was used to derive the economic efficiency estimates.

The most and least efficient farms on the basis of translog frontier production function have been presented in Annexures XV and XVI.

Thus, from the above discussion, the role of efficiency in improving productivity of dairy animals has been emphasized through the elaborate use of stochastic frontier analysis. Concentrate, green fodder and human labour in that order were found to be the significant factors affecting milk productivity of standard milch unit. However, green fodder was found to be more significant for buffalo milk productivity. The tests of significance of parameter estimates revealed presence of inefficiency in the milk production by the farm households in the study area. The factors causing such inefficiency, however, needs to be investigated. The decreasing returns to scale of 0.68 observed in

case of milk production function of SAU implied that intensity of input use has already crossed the first stage of production and was in second stage of milk production. Hence, the role of efficiency in improving productivity gains prominence.

On the whole, the irrigated large and marginal dairy farming systems had the lowest mean technical efficiencies while the irrigated landless systems had the highest technical efficiency of milk production per standard milch unit (SMU). However, in case of crossbred cows, the rainfed large and small dairy farming systems were more efficient over the rainfed marginal systems. The variability in efficiency estimates was more in the irrigated zone than in rainfed zone but in case of crossbred cows the variability was more in rainfed zone.

The average potential for increase in milk productivity per SMU varied from 4.6 percent for ILL-2 to 7.7 percent for IM-2 across various dairy farming systems in the irrigated zone while it varied from 5.5 in RS-3 to 7.0 percent in RL-3 across various dairy farming systems in the rainfed zone. The potential for increasing productivity of crossbred cow milk was found to vary from 0 to 10.7 percent with maximum being observed in case of ILL-2 system. However, the potential for the least efficient farm was observed to be quite high varying from 14.4 to 22.7 percent in the irrigated zone in ILL-2 and IS-3 system whereas it varied from 18.8 to 24 percent in case of RM2 and RLL2 system in the rainfed zone. Thus, it is clear that there is a high potential to improve the efficiency of the least efficient farms in the study area. The present investigation provides a very useful tool to identify the inefficient farms relative to the benchmarked efficient farms in the study area.

The results of estimated Cobb-Douglas cost frontier model revealed that 80.7 percent of the total error was accounted for by economic inefficiency. It was further found that there were decreasing cost economies of scale signifying increase in cost at a decreasing rate with the increase in productivity. Milk productivity was found to have positive and significant affect on the cost of milk production.

The Irrigated Landless Dairy Farming System was found to be the least economic efficient in the irrigated zone whereas irrigated small system was most economic efficient. In the rainfed zone, rainfed marginal system was the least economic efficient and rainfed large systems was the most economic efficient system.

On an average, the potential for economic efficiency improvement was maximum in the irrigated landless systems in irrigated zone, while in the rainfed zone, it was maximum in case of rainfed marginal dairy farming systems.

The frequency distribution of efficiency estimates across farm households in case of buffaloes revealed that 95 percent of households were in the range of 80-100 percent technical efficient. However, in case of crossbred cows, 25 percent of the farms were in the range of 65 to 80 percent technical efficiency signifying the greater problem of inefficiency in case of crossbred cows than buffaloes.

5.6 OPTIMAL FARM PLANS OF THE DAIRY FARMING SYSTEMS

Use of linear programming in optimal farm planning for dairying and mixed farming systems has been attempted by a number of research workers in the past. Desai (1960), Sundaresan (1973), Singh *et al.* (1977), Gangwar and Bhatia (1980), Pandey and Bhogal (1980), Saini and Singh (1980), Bhatia and Gangwar (1981), Pandey *et al.* (1982), Sardana and Panghal (1984) and Deoghare and Sharma (1992) have employed this technique to optimize utilization of farm resources for profit maximization. In the present study, the farm plans were developed by using the lexicographic goal programming techniques which are not necessarily optimal in terms of maximizing income, but also satisfy the multiple preferences or goals of the farm households representing the dairy farming systems. The goals considered in the present study were maximizing income, reducing risk from crop enterprises, minimum leisure and financial independence from informal debt. These goals were ranked according to the priorities of the dairy farming systems as determined by the Analytic Hierarchy Process (AHP). Sensitivity analysis was carried out

on adoption of frontier technology in terms of milk yield, the effect of increase in milk selling price and concentrate prices (in a range of 5-10%). The ensuing section provides the results of optimal farm plans for various dairy farming systems using lexicographic goal programming technique.

5.6.1 Optimal Farm Plans of Irrigated Landless Dairy Farming System (ILL-2)

The optimal farm plans for irrigated landless dairy farming system (ILL-2) are presented in Table 5.57. This farming system in the irrigated zone is prevalent prominently in the study area and is practiced by households who do not own any land for cultivation. The feeding of animals in this system is carried out through fodder collected from fields, roadsides, open fields mostly consisting of perennial grasses, sugarcane tops, weeds and non-conventional feed such as tree leaves, etc. The goals in order of preference for this system based on relative weights were financial self-support (1), minimizing risk (0.53), minimum leisure (0.42) and maximizing income (0.26). The goal program model satisfied all the goals except finance goal.

Table 5.57 Optimum farm plan model for irrigated landless dairy farming system (ILL-2).

Activities	Exist- ing	Optimum	Frontier Farm	+5% Milk Price	+10% Milk Price	+ 5% Feed Price	+10% Feed Price
Dairy Activities (number of milch animals)							
Buffalo	1	2	2	2	2	2	2
Cross-bred cow	0	0	1	0	0	0	0
Local Cow	1	1	0	1	1	1	1
Sensitivity indicators							
Cash Farm Income (Rs.)	8387	8526	9912	9903	11311	7920	7315
Leisure (mandays)	868	718	592	718	718	718	718
Finance Cost (Rs.)	NA	1700	1606	1485	1265	1700	1700
Non-farm labour (mandays)	215	223	209	223	223	223	223

NA: not available

A close perusal of Table 5.57 revealed the dependence of households in this system on informal debt to meet its family expenses and other working capital needs due to the daily earning nature of its occupation. Further, the number of milch buffaloes increased to 2 units from one in the optimum plan. Crossbred cow did not enter the optimal farm plan and the per kg milk price of crossbred cow needed to be increased from existing Rs.8.32 to Rs.8.99 for the crossbred cow enterprise to enter the model. The cash farm income from dairying increased from Rs.8387 to Rs.8526. The leisure goal of 868 mandays per annum was not fully achieved at 718 mandays per annum. The goal of financial independence from informal debt was not fully met under the condition that the farmer was to repay the loan taken for the purchase of the animals along with interest in a period of two years.

The simulation of the model with the frontier yield of milk production showed no change in size of buffalo enterprise. However, one Crossbred cow was introduced in the model. The cash farm income was, however, higher at Rs.9912 and with lower leisure of 592 mandays per annum.

The simulation to increase in milk prices did not show any response to the dairy enterprises in terms of introduction of new dairy activities than under optimal plan conditions. The leisure goal remained the same as the price was increased. The goal of profitability from farm enterprises also increased steadily from Rs.8526 in the optimal plan to Rs.11311 with the increase in milk prices up to 10 percent. The finance goal showed a steady decline in finance cost from Rs.1700 to Rs.1265 in terms of interest payments with 10 percent increase in milk prices. On the other hand, the simulation of the model to 10 percent increase in feed prices led to decrease in cash farm income from Rs.8526 under optimal plan to Rs.7315 with requirement for finance remaining stable at Rs.1700 under optimal conditions.

Thus, it could be concluded that the landless irrigated systems was highly sensitive to milk prices followed by concentrate prices. The best possible strategy for the irrigated landless dairy farming system could be to increase its farm profits through rise in milk prices by 10 percent of existing prices. However, since prices are determined by market forces, the

improvement in the technical efficiency of milk production to its frontier level of milk output as given by the most efficient farm in the system is the best strategy for the farmer to achieve his goals.

5.6.2 Optimal Farm Plans of Irrigated Marginal Dairy Farming System (IM-2)

The results of the optimal farm plans for the irrigated marginal dairy farming system (IM-2) have been presented in Table 5.58. The households who own marginal land for cultivation in the irrigated zone practiced this farming system. The feeding of animals for this system is through home grown green fodder and crop residues supplemented by collected grasses, weeds from open fields and non-conventional feed such as tree leaves, sugarcane tops etc. The major goals of this system based on relative weights in the order of priority were minimizing risk (1), financial self-support (0.58), minimum leisure (0.32) and maximizing income (0.21). A perusal of Table 5.58 revealed that all the goals except finance goal were satisfied. There was even surplus leisure in the optimum and simulated plans. The number of milch buffaloes remained same at one unit and there was introduction of one crossbred cow in place of local cow into the optimal plan. Local cow enterprise did not enter the optimal farm plan and it was found that the per kg price of local cow milk needs to be increased from existing Rs.8.32 to Rs.11.17 in order to introduce local cow into the optimal farm plan model. A number of earlier studies have reported the role of adopting crossbred cow in improving farm income and providing employment to the marginal farmers. Sundaresan (1973) had conducted a study where he suggested about the model scheme of crossbreeding in India -- a massive programme of bringing prosperity to 4 million farm families in addition to employment to 4 million rural labourers. Thus, he envisaged that with each family keeping three crossbred cows, there would be 12 million crossbred cows producing 24 million tons of milk a year - as much as 70 million zebu and buffalo cows were producing milk per year at that time. The present study also found the strategy of replacing local cows by crossbred cows optimizing the irrigated marginal system. However, unlike the strategy suggested by Sundaresan (1973), the

present strategy is more focused to the irrigated marginal dairy farming system and suggests replacement of local cow by only one crossbred cow along with keeping of one buffalo.

Table 5.58 Optimum farm plan model for irrigated marginal dairy farming systems (IM-2).

Activities	Exist- ing	Optimum	Frontier Farm	+5% Milk Price	+10% Milk Price	+ 5% Feed Price	+10% Feed Price
Dairy Activities (number of milch animals)							
Buffalo	1	1	1	1	1	1	1
Crossbred Cow	0	1	1	1	1	1	1
Local Cow	1	0	0	0	0	0	0
Crop Activities (in hectares)							
Land Size	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Paddy	0.57	0.64	0.64	0.64	0.64	0.64	0.64
Urad	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Wheat	0.57	0.64	0.64	0.64	0.64	0.64	0.64
Berseem	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Jowar	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Fodder selling activities (in quintals)							
Paddy Straw	0.00	49.36	46.36	49.36	49.36	49.36	49.36
Wheat Straw	0.00	16.00	16.00	16.00	16.00	16.00	16.00
Fodder buying activities (in quintals)							
Berseem	0.00	28.70	28.70	28.70	28.66	28.66	28.66
Jowar	0.00	29.15	29.20	29.15	29.15	29.15	29.15
Sensitivity indicators							
Cash Farm Income (Rs.)	9418	16130	16846	16671	17202	15531	14932
Leisure (mandays)	449	410	415	409	408	412	417
Finance Cost (Rs._	NA	589	535	518	448	589	589
Non-farm labour (mandays)	215	216	216	216	216	216	216

NA: Not Available

The farm returns or profit increased from Rs.9418 to Rs.16130. The leisure goal of 449 mandays per annum was fully achieved in the optimal plan. The goal of financial independence from informal debt was not fully met and interest costs of Rs.589 for financial debts to meet working capital needs to be paid annually.

The simulation with the frontier yield of milk production in the existing dairy farming system did not show any change when compared to optimal farm plan results. The cash farm income, however, increased from Rs.16130 to Rs.16846 and leisure decreased from 449 to 410 mandays.

The simulated plan to changes in milk prices showed no response to the dairy enterprises in terms of introduction of new dairy activities than under optimal conditions. The leisure goal, however, further increased as price increased. The goal of profitability from farm enterprises also rose marginally from Rs.16130 to Rs.17202 with the 10 percent increase in milk prices. The finance goal showed a steady decline from Rs.589 under optimal conditions to Rs.448 in loan requirements with 20 percent increase in milk prices. With 10 percent increase in feed prices, the cash farm income reduced from Rs.16130 to Rs.14932 in the optimal plan.

5.6.3 Optimal Farm Plans of Irrigated Small Dairy Farming System (IS-3)

The optimal farm plans for the irrigated small dairy farming system (IS-3) have been presented in Table 5.59. The major goals of this system in the order of priority based on relative weights were minimizing risk (1.00), minimum leisure (0.81), financial self support (0.81) and maximizing income (0.49).

A perusal of Table 5.59 revealed that the goal program model satisfied all the goals. The optimal plans showed reduction in number of milch buffaloes from two to one but number of crossbred cows remained the same at one in the lexicographic model. Local cow enterprise did not enter the optimum plan and in order to allow local cow to enter the model, it envisaged an increase in local cow milk prices from existing Rs.8.39 to Rs.10.09 per kg.

Table 5.59 Optimum farm plan model for irrigated small dairy farming system (IS-3).

Activities	Existing	Optimum	Frontier Farm	+5% Milk Price	+10% Milk Price	+ 5% Feed Price	+10% Feed Price
Dairy Activities (number of milch animals)							
Buffalo	2	1	2	2	2	1	1
Crossbred Cow	1	1	1	1	1	1	1
Crop Activities (in hectares)							
Land Size	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Paddy	0.90	0.49	0.46	0.46	0.46	0.49	0.41
Sugarcane	1.00	1.33	1.33	1.33	1.33	1.33	1.33
Urad	0.00	0.07	0.00	0.07	0.07	0.07	0.00
Wheat	0.90	0.67	0.67	0.67	0.67	0.67	0.67
Berseem	0.10	0.00	0.00	0.00	0.00	0.00	0.00
Jowar	0.08	0.11	0.13	0.13	0.13	0.107	0.15
Maize	0.08	0.08	0.09	0.09	0.09	0.077	0.09
Fodder selling activities (in quintals)							
Berseem	10.00	0.00	0.00	0.00	0.00	0.00	0.00
Jowar	6.00	60.00	60.00	60.00	60.00	60.00	60.00
Maize	4.00	45.00	45.00	45.00	45.00	45.00	45.00
Paddy Straw	75.00	54.00	51.40	51.40	51.40	54.42	54.42
Sugarcane Tops	204.00	203.87	192.68	192.68	192.68	203.87	203.87
Wheat Straw		42.00	0.00	0.00	0.00	0.00	0.00
Fodder buying activities (in quintals)							
Berseem	0.00	35.82	46.84	46.84	46.84	35.82	35.82
Wheat Straw	11.00	6.45	35.89	38.99	38.99	6.45	6.45
Sensitivity indicators							
Cash Farm Income (Rs.)	90260	97280	99924	98221	99524	96595	95909
Leisure (mandays)	885	885	693	885	885	885	885
Non-farm labour (mandays)	149	54	25	15	59	52	15

In terms of crop activities, the model showed an increase of sugarcane area from existing 1 ha to 1.33 ha. Further, there was a decrease in area under paddy from 0.9 ha to 0.49 ha and wheat from 0.9 ha to 0.67 ha. There was also an introduction of urad crop at 0.07 ha. Among fodder crops, berseem did not enter the model. The optimum plan suggested buying berseem at 35.82 quintals in the *rabi* season.

However, there was an increase in area under jowar from 0.08 ha to 0.11 ha. and the model suggested sale of jowar as green fodder to a extent of 60 quintals and maize at 45 quintals. There was a net increase in cash farm returns or profit, which increased from Rs.90260 to Rs.97281. The leisure goal of 885 mandays was fully achieved. The goal of financial independence from informal debt was also fully met. Linear programming studies carried out by various researchers in Haryana in the past found similar results. Gangwar and Bhatia 1980, studied the economics of milk production and optimum livestock cum crop combination for less than 2.2 ha farm in Haryana and concluded that local cows could not compete at all even with existing level of technology. With improved technology, buffaloes could not compete with crop production even if credit was available. Saini and Singh (1980) stated that small farms could increase income further with milch buffaloes, improved technology and borrowed capital. Bhatia and Gangwar (1981) applied an optimization model to data from small farms (less than 2.2 ha) in 8 villages of Karnal district. In their study, they found that Haryana cows could not compete economically with buffaloes under existing technology, and optimization plans called for 1-2 buffaloes/farm. Buffaloes could not compete with crossbred cows under improved technology, and although the optimum plan did not allow for cows (except for 1 cow on unirrigated farms of 1-2.19 ha) the value of milch animals in providing regular income was emphasized.

The simulation of the optimal plan with the frontier yield of milk production did not show any change in resource allocation for dairy enterprises as compared to existing conditions. The profits increased marginally from Rs.97280 to Rs.99924 per annum with reduction in leisure from 885 to 693 mandays.

The simulation to increase in milk prices did not show any change with respect to the dairy enterprises as per existing conditions but there was a marginal increase in income from Rs.97280 in optimal plan to Rs.99524 with 10 percent increase in milk prices. The leisure goal remained at the same level of 885 mandays per annum in all the simulated plans.

The increase of concentrate prices by 10 percent led to reduction to one buffalo unit from existing 2 units and the area under paddy crop reduced from optimal 0.49 ha to 0.41 ha. The cash farm income, however, reduced marginally from Rs.97280 to Rs.95909 with leisure remaining the same. The sensitivity of cash farm income to changes in milk prices or concentrate prices were not observed to be significant as the farm managed with crop production activities.

5.6.4 Optimal Farm Plans of Irrigated Large Dairy Farming System (IL-4)

The optimal farm plans for the irrigated large dairy farming system (IL-4) have been presented in Table 5.60. The goals of this system based on relative weights in order of priority were maximizing income (1.00), minimum leisure (0.44), financial self-support (0.35) and minimizing risk (0.12). A close examination of Table 5.60 revealed that under existing conditions, there was a reduction in number of milch buffaloes from 3 to 2 in the optimal plan and the number of crossbred cow remained at one as in the existing situation. Local cow did not enter any of the models and in order for the local cow to enter the model, the price of local cow milk needs to be increased from existing Rs.8.37 per kg to Rs.9.92 per kg. The model showed increase in area under paddy and wheat crops from existing 2.96 ha to 4.08 ha, respectively. However, there was a reduction in area under sugarcane from 4.07 ha to 3 ha. The cash farm income showed a marginal increase from Rs.305993 to Rs.309440. The leisure goal of 1379 mandays was fully achieved. The goal of financial independence from informal debt was also fully met.

The simulation studies with the frontier yield of milk production also suggested similar changes in resource allocation for various enterprises as observed for the optimal plan under existing conditions. The number of

buffaloes was reduced to 2 units and one crossbred cow entered the model. The cash farm income increased from existing Rs.305993 to Rs.312140. The leisure goal was fully achieved.

Table 5.60 Optimum farm plan model for irrigated large dairy farming system (IL-4).

Activities	Existing	Optimum	Frontier Farm	+5% Milk Price	+10% Milk Price	+ 5% Feed Price	+10% Feed Price
Dairy Activities (number of milch animals)							
Buffalo	3	2	2	2	2	2	2
Crossbred Cow	1	1	1	1	1	1	1
Local Cow	0	0	0	0	0	0	0
Crop Activities (in hectares)							
Land Size	7.08	7.08	7.08	7.08	7.08	7.08	7.08
Paddy	2.96	4.08	4.08	4.08	4.08	4.08	4.08
Sugarcane	4.07	3.00	3.00	3.00	3.00	3.00	3.00
Wheat	2.96	4.08	4.08	4.08	4.08	4.08	4.08
Berseem	0.28	0.00	0.00	0.00	0.00	0.00	0.00
Jowar	0.28	0.00	0.00	0.00	0.00	0.00	0.00
Maize	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Fodder selling activities (in quintals)							
Berseem	95.00	0.00	0.00	0.00	0.00	0.00	0.00
Jowar	75.00	0.00	0.00	0.00	0.00	0.00	0.00
Maize	20.00	0.00	0.00	0.00	0.00	0.00	0.00
Paddy Straw	250.00	442.20	442.27	442.30	442.30	442.30	442.30
Sugarcane Tops	550.00	505.80	505.80	505.80	505.80	505.80	505.80
Wheat Straw		252.80	252.80	252.80	252.80	252.80	252.80
Fodder buying activities (in quintals)							
Berseem	0.00	85.37	85.35	85.35	85.35	85.35	85.35
Jowar	0.00	92.40	92.41	92.41	92.41	92.41	92.41
Maize	0.00	48.50	48.51	48.51	48.51	48.51	48.51
Sensitivity indicators							
Cash Farm Income (Rs.)	305993	309440	312140	310230	311040	307480	305510
Leisure (mandays)	1379	1379	1379	1379	1379.4	1379	1379

The simulation of changes in milk prices showed similar response to the dairy enterprises as in the optimal plan. The leisure goal was, however, maintained in all sensitivity plans at 554 mandays per annum. The goal of profitability from farm enterprises also increased steadily from Rs.305993 to Rs.311040 with a 10 percent increase in milk prices. The fall in milk prices by 10 percent did not have a significant impact on cash farm income. The reduction in concentrate feed prices by 10 percent increased the cash farm income to Rs.307480 from existing Rs.305993. However, 10 percent increase in concentrate feed prices reduced the cash farm income marginally to Rs.305510.

The simulation plan with increase in milk or feed prices did not significantly affect the farm profits due to a very small proportion of profits accruing to the dairy enterprise in this system. With availability of surplus leisure and working capital in the system, the leisure goal and financial self-support goal was fully achieved.

5.6.5 Optimal Farm Plans of Rainfed Landless Dairy Farming System (RLL-2)

The optimal farm plans for the rainfed landless dairy farming system (RLL-2) have been presented in Table 5.61. This farming system is predominantly present in the study area and is practiced by households who do not own any land for cultivation. The feeding of animals in this system is carried out through fodder collected from fields, roadsides, open fields, barren and waste lands and common lands, mostly consisting of perennial grasses, weeds and non-conventional feeds such as tree leaves, etc. However, the farmers in this system also purchased green fodder to feed the animals whenever there was a scarcity of fodder. The major goals of this system based on relative weights in order of priority were financial self-support (1.00), minimizing risk (0.57), minimum leisure (0.32) and maximizing income (0.24). A close perusal of Table 5.61 revealed that the number of milch buffaloes remained the same at 2 units as in the existing plan but one crossbred cow entered the optimal model, thus, increasing the number of milch animals to 3

units in the optimal model. Local cow did not enter the optimal plan either and envisaged an increase in its milk prices from existing Rs.8.21 to Rs.10.02 per kg in order to enter the optimal plan. The cash farm income increased from Rs.5911 to Rs.6258. The leisure goal of 643 mandays per annum was not fully achieved, as only 182 mandays of leisure was available for the family under the condition that the farmer repays the principal amount of animal purchase with interest and also leads a minimum standard of life. The goal of financial independence from informal debt was not fully met and informal credit interest of Rs.2182 per annum was required to be paid.

Table 5.61 Optimum farm plan model for rainfed landless dairy farming system (RLL-2).

Activities	Existing	Optimum	Frontier Farm	+5% Milk Price	+10% Milk Price	+ 5% Feed Price	+10% Feed Price
Dairy Activities (numbers of milch animals)							
Buffalo	2	2	2	2	2	2	2
Crossbred Cow	0	1	1	1	1	1	1
Sensitivity indicators							
Cash Farm Income (Rs.)	5911	6258	7306	7491	8686	5809	5360
Leisure (mandays)	643	182	182	182	182	182	182
Finance Cost (Rs.)	NA	2182	2008	1930	1704	2182	2182
Non-farm labour (mandays)	187	286	286	286	286	286	286

NA: Not Available

The simulation of optimal farm plan with the frontier yield of milk production also showed no change in size of buffalo enterprise but crossbred enterprise did not enter the plan. The cash farm income, however, increased to Rs.7306. The finance requirements also reduced to Rs.2008 against interest payments of Rs.2182 in optimal plan. However, the number of days required for non-farm labour increased from existing 187 to 286 mandays.

The simulation of the optimal farm plan to increase in milk prices did not show any change in terms of introduction of new dairy activities in the optimal plan. The cash farm income from farm enterprises also grew steadily from Rs.6258 in optimal plan to Rs.8686 with the 10 percent rise in milk

prices. The finance goal showed a steady decline in formal loan requirements from Rs.2182 to Rs.1704 with 10 percent increase in milk prices. The response to similar change in feed prices was, however, smaller than the milk price response. In this case, 10 percent increase in feed prices reduced the farm income from optimal farm income of Rs.6258 to Rs.5360.

5.6.6 Optimal Farm Plans of Rainfed Marginal Dairy Farming System (RM-2)

The results for optimal farm plans for the rainfed marginal dairy farming system (RM-2) are presented in Table 5.62. This farming system was also significantly present in villages and was practiced by households who owned only marginal land (less than a hectare) for cultivation. The feeding of milch animals in this system was carried out through home grown fodder and crop residues cultivated by the farmer and partly through fodder collected from fields, roadsides, open fields, barren and waste lands and common lands, mostly consisting of perennial grasses, weeds and non-conventional feed such as tree leaves, etc. The major goals of this system based on relative weights in order of priority were financial self support (1.00), minimizing risk (0.51), minimum leisure (0.45) and maximizing income (0.36). A perusal of Table 5.62 revealed that the goal-programming model satisfied all the goals. The number of milch buffaloes and local cows remained the same at one unit but one crossbred cow was introduced into the model, thus, increasing the number of milch units to 3 in the optimal plan. The cash farm income decreased marginally from Rs.6096 to Rs.6084. The leisure goal of 470 mandays per annum was not fully achieved. The goal of financial independence from informal debt was fully met.

The simulation studies of the farm plan with the frontier yield of milk production showed an increase in size of buffalo enterprise to 2 units and introduction of one crossbred cow. The cash farm income showed an increase from Rs.6096 to Rs.8471. Unlike the optimal farm plan, there was a financial cost of Rs.1511 under the simulation plan with frontier yield of milk production. The leisure goal was also not fully achieved and it was 263 mandays against goal requirement of 470 mandays.

Table 5.62 Optimum farm plan model for rainfed marginal dairy farming system (RM-2).

Activities	Existing	Optimum	Frontier Farm	+5% Milk Price	+10% Milk Price	+ 5% Feed Price	+10% Feed Price
Dairy Activities (number of milch animals)							
Buffalo	1	2	3	3	3	3	3
Crossbred Cow	0	1	1	1	1	1	1
Local Cow	1	1	0	0	0	0	0
Crop Activities (in hectares)							
Land Size	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Bajra	0.35	0.17	0.17	0.17	0.17	0.17	0.17
Mustard	0.12	0.00	0.00	0.00	0.00	0.00	0.00
Urad	0.01	0.16	0.16	0.16	0.16	0.16	0.16
Gram	0.06	0.43	0.45	0.45	0.45	0.45	0.45
Wheat	0.35	0.43	0.45	0.45	0.45	0.45	0.45
Berseem	0.01	0.16	0.14	0.14	0.14	0.14	0.14
Jowar	0.01	0.21	0.21	0.21	0.21	0.21	0.21
Maize	0.01	0.15	0.14	0.14	0.14	0.14	0.14
Fodder Selling Activities (in quintals)							
Berseem	0.00	70.00	56.80	56.80	56.80	56.80	56.80
Jowar	0.00	60.00	60.00	60.00	60.00	60.00	60.00
Maize	0.00	45.00	45.00	45.00	45.00	45.00	45.00
Fodder Buying Activities (In Quintals)							
Berseem	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jowar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maize	7.00	0.00	0.00	0.00	0.00	0.00	0.00
Wheat Straw	15.00	58.30	57.50	57.50	57.50	57.50	57.50
Bazra Straw	10.00	46.25	49.05	49.05	49.05	49.05	49.05
Sensitivity indicators							
Cash Farm Income (Rs.)	6096	6084	8471	8357	10272	5508	4616
Leisure (mandays)	470	346	263	263	263	263	263
Finance Cost (Rs.)	NA	0	1511	1477	1223	1737	1737
Non-farm labour (mandays)	208	134	260	260	260	260	260

NA: Not Available

The simulation of farm plan to 10 percent increase in milk prices led to introduction of one more buffalo unit raising buffalo size to 3 and elimination of local cow from the optimal plan. The goal of profitability from farm enterprises also steadily increased from Rs.6084 to Rs.10272 with 10 percent increase in milk prices. There was a financial cost requirement of Rs.1223 as interest payments for loan with increase in milk prices to be paid as interest payments. However, 10 percent increase in feed prices led to reduction of the cash farm income from Rs.6096 to Rs.4616. The requirement of finance cost for interest payments also increased with increase in feed prices to Rs.1736.

Similar studies conducted earlier in the rainfed zone of Bhiwani district by Sardana and Panghal (1984) using a linear programming model found similar results with respect to number of milch animals. They developed optimal farm plans for small and marginal farmers in the Bhiwani district of Haryana state and showed that the introduction of two rather than one buffalo for milk and draught use and the use of improved technology could considerably improve income and increase employment.

5.6.7 Optimal Farm Plans of Rainfed Small Dairy Farming System (RS-3)

The optimal farm plans of the rainfed small dairy farming system (RS-3) are presented in Table 5.63. The major goals of this system based on relative weights in order of priority were minimizing risk (1.00), financial self support (0.88), minimum leisure (0.66) and maximizing income (0.38). The optimal plans satisfied all the goals but with more leisure.

A closer scrutiny of Table 5.63 revealed that under existing conditions, the optimal farm plan suggested reallocation of resources for the various crop and dairy enterprises. There was an increase in number of milch buffaloes from 2 to 5 and introduction of one crossbred cow along with the existing local cow, taking the total number of milch animals under optimal plan to 7. The model showed elimination of cotton, mustard and urad crops from the optimal plan and there was an increase in area under gram, wheat, berseem, jowar and maize from 0.32, 1.07, 0.05, 0.05, 0.04 ha to 1.83, 1.83, 0.29, 0.25, 0.29 ha, respectively. However, there was a decline in the area under bajra from 1.28 ha to 0.074 ha.

Table 5.63 Optimum farm plan model for rainfed small dairy farming system (RS-3).

Activities	Existing	Optimum	Frontier Farm	+5% Milk Price	+10% Milk Price	+ 5% Feed Price	+10% Feed Price
Dairy Activities (number of milch animals)							
Buffalo	2	5	5	5	6	5	5
Crossbred Cow	0	1	2	1	1	1	1
Local Cow	1	0	0	1	0	0	0
Crop Activities (in hectares)							
Land Size	2.12	2.12	2.12	2.12	2.12	2.12	2.12
Bajra	1.28	0.07	0.07	0.07	0.19	0.07	0.07
Cotton	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Mustard	0.43	0.00	0.00	0.00	0.16	0.00	0.00
Urad	0.04	0.00	0.00	0.00	0.393	0.00	0.00
Gram	0.32	1.83	2.08	1.88	1.63	1.83	1.83
Wheat	1.07	1.83	2.10	1.88	1.66	1.83	1.83
Berseem	0.05	0.29	0.02	0.24	0.31	0.29	0.29
Jowar	0.05	0.25	0.00	0.21	0.00	0.25	0.25
Maize	0.04	0.29	0.00	0.24	0.00	0.29	0.29
Fodder selling Activities (in quintals)							
Berseem	0.00	110.00	110.00	68.60	110.00	110.00	110.00
Jowar	0.00	0.00	21.85	0.00	0.00	0.00	0.00
Maize	0.00	46.09	48.46	24.43	0.00	46.09	46.09
Bazra Straw	45.00	0.00	0.00	0.00	0.00	0.00	0.00
Wheat Straw	0.00	0.00	21.00	0.00	0.00	0.00	0.00
Fodder buying Activities (in quintals)							
Berseem	0.00	0.00	97.93	0.00	0.00	0.00	0.00
Jowar	10.00	1.51	174.59	45.05	170.00	1.51	1.51
Maize	10.00	0.00	65.68	0.00	62.00	0.00	0.00
Wheat Straw	12.00	28.03	33.99	47.13	62	28.03	28.03
Bazra Straw	0.00	52.16	61.60	63.72	54.00	52.16	52.16
Sensitivity indicators							
Cash Farm Income (Rs.)	44092	80972	85718	84369	85802	79831	78689
Leisure (mandays)	604	222	121	117	70	222	222
Non-farm labour (mandays)	45	14	32	27	38	32	14

The net cash farm income increased from existing Rs.44092 to Rs.80972 in the optimal plan. The leisure goal of 604 mandays was not fully achieved in lexicographic model but it was lower at 222 mandays. The goal of financial independence from informal debt was also fully met.

The sensitivity analysis with the frontier yield of milk production also showed change in resource allocation for various activities with cash farm income increasing marginally from Rs.80972 under the optimal farm plan to Rs.85718. The number of buffaloes increased to 5 and there were 2 crossbred cows. There was also a change in the allocation of crop activities with increase in area under gram and wheat in the *rabi* season. The area under berseem, however, decreased from 0.29 ha in the optimal plan to 0.02 hectares in the simulated plan. There was a need to buy berseem, jowar and maize to feed the animals at 98, 175 and 66 quintals per annum in the plan. There was also need to buy wheat straw and bajra straw at 34 and 62 quintals, respectively, to feed the animals.

The simulation of changes in milk prices showed positive response to the dairy or crop enterprises in terms of increase in their activities than under existing conditions resulting into increase in income. The 5 percent increase in milk prices led to introduction of one local cow into the model. However, the number of milch buffaloes increased from 5 to 6 with 10 percent price increase in milk prices raising the number of milch animals to 7. Similar plans for mixed farming system were developed by Pandey *et al.* (1982) showed preference for increase in number of buffaloes with increase in price of buffalo milk. Local cows were, however, not found to be economic at any of the cow milk prices in the range of Re 0.75-2.25/kg.

The leisure goal, however, reduced from 222 to 70 mandays per annum with 10 percent increase in milk prices. The goal of profitability from farm enterprises also increased steadily from Rs.80972 in the optimal plan to Rs.85802 with the rise in milk prices by 10 percent. The finance goal was, however, achieved in all the simulated farm plans. The increase in feed

prices, brought no changes in dairy activities as in the optimal plan but decreased the cash farm income marginally from Rs.80972 to Rs.78689 with 10 percent increase in feed prices thereby signifying the less sensitivity on the farm income to feed prices.

5.6.8 Optimal Farm Plans of Rainfed Large Dairy Farming System (RL-3)

The optimal farm plans of rainfed large dairy farming system (RL-3) are presented in Table 5.64. The major goals of this system based on relative weights in order of priority were maximizing income (1.00), minimizing risk (0.63), minimum leisure (0.40), and financial self-support (0.12). The optimal farm plan model and the simulated strategies satisfied all the goals.

A close perusal of Table 5.64 revealed that under existing conditions, the optimal model showed reallocation of resources for various crop and dairy enterprises. The number of crossbred cows increased from one to five whereas the number of buffaloes reduced from three to one in the optimal farm plan. The optimal farm plan model showed increase in area under wheat, gram and mustard from existing 3.57, 1.07 and 1.43 ha to 3.6, 3.6 and 3.149 ha, respectively, but there was reduction in area under bajra from 4.28 ha to 4.16 ha. Cotton crop was eliminated in the optimal plan. The plan also eliminated jowar from the model but there was an increase in area under berseem and maize from 0.18 and 0.14 ha to 0.39 and 0.26 ha, respectively. The cash farm income increased from existing Rs.142759 to Rs.227840 in the optimal farm plan. The leisure goal of 656 mandays got reduced to 326 mandays. The goal of financial independence from informal debt was fully met.

The simulation studies with the frontier yield of milk production showed similar dairy and crop activities as in the optimal plan with number of buffaloes at 1 unit and crossbred cows remaining at 5 units.

The simulation of the optimal farm plan to increase in milk prices showed no response to the dairy activities in terms of increase in number of milch animals than under optimal plan. The goal of profitability from farm enterprises also rose steadily from Rs.227840 to Rs.236250 with 10 percent

rise in milk prices. The simulation of increase in feed prices was, however, not much as the rise in feed prices by 10 percent reduced the cash farm income from Rs.227840 to Rs.226840.

Table 5.64 Optimum farm plan model for rainfed large dairy farming system (RL-3).

Activities	Existing	Optimum	Frontier Farm	+5% Milk Price	+10% Milk Price	+ 5% Feed Price	+10% Feed Price
Dairy activities (number of milch animals)							
Buffalo	3	1	1	1	1	1	1
Crossbred Cow	1	5	5	5	5	5	5
Crop activities (in hectares)							
Land Size	7.13	7.13	7.13	7.13	7.13	7.13	7.13
Bajra	4.28	4.13	4.13	4.13	4.13	4.13	4.13
Cotton	0.14	0.00	0.00	0.00	0.00	0.00	0.00
Mustard	1.43	3.14	3.14	3.14	3.14	3.14	3.14
Urad	0.14	1.50	1.50	1.50	1.47	1.47	1.47
Gram	1.07	3.60	3.60	3.60	3.60	3.60	3.60
Wheat	3.57	3.60	3.60	3.60	3.60	3.60	3.60
Berseem	0.18	0.39	0.39	0.39	0.39	0.39	0.39
Jowar	0.24	0.00	0.00	0.00	0.00	0.00	0.00
Maize	0.14	0.26	0.26	0.26	0.26	0.26	0.26
Fodder selling activities (in quintals)							
Berseem	20.0	150.0	150.0	150.0	150.0	150.0	150.0
Jowar	15.0	0.0	0.0	0.0	0.0	0.0	0.0
Maize	5.0	34.0	34.0	34.0	34.0	34.0	34.0
Bazra Straw	135.0	232.6	232.6	232.6	232.6	232.6	232.6
Wheat Straw	65.0	90.0	90.0	90.0	90.0	90.0	90.0
Fodder buying activities (in quintals)							
Berseem	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jowar	0.0	166.0	166.0	166.0	166.0	166.0	166.0
Maize	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bazra Straw	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sensitivity indicators							
Cash Farm Income (Rs.)	142759	227840	228790	232090	236250	227340	226840
Leisure (mandays)	656	326	326	326	326	326	326

Thus, it can be concluded from the analysis of the plans developed using lexicographic goal programming models and various sensitivity analysis to increase in milk prices and adoption of frontier cost or yield technology, that there are various options to raise farm income.

5.7 OPTIMAL STRATEGIES FOR MAXIMIZING CASH FARM INCOME

In the previous section, a number of strategies have been studied and analyzed to achieve the multiple goals and preferences of the farm household viz. maximizing cash farm income, minimizing risk, minimum leisure and financial self-support. In order to select the best strategy, the proportional change in cash farm income to existing income has been reported in Table 5.65.

Table 5.65 Optimal strategies to maximize cash farm income across the dairy farming systems in the study area.

(%)

Dairy Farming System	Optimum farm plan	Frontier farm	Milk prices increase by 5%	Milk prices increase by 10%
ILL-2	33.5	55.2	55.1	77.1
IM-2	71.3	78.9	77.0	82.7
IS-3	7.8	10.7	8.8	10.3
IL-4	1.1	2.0	1.4	1.7
RLL-2	60.0	86.8	91.5	122.1
RM-2	0.0	39.0	37.1	68.5
RS-3	83.6	94.4	91.4	94.6
RL-3	59.6	60.3	62.6	65.5

A perusal of Table 5.65 revealed that in case of the irrigated landless dairy farming system (ILL-2), adoption of the optimal farm plan without any changes in prices or frontier milk yield gave only 33.5 percent increase in cash farm income. The frontier yield of milk production also gave significant increase in cash farm income by 55.2 percent. The strategy of raising milk prices by 10 percent gave maximum increase in cash farm income by 77 percent. Thus, the best way for the farmer in the ILL-2 system to increase farm income was to adopt the frontier yield of milk production as raising milk prices is generally not in his hands.

In case of the irrigated marginal dairy farming system (IM-2), adoption of the optimal farm plan without any changes in prices or yield will give 71 percent increase in cash farm income. The simulation with frontier milk yield also gave significant increase in cash farm income by 79 percent. The strategy of increasing milk prices by 10 percent brought maximum increase in cash farm income by 82.65 percent. Thus, the best way for the irrigated marginal buffalo based dairy farming systems (IM-2) to increase its farm income could be to adopt the frontier yield of milk production of the most efficient farm of the system as again increasing milk prices is market determined.

In case of the irrigated small dairy farming system (IS-3), adoption of the optimal farm plan without any changes in prices or yield provided 7.8 percent increase in cash farm income. The strategy of adopting the frontier milk yield brought increase in cash farm income by 10.7 percent. The increase in milk prices also gave increase in cash farm income by 10.26 percent. Thus, the best way for IS-3 to increase its farm income is to increase its technical efficiency to the level of frontier yield of milk production of the most efficient farm of the system.

In case of the irrigated large dairy farming system (IL-4), Adoption of the optimal farm plan without any changes in prices or yield gave 1.1 percent increase in cash farm income. The strategy of adopting the frontier farm milk yield brought maximum increase in cash farm income by 2.01 percent. The increase in milk prices also gave increase in cash farm income by 1.65 percent. Thus, the best way for IL-4 to increase its farm income is to improve its technical efficiency of milk production to the frontier yield level of milk production of the most efficient farm of the system. It may be observed that the IL-4 dairy farming system is more or less performing at the optimal level; hence, there was not much significant change in the income through external interventions.

In case of the rainfed landless dairy farming system (RLL-2), adoption of the optimal farm plan without any changes in prices or yield gave only 60 percent increase in cash farm income. The next best strategy found was

adoption of the frontier milk yield which brought 86.8 percent increase in cash farm income. The strategy of raising milk prices by 10 percent and 5 percent brought maximum increase in cash farm income by 122.1 and 91.5 percent, respectively. Thus, the best way for ILL-2 to increase its farm income is to raise its technical efficiency of milk production to the frontier yield level of milk production or implement policies to raise milk prices by 10 percent.

In case of the rainfed marginal dairy farming system (RM-2), adoption of the optimal farm plan without any changes in prices or yield gave only 0.2 percent decrease in cash farm income. Adoption of frontier milk yield would give an increase of 39 percent. The strategy of raising milk prices by 10 percent brought maximum increase in cash farm income by 68.5 percent. while Thus, the best way for RM-2 to increase its farm income is to implement policies to raise milk prices by 10 percent or increase its technical efficiency of milk production to the frontier level of milk production yield.

In case of the rainfed small dairy farming system (RS-3), adoption of the optimal farm plan without any changes in prices or yield would give 60 percent increase in cash farm income. The strategy of adopting the frontier farm milk yield of the most efficient farm of the system brought increase in cash farm income by 94 percent. The increase in milk prices also led to maximum increase in cash farm income by 94.6 percent. Thus, the best way for RS-3 to increase its farm income is to increase its technical efficiency of milk production to the frontier yield level of milk production of the most efficient farm of the system.

In case of the rainfed large dairy farming system (RL-3), adoption of the optimal farm plan without any changes in prices or yield will give rise to 60 percent increase in cash farm income. The strategy of adopting the frontier farm milk yield of the most efficient farm of the system brought an increase in cash farm income by 60 percent. The increase in milk prices by 10 percent also gave maximum increase in cash farm income by 65.5 percent. Thus, the best way for IL-4 to increase its farm income is to improve its technical efficiency of milk production to the frontier yield level of milk production of the most efficient farm of the system, as milk prices are market determined.

5.8 RESPONSE OF INCREASE IN MILK AND FEED PRICES ON CASH FARM INCOME

An attempt has been made in the present section to study the response of increase in milk and feed prices on cash farm income on the basis of optimal farm plans obtained earlier. The increase in price of milk in a year generally varied between 5 and 10 percent based on the existing data on farm gate milk prices of cooperatives in Haryana. Therefore, simulation were carried out at 5 and 10 percent increase over existing prices of milk for all the farm plans developed for each of the dairy farming systems. Similarly, simulation plans were developed for 5 and 10 percent increase in feed prices. The results of the simulations are presented in Table 5.66.

Table 5.66 Response of cash farm income to increase in milk and feed prices across dairy farming systems in the study area.

(%)

Dairy Farming System	5% increase in milk prices	10% increase in milk prices	5% increase in feed prices	10% increase in feed prices
ILL-2	16.2	32.7	-7.1	-14.2
IM-2	3.4	6.6	-3.7	-7.4
IS-3	1.0	2.3	-0.7	-1.4
IL-4	0.3	0.5	-0.6	-1.3
RLL-2	19.7	38.8	-7.2	-14.4
RM-2	37.4	68.8	-9.5	-24.1
RS-3	4.2	6.0	-1.4	-2.8
RL-3	1.9	3.7	-0.2	-0.4

A perusal of the table revealed that in case of ILL-2 system, the response to 10 percent rise in milk prices led to increase in cash farm income by 32.7 percent of the optimum plan whereas with a 10 percent increase in concentrate prices, the cash farm income fell by 14.2 percent.

In case of IM-2 system, the response to 10 percent rise in milk prices led to increase in cash farm income by 6.6 percent of the optimum plan whereas with a 10 percent increase in concentrate prices, the cash farm income reduced by 7.4 percent.

In case of IS-3 system, the response to 10 percent rise in milk prices increased the cash farm income by 2.3 percent of the optimum plan whereas a 10 percent increase in concentrate prices reduced the cash farm income by 1.4 percent.

In case of IL-4 system, the response to 10 percent rise in milk prices increased the cash farm income by 0.5 percent of the optimum plan whereas a 10 percent increase in concentrate prices reduced the cash farm income by 1.3 percent.

In case of RLL-2 system, the response to 10 percent rise in milk prices increased the cash farm income by 38.8 percent of the optimum plan whereas a 10 percent rise in feed prices reduced the cash farm income by 14.4 percent.

In case of RM-2 system, the response to 10 percent rise in milk prices increased the cash farm income by 68.8 percent of the optimum plan whereas a 10 percent rise in concentrate prices reduced the cash farm income by 14.4 percent.

In case of RS-3 system, the response to 10 percent rise in milk prices increased the cash farm income by 6.0 percent of the optimum plan whereas a 10 percent rise in concentrate prices reduced the cash farm income by 2.8 percent.

In case of RL-3 system, the response to 10 percent rise in milk prices increased the cash farm income by 3.7 percent of the optimum plan whereas a 10 percent rise in concentrate prices reduced the cash farm income by 0.4 percent.

Response to change in milk prices in terms of cash farm income was the highest in the case of rainfed marginal dairy farming system (RM-2). In this case 10 percent increase in milk prices led to 68.8 percent increase in the cash farm income. In general, the landless irrigated and rainfed systems and marginal rainfed systems were the most sensitive to milk and feed prices. The small and large systems were least sensitive to change in milk and feed prices in both the irrigated and rainfed zones.

Thus, it may be concluded from the above discussion that the farm plan developed based on multiple conflicting goals enabled to come up with the possibility of trade-off solutions for all the identified dairy farming systems. Different simulations carried out using frontier milk yield and increase in milk and feed prices, enabled to identify optimal strategies to maximize cash farm income.

It was found that in case of irrigated landless dairy farming system, the simulation with frontier farms milk productivity showed introduction of crossbred cow into the model. This signified the increase in efficiency of the milk production in the system resulting into increased cash farm income but at the same time the system was dependent on informal debt. In case of the irrigated marginal dairy farming system, it was observed that replacing local cow by crossbred cow brought significant increase in cash farm income in this system. The farm should purchase green fodder and specialize in wheat and paddy cultivation only. In case of the irrigated small dairy farming system, it was found that the herd size should be reduced to two milch animals in the optimal plan. The area under sugarcane crop also increased leading to rise in cash farm income and more leisure. However, simulation plan with frontier milk yield gave similar results with regard to number of milch animals and its composition as in existing situation. In the irrigated small dairy farming systems, the optimal farm plan suggested cultivation of green fodder crops for sale. In case of the irrigated large dairy farming system, the model envisaged reduction to 3 milch animals and decrease in area under sugarcane with more area under paddy and wheat. Leisure goal was fully satisfied in this system.

The rainfed landless dairy farming system model suggested the introduction of crossbred cow into the model with substantial reduction in leisure availability per household per annum. In the rainfed marginal dairy farming system, number of milch animals increased significantly from 2 to 4 units suggesting scope for dairying in this system. The area under green fodder such as berseem and jowar was found to increase in the optimal plan and there was surplus fodder available for selling. On the other hand, wheat

and bazra straw was required to be purchased. In case of rainfed small dairy farming system the number of milch animals increased from 3 to 6 units with majority of buffaloes and considerable increase in cash farm income with reduced leisure time. Similarly in the rainfed large dairy farming system the optimal plan envisaged an increase in number of milch animals from 3 to 6 units with 5 crossbred cows and 1 buffalo. There was also significant increase in cash farm income with reduced leisure time unlike the Irrigated large dairy farming system. Minimum provision of non-farm employment for 134 to 286 mandays was found essential in both the irrigated and rainfed, marginal and landless dairy farming systems.

The importance of timely and suitable credit to meet the farm and non-farm consumption expenses for the landless and the marginal dairy farming systems was quite evident in increasing cash farm income. Gangwar and Bhatia (1980) and Deoghar and Sharma (1992) also found similar results in their study conducted on small and marginal farmers. The non-farm employment ranging from 134 to 286 mandays per farm household in the marginal and landless dairy farming systems of both the zones was found to fulfill their multiple preferences. Similar results were also reported by Saini (1982).

It is quite clear from the above discussion that priorities vary from system to system even with similar resources across agro-climatic zones. It may be noted that increasing the milk prices was found to be a good strategy for the irrigated landless, rainfed landless and rainfed marginal dairy farming systems but not so for the irrigated marginal dairy farming systems and the small and large systems in both the zones. Similarly the sensitivity to feed price increase was found to be higher in the irrigated marginal system. The differential response of cash farm income to feed prices in the 5-10 percent range was found to be the same in all systems except in the rainfed marginal systems where it showed an increasing trend. Similarly the differential response of cash farm income to 5-10 percent increase in milk prices was the same in all dairy farming systems except in the rainfed small systems where it

showed a decreasing trend. However, increasing the technical efficiency of milk production to achieve frontier milk yield is the most feasible alternative strategy in all the dairy farming systems to increasing milk prices as prices are not controlled by the farmers and is the best strategy in the case of irrigated small and large dairy farming systems.

Summary and Conclusions

6. SUMMARY AND CONCLUSIONS

India has made significant achievements in dairying in terms of milk production, milch animal productivity and its contribution to the growth of the country's economy. Milk production, at an average annual growth rate of 4.48 percent, was anticipated as 84.5 million tons in 2001-02, thus making India the largest milk producer in the world (GOI, 2002). However, in spite of significant developments in the dairy sector over the last three decades, there are many challenges that need to be overcome in order to ensure the sustainability of the dairy development made so far. Landless and marginal farm households numbering more than 70 million, owning less than a hectare land, rear more than 80 percent of bovines in India. The average productivity of cow and buffalo in 1997 was much lower at 917 and 1300 litres of milk per milch animal per year (FAO, 2000) in comparison to world average of 2192 kg per animal and other major milk producing countries in the world due to lack of resources to improve upon their genetic potential and the nutrition standards.

Productivity of milch animals can be increased through technological change, economic efficiency change and scale efficiency change. Of these, the option of scale efficiency change and technological change requires proper social, economic and infrastructural investment. A few efficiency studies in milk production carried out in the past (Srivastava, 1995, Chand, 1998) have concentrated on the deterministic approach of quantifying the efficiency of resource use in milk production. But there is always the risk of significant bias in deterministic estimates of efficiency due to the inherent assumptions of the approach that all variations in milk production is due to inefficiency of resource use. Dixit (1999) used the Corrected Ordinary Least Square (COLS) approach to estimate the technical efficiency of milk production using stochastic frontier production function. However, this approach has been criticized by Coelli (1995) on account of unreliability of

parameter estimates using COLS method when the contribution of technical inefficiency effects to the total variance term is large. A stochastic approach using maximum likelihood estimation (MLE) method to take care of these limitations and thereby estimating efficiency of milk production has not been attempted so far in India.

Prior to evaluating efficiency, it is necessary to identify dairy farming systems to provide decision support to the farmers and policy makers and also to address more general dairy development questions. The issue is how to describe the diversity of complex dairy farming systems, whilst avoiding the pitfalls of singling out each and every production system as unique.

Most of the studies have considered profitability as the single major criteria in developing ex-ante strategies for improving upon social efficiency and managerial efficiency through increase in farm income and employment (Desai, 1960; Gangwar and Bhatia, 1980,1981; Pandey *et al.*, 1982; Rai and Singh, 1982; Sardana and Panghal, 1984; Singh and Sharma, 1987; Deoghare and Sharma 1992). The available literature on evaluation of dairy farming systems in India using multi criteria approach is rather scanty. The limited studies that have been carried out in farm planning are mostly those dealing with minimizing farmers' risk, stability of farm income in addition to maximization of expected total gross margin or profit (Singh and Jain, 1983; Vijayalakshmi, 1985; Sharma *et al.*, 1990; Jha, 1994). This may be mostly due to the perception and belief that other objectives are negligible in the farm business. It may be reasonable to make this assumption for farms in developed countries, but for the small farms in developing countries, majority of which are partly subsistence, this assumption may not hold. The farmer may have other objectives, which should not be neglected in their farm planning, for farming is just not a business but a way of life for them.

In view of the justification given above, the present study was undertaken with the following objectives:-

1. To identify and classify the different dairy farming systems in the study area;

2. To measure the technical and economic efficiencies of the dairy farming systems;
3. To develop and evaluate optimal plans of different dairy farming systems.

The state of Haryana was selected for the present study considering both the importance of dairying for Haryana economy and the significance of this study to serve as a model to be replicated in other regions of the country. Keeping into view the variations in agro-climatic features, cropping pattern, irrigation intensity, dairy and other livestock enterprises and socio-economic characteristics, the districts of Yamunanagar, Bhiwani and Gurgaon in Haryana were purposively selected for the study.

One block was selected to represent the unique characteristics of that particular district in terms of climate, agri-inputs, socio-economic, cropping pattern and infrastructure characteristics from each of the districts. The blocks selected were Radaur block from Yamunanagar, Dadri block from Bhiwani and Sohna block from Gurgaon districts, respectively. Two villages were selected in such a way that one village was within the periphery of the town / city and the other away from it from each of the selected block. The villages selected near and away from town were Bendi and Antawa from Yamunanagar, Mehra and Dokhaharia from Bhiwani, and Alipur and Berka from Gurgaon districts, respectively.

Complete enumeration of all the farm households was carried out in the selected villages. The dairy farming systems were identified using data on herd size, number and composition of milch animals, land size, area under fodder crops for all the farm households in the selected villages employing complete linkage hierarchical method of cluster analysis. A sample of 60 farm households from two selected villages of each block were selected on the basis of probability proportional to size subject to a minimum of five from each of the identified dairy farming system thus selecting a total of 180 sample households for the study. The detailed data on parameters relating to the socio-economic characteristics and input-output parameters of crop and dairy

enterprises of the sampled households was collected for the year 2000-01 through household surveys, personal interviews and group discussion for three seasons, namely, *kharif*, *rabi* and summer.

The technical efficiency was determined by considering the stochastic frontier translog and Cobb-Douglas production function approach. The stochastic Cobb-Douglas functional form of cost function was chosen despite its well-known limitations because the methodology employed requires that the production function used be self-dual. Besides Cobb-Douglas functional form has been used widely in farm efficiency studies by developing and developed countries (Kalirajan and Flinn, 1983; Battese *et al.* 1989; Battese, 1992; Bravo-Ureta and Pinheiro, 1993; Parikh and Shah, 1996; Bravo-Ureta and Pinheiro, 1993).

In order to measure the preferences of the farmers quantitatively, Analytic Hierarchy Process (AHP) was employed. AHP is a systematic procedure for representing the elements of any problem, hierarchically, i.e., setting priorities in steps. The four goals of the farm households representing the dairy farming systems in the study area were:

- Maximizing expected cash farm income
- Ensuring farm family's survival with a specified level of probability
- Achieving desired financial self support
- Maximizing family labour use with minimum amount of leisure

The relative importance of various criterion namely maximizing cash farm income, minimizing risk, financial independence and leisure preferences with reference to overall goal of selecting the most preferred farming system was determined on the basis of a well structured questionnaire to quantify the farmers' preferences. The formulation of the farm plan for different dairy farming systems was viewed as the selection of an appropriate set of crop and dairy activities for the farm and the most suitable level at which each activity was to be undertaken. The mathematical formulation of the model was constructed considering the whole farm household, interactions within and

between enterprises, in terms of labour availability, resources availability, cash needs and cash availability at regular points of time, the home consumption needs, the need for leisure, the requirement and availability of temporary labour, and non farm employment.

The algorithm available for solving general linear programming models in GAMS (General Algebraic Modeling System) are many but since the problem involved both crop and dairy enterprises, the MIP (Mixed Integer Programming) was selected as the solver for the model with the dairy enterprises as integer variables (Lee and Morris, 1977). The program was written in GAMS model for lexicographic goal programming model separately for each of the identified dairy farming systems. Thus the problem of returns to scale was overcome as different models were fitted for the different systems.

The naming of the eight identified clusters relevant to dairying were made on the basis of most important and significant variables characterizing the clusters namely, type of milch animal, number of milch animals and operational land holdings. Since all the systems were buffalo based, therefore, it has not been used in naming the systems identified. The dairy farming systems identified are stated as under:

- Irrigated landless dairy farming system (ILL-2)
- Irrigated marginal dairy farming system (IM-2)
- Irrigated small dairy farming system (IS-3)
- Irrigated large dairy farming system (IL-4)
- Rainfed landless dairy farming system (RLL-2)
- Rainfed marginal dairy farming system (RM-2)
- Rainfed small dairy farming system (RS-3)
- Rainfed large dairy farming system (RL-3)

The number adjacent to the abbreviation of the system represents the average number of milch animals found in the system.

The irrigated landless dairy farming system (ILL-2) was the most prominent system in the irrigated zone of Haryana with 46 percent of the farm households in the selected villages of this zone followed by the irrigated small (16%), irrigated marginal (10%) and irrigated large (7%) dairy farming systems in that order. In the rainfed zone, rainfed small dairy farming system (RS-3) was the most prominent system with 31 percent of the households belonging to this system followed by rainfed marginal (23%), rainfed landless (14%), and rainfed large (6%) dairy farming systems.

The average milk yield across various dairy farming systems was observed to be better in the partially rainfed zone system than the irrigated zone. The mean milk yield per standard animal unit per annum varied from 630 kg in IM-2 system to 1064 kg in IS-3 system in the irrigated zone. In the rainfed zone, the milk yield varied from 732 kg in the RM-2 system to 1191 kg in the RL-3 system.

Liberal quantities of green fodder, viz., berseem, jowar and maize feeding was practiced by the large systems of the irrigated and rainfed zones. Wheat straw was the predominant dry fodder fed in the irrigated and rainfed zone while paddy straw was only fed by the landless and marginal systems in the irrigated zone. Bajra / Jowar straw was, however, fed in the entire dairy farming systems in the rainfed zone. Maximum amount of wheat straw was fed in the irrigated small system while maximum amount of bajra / jowar straw was fed in the rainfed marginal system. The concentrate feed fed to the milch animals was comparatively higher in the small and large systems in the rainfed zone than in the irrigated zone. The amount of concentrates fed in the landless and marginal systems were almost similar in both the zones.

The per kg cost of buffalo milk production was found to be the lowest in the Irrigated small dairy farming system (IS-3) at Rs.11.01 followed by IL-3 at Rs.11.56, RS-3 at Rs.12.81, ILL-2 at Rs.13.94, RM-2 at Rs.14.39, IL-4 at Rs.15.48, IM-2 at Rs.16.12 and RLL-2 at Rs.17.47, respectively. The per kg cost of crossbred cow milk production was found to be the lowest in the rainfed large dairy farming system at Rs.7.91 followed by RS-3 at Rs.9.04, IS-

3 at Rs.9.53, RM-2 at Rs.9.89, IM-2 at Rs.10.24, IL-4 at Rs.10.63, and ILL-2 at Rs.10.69, respectively. In case of local cow the per kg cost of milk production was found to be the lowest in case of rainfed large dairy farming system at Rs.9.38 followed by RS-3 at Rs.10.80, ILL-2 at Rs.11.35, IL-4 at Rs.11.80, RLL-2 at Rs.12.18, IS-3 at Rs.13.31 and IM-2 at Rs.14.01. Thus, it can be observed that the costs of buffalo milk production were lower in the dairy farming systems in irrigated zone whereas cost of local and crossbred cow were lowest in the rainfed zone system. The full economic costs of buffalo milk production was covered only by the irrigated small dairy farming system while that of crossbred cow milk was covered fully only by the rainfed large dairy farming system.

The cash costs of milk production (total costs – opportunity costs – depreciation) except the irrigated large dairy farming systems were covered by all the systems. The net family returns ranged from Rs.29190 in irrigated landless system to Rs.309643 in irrigated large system and Rs.24069 in rainfed landless system to Rs.145809 in rainfed large system signifying higher inequity in family income in irrigated zone than rainfed zone. The share of feed and fodder costs were the maximum across all the systems followed by labour costs, and were the main components in milk production. Evidently the opportunity costs comprising of owned capital and family labour involved in collection of feeds and fodder and other dairy operations were the maximum in the landless and marginal systems in both the zones. This showed the family labour intensive nature of dairy enterprise in the landless and marginal dairy farming systems in the study area. However, in terms of family farm income, the landless dairy farming systems (ILL-2 and RLL-2) performed better in both the zones. None of the systems were found to make positive net profits in local cow milk production in the study area whereas irrigated small system (IS-3) made net profit in buffalo milk production and rainfed large system (RL-3) made positive profits in crossbred cow milk production.

In terms of gross returns to family income, the contribution of dairying was significant in case of landless dairy farming systems in both the irrigated and rainfed zone. The returns from milk varied from 7.8 percent in the

irrigated large buffalo based dairy farming system to 46.6 percent in the irrigated landless buffalo based dairy farming system. Other dairy returns contributed 24.5 percent in the rainfed large buffalo based systems. The most significant contribution to family income in the landless systems was from the other farm and non-farm income at 65.8 percent in the irrigated zone (Rs.18052) to 68.7 percent in the rainfed zone (Rs.15908). The share of non farm income was also significant in the case of marginal dairy farming systems in both the zones varying from 57.6 percent in the irrigated zone to 63.6 percent in the rainfed zone.

Based on log likelihood ratio tests of significance, the Cobb-Douglas model was found to be better fit than the translog frontier model. The mean technical efficiency (TE) indices for SMU ranged from 73 to 98 percent across the farm households in the sample, with an average of 91.1 percent. Most of the farms lay in the efficiency range of 80-95 percent in Cobb-Douglas frontier. However, the farms lay in the efficiency range of 65-95 percent in translog frontier. The technical efficiency indices for buffalo ranged from 70 to 98 percent across the farm households in the sample with an average of 90.9 percent. The technical efficiency indices for crossbred cow also ranged from 70 to 98 percent for the farm households in the sample but with a lower average of 87.8 percent. Thus the potential to improve the mean technical efficiency of crossbred cow was higher than buffalo. On the whole, the irrigated landless systems (ILL-2) was the most technically efficient while the irrigated large system (IL-4) was the least efficient dairy farming system in the study area in terms of milk production by standard animal unit or buffalo unit. The variation in mean efficiency estimates was found to be more in the irrigated zone than in the rainfed zone.

The economic efficiency (EE) indices based on Cobb-Douglas cost frontier model for Standard Milch Unit (SMU) were found to vary from 28 to 97 percent across sample farm households, with an average of 81.5 percent. On the whole, the most economically efficient dairy farming system was found to be the rainfed large (RL-3) system while the rainfed marginal (RM-2) system was the least efficient system in the rainfed zone. The variation in mean

efficiency estimates was found to be more in the rainfed zone than the irrigated zone. The economic efficiency (EE) indices based on Cobb-Douglas frontier model of cost of milk production by buffalo were observed to be between 26 and 96 percent across sample farm households, with an overall average of 78.5 percent.

It may be inferred from average technical efficiency estimates of the respective dairy farming systems that there is a scope to increase milk production and returns across farm households without incurring any extra expenditure. The potential increase in milk production for SMU ranged from 4.6 percent in the irrigated landless systems (ILL-2) to 7.0 percent in irrigated marginal systems (IM-2). In case of buffalo, the potential of increasing milk productivity ranged from 4.2 to 8.0 percent while it was 0 to 10.7 in case of crossbred cow. However, in case of local cow, there was no potential to increase milk productivity through technical efficiency improvement, as all farms with local cows were found technically efficient. Similar studies were carried out by Srivastava (1995), and Chand (1998) using deterministic frontier model in commercial herds. Srivastava (1995) found that technological efficiency which included both technical efficiency and technological change factors contributed 44, 28, 11, 19 and 14 percent respectively on cow, buffalo, cow mix, buffalo mix and overall mix technology dairy farms and hence showed higher contribution to overall productivity. Chand (1998) observed that there existed a potential of 8, 9 and 7 percent increase in milk production and returns without incurring any extra expenditure in small, medium and large herd categories respectively.

The potential for improvement in milk productivity in case of SMU as compared to the least technically efficient farm households was much higher ranging from 14.4 to 24 percent. In case of buffaloes, it was still higher ranging from 0 to 28.6 percent while in case of crossbred cows it ranged from 0 to 27.8 percent.

The results of average economic efficiency for SMU indicated that there existed a potential of 4.5 to 21.1 percent reduction in milk production costs across farm households belonging to different dairy farming systems. In

case of buffalo milk production, the potential for reducing milk production costs ranged from 7.4 to 22.8 percent while in case of local cow milk production it ranged from 0 to 18.6 percent.

It can be inferred on the basis of least economic efficient farms in each of the dairy farming systems that the potential to lower cost of milk production per SMU ranged from 12.4 to 69.9 percent across various dairy farming systems. However, in case of buffalo milk production, the potential was still higher ranging from 16.3 to 72.9 percent, whereas, in case of local cow milk production, this potential ranged from 0 to 76.9 percent.

It may, therefore, be concluded that there existed a potential to improve the milk production and lower costs with the existing resources in the study area through proper resource allocation and their efficient utilization across the farm households in different dairy farming systems. It was further observed that there was a greater problem of economic efficiency than technical efficiency in the study area. Maximum potential for economic efficiency improvement was found in the irrigated landless dairy farming systems in the irrigated zone and in the rainfed marginal system in the rainfed zone.

The results of lexicographic goal programming model showed that in irrigated landless dairy farming system (ILL-2), the number of milch buffaloes increased from one to two units in the optimum plan. Crossbred cow did not enter the optimal farm plan and the per kg price of crossbred cow milk need to be increased from existing Rs.8.32 to 8.99 for the crossbred cow to enter the model. The net cash farm returns or profit increased from Rs.8387 to 8526. The leisure goal of 868 mandays per annum was not fully achieved at 718 mandays per annum. The goal of financial independence from informal debt was not fully met.

In irrigated marginal dairy farming system (IM-2), the number of milch buffaloes remained same at one unit and one crossbred cow was introduced in place of local cow into the optimal plan. The net farm returns or profit increased from Rs.9418 to 16130. The leisure goal of 449 mandays per

annum was fully achieved in the optimal plan. The goal of financial independence from informal debt was not fully met and finance interest costs of Rs.589 was to be paid annually.

The optimal plans in irrigated small dairy farming system (IS-3) showed reduction in number of milch buffaloes from 2 to 1 but number of crossbred cows remained the same at one in the lexicographic goal programming model. Local cow enterprise did not enter the model and the plan envisaged an increase in local cow milk prices from existing Rs.8.39 to Rs.10.09 per kg to allow local cow activities to enter the model. The model showed increase of sugarcane area from existing 1 ha to 1.33 hectares. Further, there was decrease in area under paddy from 0.9 ha to 0.49 ha and wheat from 0.9 ha to 0.67 ha. Cultivation of green fodder crops for sale was found to significantly enhance farm income in the optimum farm plans of irrigated small, and rainfed marginal and small dairy farming systems. This could signify the commercialization of cultivation of green fodder crops in the newly emerging dairy farming systems.

There was a reduction in number of milch buffaloes from 3 to 2 in the optimal plan of irrigated large dairy farming system (IL-4). However, one crossbred cow entered the model. Local cow did not enter any of the models and the price of local cow milk need to be increased from existing Rs.8.37 per kg to Rs.9.92 per kg or the equivalent local cow milk productivity needs to be increased or cost decreased in order to allow the local cow to enter the model. The model showed increase in area under paddy and wheat from existing 2.96 ha to 4.08 ha each respectively for both the crops but area under sugarcane decreased from 4.07 to 3 ha. The net farm returns or profit marginally increased from Rs.305993 to Rs.309440. The leisure goal of 1379 mandays was fully achieved. The goal of financial independence from informal debt was also fully met.

In rainfed landless dairy farming system (RLL-2), the number of milch buffaloes units remained same at 2 units but crossbred cow was introduced into the model at 1 unit, thus increasing the number of milch units to 3 in optimal model. Local cow did not enter the optimal plan and its entry

envisaged an increase in its milk prices from existing Rs.8.21 to Rs.10.02 per kg or equivalent increase in productivity or decrease in cost of local cow milk production. The net farm returns increased from Rs.5911 to Rs.6258. The leisure goal of 643 mandays per annum was not fully achieved as only 182 mandays of leisure was available for the family under the condition that the farmer repays the principal amount of animal purchase with interest and also leads a minimum standard life. The goal of financial independence from informal debt was not fully met and informal credit interest of Rs.2182 per annum was required to be paid.

In the case of the rainfed marginal dairy farming system (RM-2), the number of milch buffaloes and local cows remained same at one unit but one crossbred cow was introduced into the model, thus increasing the number of milch animals to 4 in the optimal plan. The cash farm income decreased marginally from Rs.6096 to Rs.6084. The leisure goal of 470 mandays per annum was not fully achieved. The goal of financial independence from informal debt was fully met. The significance of non-farm employment varying from 134 to 286 mandays for satisfying the farm household goals in the landless and marginal dairy farming systems of both the zones was found in the optimal farm plans. Similar results were found by Saini (1982) in his work on marginal and small farms in Uttar Pradesh.

The number of milch buffaloes increased from 2 to 5 units in the rainfed small dairy farming system (RS-3), and there was an introduction of one crossbred cow along with the existing local cow, raising the total number of milch animals in the optimal plan to 7. The model showed elimination of cotton, mustard and urad crops from the plan and there was an increase in area under gram, wheat and fodder crops such as berseem, jowar and maize from 0.32, 1.07, 0.05, 0.05, 0.04 to 1.83, 1.83, and 0.29, 0.25, 0.29 ha respectively. However, there was a decline in the area under bajra crop from 1.28 ha to 0.074 ha. The net cash farm returns increased from Rs.44092 to Rs.80972 in the optimal plan. The leisure goal of 604 mandays was not fully achieved in lexicographic model but was lower at 222 mandays. The goal of financial independence from informal debt was also fully met. Of all the

systems, maximum change in optimum farm plan in cash farm income relative to the existing income was found in this system. The simulation of the farm plan with frontier yield of milk production also showed maximum change in cash farm income relative to optimal farm plan in this system. This signified the high sensitivity to strategies like change in resource allocation or improving technical efficiency of milk production in increasing cash farm income by the rainfed small dairy farming system.

In the rainfed large dairy farming system (RL-3), the number of crossbred cows increased from one to 5 units in the models, while the number of buffaloes reduced from 3 to one and no local cow entered in the optimum farm plan. The model showed increase in wheat, gram and mustard crops from existing 3.57 ha, 1.07 ha and 1.43 ha to 3.6 ha, 3.6 ha and 3.15 ha respectively but area under bajra and cotton reduced from 4.28 and 0.14 to 4.16 and 0 ha respectively. The plan also eliminated jowar from the model but increased area under berseem and maize from 0.18 and 0.14 ha to 0.39 and 0.26 ha. The net farm returns or profit increased from Rs.142759 to Rs.227840. The leisure goal of 656 mandays was achieved at a lower level of 326 mandays. The goal of financial independence from informal debt was fully met.

The simulation of the farm plan models to increase in milk prices and feed prices by 5-10 percent revealed that, increasing the milk prices was a good strategy for the irrigated landless, rainfed landless and rainfed marginal dairy farming systems but not so for the irrigated marginal dairy farming systems and the small and large systems in both the zones. Similarly the sensitivity to feed price increase was found to be higher in the irrigated marginal system.

Thus, it may be concluded from the above discussion that the farm plan developed based on multiple conflicting goals enabled to come up with the possibility of solutions that satisfied prioritized goals to the maximum possible extent for all the identified dairy farming systems. Different simulations carried out using frontier milk yield and increase in milk and feed prices, enabled to identify optimal strategies to maximize cash farm income.

RECOMMENDATIONS

Based on the results and discussion, the following recommendations are made:

- The cluster analysis technique can be used to categorize farm households into different dairy farming systems based on number of milch animals and their composition as well as size of operational land holdings. This could possibly be one of the best classification strategies at the household level for evaluation and target oriented need based research. Based on the above criteria and by using hierarchical complete linkage method of cluster analysis, the present study could identify eight buffalo based dairy farming systems with 4 each from the two agro-climatic zones, viz., irrigated and rainfed. The technical efficiencies of buffalo milk production across farm households were observed to be relatively higher as compared to other milch species thereby suggesting the importance of buffaloes for dairy farming in Haryana.
- The farm income analysis indicated the importance of dairying in the landless and marginal dairy farming systems in both irrigated and rainfed zones of Haryana. The irrigated landless dairy farming systems had the lowest cash costs of buffalo milk production and Dairying contributed a significant share of income and employment in these systems, being adopted by majority of the farm households. Therefore, attention should be focused to these dairy farming systems in order to further increase income and employment generation.
- There is a scope to enhance milk productivity of buffalo up to 8.0 percent and that of crossbred cow up to 10.7 percent across dairy farming systems using the existing resources as shown by technical efficiency estimates. This could possibly have significant implications on the sustainability of dairy development programme as is evident from the significant increase in cash farm income in the simulated farm

plan models of the landless and marginal systems using frontier milk yield of the respective dairy farming systems over the optimal plans using observed milk yield.

- There is a potential to reduce the cost of milk production up to 22.8 percent in the case of buffaloes and up to 18.6 percent in the case of local cows in the study area as shown by economic efficiency estimates. Therefore, suitable strategies to improve resource use and its allocation will make dairying more economical and sustainable particularly among landless and marginal dairy farming systems of Haryana. Besides, the average net returns per milch animal by all species was negative across all the dairy farming systems except the irrigated small dairy farming system for buffalo and rainfed large dairy farming system for crossbred cow. Therefore, improvement in economic efficiency without any extra input through efficient utilization and reallocation of existing resources can bring about improvement in the net farm income to dairy farming in Haryana.
- The use of stochastic frontier analysis enabled the ranking of the farm households based on efficiency of milk production thereby identifying the most efficient and the most inefficient farms across various dairy farming systems in the region. The potential increase in milk productivity of the least efficient farms ranged from 12.4 to 28.6 percent in buffaloes; and 0 to 27.8 percent in crossbred cows across the identified dairy farming systems in the study area. Similarly, the scope for reduction in cost of milk production ranged from 16.3 to 50.5 percent in the case of buffalo and 0 to 76.9 percent in the case of local cow. Thus suitable interventions targeting these farms need to be made to bring about significant increase in farm income for these households in both the zones. The most efficient farms identified within each of the dairy farming systems can serve as model farm for improving efficiency of milk production in the study area.

- The multi-objective optimal farm plan results revealed that replacing the local cows with crossbred cows can possibly be a better strategy for the landless and large dairy farming systems in the rainfed zone and marginal system in the irrigated zone respectively whereas increasing the number of buffaloes will be a better strategy in the case of the rainfed marginal and small dairy farming systems. Promoting local cow will necessitate reducing its cost of milk production by improving its productivity with the existing resources. On the whole, the increase in number of milch animals could be the best possible strategy for increasing farm income and employment in the rainfed zone at the cost of less leisure for better quality of life.
- The optimal plans developed using multiple goals programming technique also revealed the dependency of landless and marginal dairy farming systems on non-farm employment and external financial support even though it had top priority of the four goals to be achieved. Hence, suitable mechanism to ensure non-farm employment and provide timely minimum credit support to the farm households belonging to especially the landless dairy farming systems to meet their farm and non-farm consumption expenses may improve both the farm income and employment and thus promote dairying in the Haryana State.
- The use of multiple lexicographic goal programming technique indicated that more leisure for better social life and living standards and financial self dependence goal priorities could be the possible reasons for not increasing the number of milch animals in the optimal plan for the irrigated small and large dairy farming systems. However, it was found that these systems needs to focus more on crop enterprises namely sugarcane and cereals respectively. The irrigated and rainfed small dairy farming systems need to give more emphasis on sale of cultivated green fodder crops, so as to increase their farm income. Promoting dairying in these systems could involve commercialization of dairy farming ensuring that their multiple goals and relative preferences of minimum leisure and financial self dependence goals are met.

- The evaluation of simulated plans showed highest differential response to 5 and 10 percent increase in milk and feed prices for landless and marginal dairy farming systems. Therefore, suitable incentives to promote dairying need to be given to the landless and marginal systems in both the zones. One of the most sustainable options may be to provide equivalent incentives to increase efficiency of milk production so as to achieve frontier yield in the respective systems as simulated plans with frontier milk yield showed significant increase in cash farm income over the optimal plans using existing milk yield.

Thus, it may be concluded that a systems framework of classifying farm households into dairy farming systems for target oriented, need based research and interventions will bring about efficient and sustainable improvement in income and employment through dairying in Haryana. There is a potential to improve dairy farming and make it more economically sustainable using existing resources through efficiency improvement. Strategies of promoting crossbred cow and buffaloes in the rainfed zone and in the landless and marginal systems in the irrigated zone will improve farm income. Suitable credit policies and incentives are needed for landless and marginal systems for sustainable dairy development in Haryana state.

SUGGESTIONS FOR FUTURE LINE OF WORK

Suggestions for future research emerge mainly from the limitations of the study and recommendations of the study:

1. Efforts to harmonize data collection by statistical agencies on aspects to identify dairy farming systems using more variables at household, regional and national level need to be initiated. Efforts to collect such information through agricultural census and socio-economic surveys and database design and development needs to be explored for identification of dairy farming systems for better policy and decision-making. The aspect of improving the reliability of data collection methods is required.

2. Optimization of economic profitability for the dairy farming systems requires suggesting to farmers the optimal proportion of wet and dry animals in the herd at different points of time in the year. However, it requires development of a strategy of data collection at more frequent intervals like weekly or monthly of the identified sampled households representing the systems.
3. Efforts to identify factors determining risk in dairy farming needs to be identified and database developed for assessment
4. Further research on identifying the factors affecting efficiency of dairy farming systems needs to be carried out.
5. The ecological sustainability dimensions needs to be explored for dairy farming through estimation of environmental efficiency in a multiple output framework for dynamic effects.
6. The focus of this study was based on positive conditions of farm households but the importance of frontier technologies and their role in improving competitiveness of milk production cannot be ignored and needs to be explored through further extrapolation of this study in areas of productivity measurement due to technical change, technological change and impact of frontier technologies.
7. Identifying means to quantify the preferences of farmers in keeping livestock to meet their social and other non commercial needs in determining the efficient farm plans of the dairy farming systems needs more research in this direction.
8. Efforts to harmonize the regional goals and constraints of various developmental agencies (at local / district level) needs to be incorporated into the micro-level multiple goal programming model so as to mirror the sustainable regional plans for the area in dairy development.

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Annexures

ANNEXURE-I**AVERAGE MONTHLY NORMAL RAINFALL ACROSS SELECTED DISTRICTS IN
HARYANA FOR 1999**

(In mm)

Month	Yamunanagar		Bhiwani		Gurgaon	
	Rainfall	Percent	Rainfall	Percent	Rainfall	Percent
January	82.0	10.6	19.6	8.9	17.4	3.9
February	1.5	0.2	0.4	0.2	0.0	0.0
March	0.0	0.0	4.4	2.0	8.4	1.9
April	0.0	0.0	0	0.0	0.0	0.0
May	12.0	1.6	13.8	6.3	6.0	1.4
June	50.0	6.5	7.8	3.6	75.1	17.0
July	269.0	34.9	64	29.2	97.9	22.1
August	210.5	27.3	93.4	42.6	76.1	17.2
September	142.0	18.4	15.8	7.2	132.1	29.8
October	0.0	0.0	0	0.0	29.6	6.7
November	0.0	0.0	0	0.0	0.0	0.0
December	4.0	0.5	0	0.0	0.0	0.0
Total	771.0	100.0	219.2	100.0	442.6	100.0

Source: Statistical Abstract of Haryana, 2000-01

ANNEXURE-II

NUMBER AND AREA OF OPERATIONAL HOLDINGS BY SIZE GROUPS IN SELECTED DISTRICTS OF HARYANA FOR 1995-96

Land size categories	Yamunanagar		Bhiwani		Gurgaon		Haryana	
	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)	No.	Area (ha)
<0.5	18482 (28.3)	6048 (4.7)	28183 (19.6)	9228 (2.2)	38941 (31.1)	11143 (5.9)	479463 (27.7)	149380 (4.1)
0.5-1.0	13101 (20.0)	10469 (8.1)	21963 (15.3)	16029 (3.9)	29827 (23.8)	21673 (11.6)	335196 (19.4)	254775 (6.9)
1.0-2.0	13143 (20.1)	20439 (15.7)	32163 (22.4)	38398 (9.2)	27061 (21.6)	39726 (21.2)	338446 (19.6)	473042 (12.9)
2.0-3.0	8031 (12.3)	19836 (15.3)	17297 (12.0)	41373 (10.0)	12488 (10.0)	28535 (15.2)	196526 (11.4)	468492 (12.7)
3.0-4.0	4720 (7.2)	16362 (12.6)	12462 (8.7)	43035 (10.4)	6346 (5.1)	20622 (11.0)	131941 (7.6)	447061 (12.2)
4.0-5.0	2909 (4.5)	12564 (9.7)	8082 (5.6)	35622 (8.6)	3691 (2.9)	15633 (8.3)	83478 (4.8)	375067 (10.2)
5.0-7.5	2775 (4.2)	17170 (13.2)	10155 (7.1)	62172 (15.0)	4374 (3.5)	23428 (12.5)	81411 (4.7)	497488 (13.5)
7.5-10.0	1185 (1.8)	10368 (8.0)	5650 (3.9)	47523 (11.4)	1747 (1.4)	13788 (7.4)	41469 (2.4)	349876 (9.5)
10.0-20.0	866 (1.3)	10980 (8.4)	6338 (4.4)	81187 (19.5)	479 (0.4)	5776 (3.1)	32435 (1.9)	431635 (11.7)
>20.0	155 (0.2)	5739 (4.4)	1540 (1.1)	41084 (9.9)	243 (0.2)	6997 (3.7)	7628 (0.4)	228911 (6.2)
Total	65367 (100.0)	130002 (100.0)	143833 (100.0)	415651 (100.0)	125197 (100.0)	187321 (100.0)	1727993 (100.0)	3675727 (100.0)
Average size		1.99		2.89		1.50		2.13

ANNEXURE-III

TOTAL PRODUCTION OF FOOD GROUP ITEMS IN HARYANA FOR 1999-2000

(In '000 tons)

Food group	Yamunanagar	Bhiwani	Gurgaon	Haryana
Cereals	428	649	581	12987
Pulses	1.8	23.6	5.4	78
Foodgrains	429.8	672.6	586.4	13065
Oilseeds	3	128	61.2	605

ANNEXURE-IV

**AREA UNDER IMPORTANT CROPS IN SELECTED DISTRICTS OF HARYANA
FOR 1999-2000**

Crops	Yamunanagar		Bhiwani		Gurgaon		Haryana	
	Area ¹	Yield (qtl.)	Area	Yield (qtl.)	Area	Yield (qtl.)	Area	Yield (qtl.)
Rice	54.8 (28.4)	29.02	7.3 (1.2)	23.9	9.5 (3.2)	23.9	1083.1 (18.0)	23.9
Wheat	63.3 (32.8)	41.5	140.4 (22.6)	33.2	129.6 (43.5)	37.4	2316.5 (38.4)	41.7
Bajra	1.2 (0.6)	9.9	196.4 (31.6)	7.8	59.1 (19.8)	11.0	586.7 (9.7)	9.9
Jowar	--	--	3.4 (0.5)	3.3	18.7 (6.3)	15.8	111.8 (1.9)	2.0
Total cereals	121.6 (63.0)		352.1 (56.7)		219.2 (73.6)		4153.0 (68.9)	
Gram	0.2 (0.1)	--	47.2 (7.6)	4.9	4.7 (1.6)	8.7	100.4 (1.7)	5.8
Massar	2.3 (1.2)	7.5	--	--	1.9 (0.6)	4.1	8.7 (0.1)	9.3
Total pulses	2.8 (1.5)		50 (8.1)		8 (2.7)		136.6 (2.3)	
Rapeseed and mustard	1.5 (0.8)	9.4	108.8 (17.5)	11.7	43.5 (14.6)	14.3	449.8 (7.5)	13.2
Total oilseeds	2.3 (1.2)		462.6 (74.5)		45.0 (15.1)		462.6 (7.7)	
Sugarcane	40.9 (21.2)	56.0	0.8 (0.1)	48.0	0.3 (0.1)	-	136.7 (2.3)	55.8
Cotton	--	--	50.5 (8.1)	4.09	0.2 (0.1)	-	543.7 (9.0)	4.08
Gross cropped area	193.0 (100.0)		621.0 (100.0)		298.0 (100.0)		6029.0 (100.0)	

¹ Area in '000 ha and yield in quintals / ha
source: Statistical Abstract of Haryana, 2000-01

**ESTIMATED MILK PRODUCTION AND PER CAPITA PER DAY MILK
AVAILABILITY IN HARYANA FOR 1990-2001**

Year	Estimated production of milk (in lakh tones)	Per capita availability per day (in grams)
1990-91	34.19	571
1991-92	35.65	579
1992-93	37.15	601
1993-94	38.5	602
1994-95	40.62	620
1995-96	40.56	602
1996-97	42.04	611
1997-98	43.73	621
1998-99	45.27	626
1999-00	46.79	631
2000-01	48.45	637

Source: Statistcal Abstract of Haryana, 2000-01

ANNEXURE-VI**LIVESTOCK POPULATION ACROSS SELECTED DISTRICTS IN
HARYANA FOR 1997**

(In hundreds)

Species	Yamunanagar	Bhiwani	Gurgaon	Haryana
Cattle	1116 (26.9)	995 (13.1)	1283 (19.4)	23998 (21.7)
Buffaloes	1636 (39.5)	3510 (46.1)	2065 (31.2)	48224 (43.7)
Horses and ponies	26 (0.6)	9 (0.1)	23 (0.3)	491 (0.4)
Donkeys	11 (0.3)	48 (0.6)	52 (0.8)	634 (0.6)
Mules	16 (0.4)	23 (0.3)	15 (0.2)	345 (0.3)
Sheep	305 (7.4)	1120 (14.7)	1145 (17.3)	12933 (11.7)
Goats	310 (7.5)	1029 (13.5)	1290 (19.5)	7972 (7.2)
Camels	--	225 (3.0)	16 (0.2)	962 (0.9)
Pigs	468 (11.3)	197 (2.6)	385 (5.8)	6751 (6.1)
Dogs	258 (6.2)	462 (6.1)	341 (5.2)	8105 (7.3)
Total	4146 (100.0)	7618 (100.0)	6615 (100.0)	110415 (100.0)
Poultry	6765	3151	9286	92229

Source: Statistical Abstract of Haryana, 2000-01

Annexure-VII

DISTRIBUTION OF BOVINE POPULATION ACROSS SELECTED DISTRICTS OF HARYANA IN 1997

(In hundreds)

Sl. No.	Particulars	Yamunanagar			Bhiwani			Gurgaon			Haryana		
		Cattle		Buffalo	Cattle		Buffalo	Cattle		Buffalo	Cattle		Buffalo
		LC	CB	B	LC	CB	B	LC	CB	B	LC	CB	B
1.	Male over three years (2½ years)*												
a)	Used for breeding only	4	39	10	9	-	9	13	25	14	343	383	406
b)	Used for work only	90	23	86	104	-	-	28	21	16	2863	571	1873
c)	Used for breeding and work	10	31	91	-	-	1	17	23	15	281	293	874
d)	Not in use for breeding or work	9	15	-	2	-	-	9	8	8	205	188	318
	Total	113	108	187	115	0	10	67	77	53	3692	1435	3471
2.	Female over three years (2½ years)*												
a)	In milk	116	163	606	266	27	1256	179	78	724	3057	1668	14991
b)	Dry	32	51	153	90	8	359	87	40	118	1246	925	5281
c)	Not yet calved	15	20	51	23	3	147	61	59	175	634	685	2774
d)	Others	11	25	4	2	-	1	12	33	9	147	279	180
	Total	174	259	814	381	38	1763	339	210	1026	5084	3557	23226
3.	Young stock 1 to 3 (1 to 2½ years)*												
a)	Male	56	52	114	50	2	89	75	28	169	1330	655	1977
b)	Female	67	57	168	117	4	605	129	55	298	1940	1031	7464
	Total	123	109	282	167	6	694	204	83	467	3270	1686	9441
4.	Young stock under 1 year												
a)	Male	103**		168	120		385	120		250	2558		5203
b)	Female	127		185	168		658	183		269	2716		6883
	Total	230		353	288		1043	303		519	5274		12086
	Grand Total	640	476	1636	951	44	3510	913	370	2065	17320	6678	48224

* Age in brackets is applicable for crossbred cattle only; ** includes crossbred calves below one year.

Source : Statistical Abstract of Haryana 2000-01.

ANNEXURE-VIII**CLASSIFICATION OF SAMPLE HOUSEHOLDS BASED ON LANDHOLDINGS IN
THE SELECTED VILLAGES OF STUDY AREA**

Village (District)	Number of households					Dominant caste
	Landless	Marginal	Small	Large	Total	
Bendi (Yamunanagar)	119 (58.5)	32 (15.8)	32 (15.8)	20 (9.9)	203 (100.0)	S.C., Jat
Antawa (Yamunanagar)	94 (59.5)	17 (10.8)	32 (20.2)	15 (9.5)	158 (100.0)	Rajput, S.C.
Mehra (Bhiwani)	145 (41.4)	75 (21.4)	90 (25.7)	40 (11.4)	350 (100.0)	Jat, S.C.
Dokhaharia (Bhiwani)	94 (19.9)	88 (18.6)	255 (54.0)	35 (7.4)	472 (100.0)	Jat, S.C.
Alipur (Gurgaon)	109 (32.1)	149 (43.8)	78 (22.9)	4 (1.2)	340 (100.0)	Jat, S.C.
Berka (Gurgaon)	60 (33.7)	64 (36.0)	48 (27.0)	6 (3.4)	178 (100.0)	Gujar, S.C.

Figure in parenthesis represent percentage of total households

ANNEXURE-IX**SOURCE OF IRRIGATION ACROSS SELECTED DISTRICTS IN
HARYANA FOR 2000-2001**

(In '000 hectares)

Source of irrigation	Yamunanagar	Bhiwani	Gurgaon	Haryana
Govt. Canals	3 (2.8)	135 (61.4)	16 (20.0)	1476 (49.9)
Wells / tubewells	106 (97.2)	85 (38.6)	64 (80.0)	1467 (49.6)
Others	0 (0.0)	0 (0.0)	0 (0.0)	14 (0.5)
Total (NAI)	109 (100.0)	220 (100.0)	80 (100.0)	2958 (100.0)
Gross area irrigated (GAI)	171	377	192	5223
GAI / TCA * 100 percent	89.5	55	64	85.4
Irrigation intensity (GAI / NAI * 100)	156.9	171.4	240	176.6
Tubewells and pumping sets (number)**	26619	28955	31850	595524

*NAI : Net Area Irrigated

**For 2001-02 (P)

Figures in parenthesis represent percentage to net area irrigated

FARM LEVEL MODEL SYNTAX OF LEXICOGRAPHIC GOAL PROGRAMMING MODEL

\$title Agreste Farm Level Model of Haryana, India (DFSHARYANA)

\$stitle set definitions

* This is a farm level Lexicographic goal programming model of the north east of Haryana (Yamunanagar district) of irrigated large buffalo based dairy farming systems in GAMS

* There are 3 types of land and risk on revenue is considered.

set GOALS GOALS IN THE ORDER THEY ARE TO BE MET

/RISK,FINANCE, LEISURE, MPROFIT /

c crops /

paddy	paddy
sugarcane	sugarcane
mustard	mustard
urad	urad
wheat	wheat

/

f fcrops /

berseem	berseem
jowar	jowar
maize	maize
wheatstraw	wheatstraw
paddystraw	paddystraw
sugarcane tops	sugarcane tops

/

m dairy /

buffalo	buffalo
crossbred	crossbred
indigineous	indigineous/

tm months /jan, feb, mar, apr, may, jun, jul, aug, sep, oct, nov, dec /

p cropping activities /

crop-02	paddy
crop-05	sugarcane
crop-10	mustard
crop-12	urad
crop-15	wheat

/

q fodder activities /

crop-03	berseem
crop-04	jowar
crop-05	maize
crop-15	wheatstraw
crop-17	paddystraw
crop-18	sugarcane tops

/

d dairy activities /

dairy-01	buffalo
dairy-05	crossbred
dairy-10	indigineous /

s land types /good irrigated and fertile /

sc(s) crop lands /good /

r livestock feeding alternatives /rec-1/

ty year / 1990 * 1999/

dr family consumption bundle alternatives /one/

km technology characteristics /

equipment, fertilizer, seeds, pesticides, fuel /

qs(q,s) fprocess-land possibilities

ps(p,s) process-land possibilities

tr transfer cash /jan-feb, feb-mar, mar-apr, apr-may, may-jun, jun-jly, jly-aug, aug-sep, sep-oct, oct-nov,

nov-dec, dec-jan /

nfi non farm income / nf /

alias (s,sp);

ALIAS(GOALS,GOAL) ;

parameter

creditinf(tm) informal credit rates /jan .13 , feb .01, mar .08, apr .05, may .03, jun .3, jul .18, aug .15, sep .12, oct .08, nov .10, dec .12 /

TARGET(GOALS) GOAL TARGET LEVELS

/MPROFIT 435708.43, LEISURE 1379.4, RISK 335993, FINANCE 0/

DEV(GOALS) MAXIMUM DEVIATION BY GOAL

WEIGHTS(GOALS) WEIGHTS BY GOAL

landc(s) land data (ha) / good = 7.08/

xdairy1(d,r) limits on dairy activities ;

xdairy1("dairy-01","rec-1") = 0 ;

xdairy1("dairy-05","rec-1") = 0 ;

xdairy1("dairy-10","rec-1") = 0;

DEV(GOALS)= 999999;

WEIGHTS(GOALS)= 0.00001;

table aration(d,r)

rec-1

dairy-01 14303.82

dairy-05 10547.53

dairy-10 5078.15

table vcost(d,r)

rec-1

dairy-01 151.98

dairy-05 191.98

dairy-10 100

table ocost(d,r)

rec-1

dairy-01 407

dairy-05 487

dairy-10 250

table landreq(p,tm) month of land occupation by crop (hectares)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
crop-02					1	1	1	.5				
crop-05	1				1	1	1	1	1	1	1	
crop-10	1	1									1	
crop-12						1	1	1				
crop-15	1	1	1	.5							1	

table flandreq(q,tm) month of land occupation by fodder crop (hectares)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
crop-03	1	1							1	1		
crop-04					1	1	1	1				
crop-05				1	1	1						

table lio(d,s,f) feed requirements for lvsstk feed alternatives (qnt per head)

	berseem	maize	jowar	wheat	straw	paddy	straw	sugarcane	tops
dairy-01.good	27.231	15.28	30.838	17.803	0	7.784			
dairy-05.good	30.891	15.95	30.735	19.189	0	12.485			
dairy-10.good	23.273	18.225	30.724	17.124	0	11.885			

table labor(p,tm) labor requirements for cropping (mandays per ha)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
crop-02				4	7	3	3	5				
crop-05	9			5	3	2	4	2	3	2	2	
crop-10	5.78	3.37	10.03								5.05	
crop-12						4	4	5				
crop-15	5	4	7	9						4		

table flabor(q,tm) labor requirements for cropping (mandays per ha)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
crop-03	18	18								5	8	
crop-04					5	5	12	15				
crop-05				5	5	12						

table llab(d,tm,r) labor requirement for lvstk feed (mandays per head)

rec-1

dairy-01.jan	7.375
dairy-01.feb	7.375
dairy-01.mar	7.375
dairy-01.apr	7.375
dairy-01.may	7.375
dairy-01.jun	7.375
dairy-01.jul	7.375
dairy-01.aug	7.375
dairy-01.sep	7.375
dairy-01.oct	7.375
dairy-01.nov	7.375
dairy-01.dec	7.375
dairy-05.jan	9.588
dairy-05.feb	9.588
dairy-05.mar	9.588
dairy-05.apr	9.588
dairy-05.may	9.588
dairy-05.jun	9.588
dairy-05.jul	9.588
dairy-05.aug	9.588
dairy-05.sep	9.588
dairy-05.oct	9.588
dairy-05.nov	9.588
dairy-05.dec	9.588
dairy-10.jan	7.542
dairy-10.feb	7.542
dairy-10.mar	7.542
dairy-10.apr	7.542
dairy-10.may	7.542
dairy-10.jun	7.542
dairy-10.jul	7.542
dairy-10.aug	7.542
dairy-10.sep	7.542
dairy-10.oct	7.542
dairy-10.nov	7.542
dairy-10.dec	7.542

table yield(p,c,s) crop yields (quintals per ha)
good

crop-02.paddy	83.38
crop-05.sugarcane	877.9
crop-10.mustard	17
crop-12.urad	15.584
crop-15.wheat	53.19

table fyield(q,f,s) fcrop yields (quintals per ha)
good

crop-03.berseem	720
crop-04.jowar	525
crop-05.maize	500
crop-15.wheatstraw	75.4
crop-17.paddystraw	108.4
crop-18.sugarcane tops	177.95

table yieldd(d,m,r) milk yield (litres per head)
rec-1

dairy-01.buffalo	1137
dairy-05.crossbred	1354
dairy-10.indigineous	1335

```

;
ps(p,s) = yes$sum(c, yield(p,c,s));
qs(q,s) = yes$sum(f, fyield(q,f,s));

ravg(c) = sum(ty, crev(c,ty))/card(ty);
prdev(c,ty)$ravg(c) = price(c)*(crev(c,ty)/ravg(c) - 1);
phi = 0.7;
display ravg,prdev;

```

table techc(p,km) cropping technology requirements (cr per ha)

	equipment	fertilizer	seeds	pesticides	fuel
crop-02	2811.1	12493.75	1874	4585	9370
crop-05	3015	13399	2010	5025	10049
crop-10	1170	3901	780	550	5501
crop-12	1558	5550	1112	927	9257
crop-15	1243	5525	829	2072	4144

table techf(q,km) fcropping technology requirements (cr per ha)

	equipment	fertilizer	seeds	pesticides	fuel
crop-03	2497	11098	1555	4152	8323
crop-04	2248	9989	1498	3745	7492
crop-05	2027	9008	1351	3378	5755
crop-15	250.57	1158.55	173.78	434.45	858.91
crop-17	82.81	358.03	55.20	138.01	275.02
crop-18	33.01	145.72	22.01	55.02	110.04

table wc(p,tm) working capital requirements crop (cr per ha)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
crop-02					5247	5247	5247	5247	5247			
crop-05		3448		3350	3350	3350	3350	3350	3350	3350	3350	3350
crop-10		3251	3251							3251	3251	
crop-12						5178	5178	5178				
crop-15		2753	2753	2753	2753						2753	

table wf(q,tm) working capital requirements crop (cr per ha)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
crop-03		5935	5935							5935	5935	
crop-04					5243	5243	5243	5243				
crop-05				7505	7505	7505						
crop-15		579	579	579	579						579	
crop-17				184	184	184	184	184				
crop-18		357										

table wcd(d,tm) working capital requirements dairy (cr per ha)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
dairy-01	1192	1192	1192	1192	1192	1192	1192	1192	1192	1192	1192	1192
dairy-05	887	887	887	887	887	887	887	887	887	887	887	887
dairy-10	507	507	507	507	507	507	507	507	507	507	507	507 ;

table wccc(c,tm) cash flow from crop (cr)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
paddy							1					
sugarcane		1										
mustard		1										
urad												
wheat			1									

table wccf(f,tm) cash flow from fcrop (cr)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
berseem		.5	.5									
jowar							.5	.5				
maize				.5	.5							
wheatstraw				1								
paddystraw								1				
sugarcane tops		1										

table wccd(m,tm) cash flow from dairy (cr)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
buffalo	.17	.17	.17						.17	.17	.17	
crossbred			.13	.13	.10	.12	.13	.13	.13	.13		
indigineous	.10	.10	.10	.8	.5	.8	.8	.8	.8	.8	.8	

table cbndl(c,dr) consumption bundles (tons per bundle)

one

paddy 4.55
wheat 9.40
sugarcane .000

table dbndl(m,dr) consumption bundles (litres per choice)

one

buffalo 1545
crossbred 450
indigineous 0

table crev(c,ty) crop revenue time series (cr per ha)

	1990	1991	1992	1993	1994	1995	1995	1997	1998	1999
paddy	2775	2750	2559	2730	2802	2225	2957	2700	2800	2250
sugarcane	5273	5200	4859	5758	5849	5515	5558	5700	5700	5812
mustard	1338	1320	1325	1300	1350	1355	1381	1300	1305	1320
wheat	3479	3420	3521	3519	3575	3880	3585	3520	3570	3875;

parameter price(c) crop reference prices (cr per kg) / paddy = 580 , wheat = 500 , mustard = 1300 , urad = 1500,

sugarcane = 110 /

fprice(f) crop reference prices (cr per kg) / berseem = 70, jowar = 55 , maize = 55, wheatstraw = 110, paddystraw = 20 ,sugarcane tops = 10 /

prices(m) milk reference prices (rs per kg) /buffalo = 11.45, crossbred = 8.39, indigineous = 8.37 /

nfjoba(tm) nonfarm job availability monthwise /jan = .5, feb = .5, mar = .7, apr = 1.5, may = 1.5, jun = 2, jul = 1.5, aug = .5, sep = .5, oct = .2, nov = .2, dec = .5 /

pricee(nfi) wage rate of non farm labour / nf = 80 /

hc(tm) household expenditure monthly /jan = 10000, feb = 10000, mar = 10000, apr = 10000, may = 10000, jun = 10500, jul = 10700, aug = 17500, sep = 10000, oct = 10000, nov = 12000, dec = 11500 /

avg(c) average crop revenues (cr per ha)

prdev(c,ty) price deviations for crops (cr per ton)

scalar fwage family reservation wage rate (cr per man-month) / 0 /

twage temporary labor wage rate (cr per man-month) / 2000 /

vsc value of self-consumption (cr per bundle) / 0 /

wcbar working capital (cr) / 400909.52 /

famlab family labor (man equivalent wrks) / 182.5 /

dpm man days per man month / 25 /

phi risk factor

infr max informal credit / 5000 /

nfjob non farm job maximum / 0 /

```

table ctrf(tr,tm) transfer cash within (cr)
      jan  feb  mar  apr  may  jun  jul  aug  sep  oct  nov  dec
jan-feb  -1    1
feb-mar   -1    1
mar-apr    -1    1
apr-may    -1    1
may-jun    -1    1
jun-jly    -1    1
jly-aug    -1    1
aug-sep    -1    1
sep-oct    -1    1
oct-nov    -1    1
nov-dec    -1    1
dec-jan    1

```

```

parameter pcost(p) cropping technology costs      (cr per ha)
      fcost(q) fodder technology costs
      a(p)   cropping constants
      b(q)   foddercrop constants;

```

```

pcost(p) = sum(km, techc(p,km)); display pcost;
fcost(q) =sum(km,techf(q,km)); display fcost;
a(p) = 1;
b(q) = 1;

```

```
display pcost,a;
```

```
$stitle model definition
```

```

variables xcrop(p,s) cropping activities      (ha)
      xfcrop(q,s) fodder cropping activities
      xliver(d,r) livestock activity defined on feed techniques (head)
      xlive      total livestock for milk production      (litres)
      fsales(f)  fodder crop sold or brought
      lswitch(s) land downgrading      (ha)
      xprod(c)   crop production      (quintals)
      xfprod(f)  fodder crop production      (quintals)
      mprod(m)   milk production      (litres)
      cons(dr)   on-farm consumption      (ton)
      sales(c)   crop sales      (ton)
      msales(m)  milk sales      (litres)
      flab(tm)   family labor      (man-days)
      tlab(tm)   temporary labor      (man-days)
      plab       permanent labor      (workers)
      rationr    livestock ration requirements      (Rs.)
      pdev(ty)   positive price deviations      (Rs.)
      ndev(ty)   negative price deviations      (Rs.)
      yfarm      farm income      (Rs.)
      revenue    from crop and livestock sales      (Rs.)
      cropcost   accounting: cropping activities cost      (Rs.)
      ccost      cost of credit      (Rs)
      labcost    accounting: labor costs - including family      (Rs.)
      vetcost    accounting: veterinary services cost      (Rs.)
      fxcost     other fixed costs in dairying
      xinfcrr(tm) informal credit defined monthwise      (Rs.)
      xtrnc(tr)  transfer cash monthly      (Rs.)
      savings(tm) savings per month      (Rs.)
      xnfinctm) non farm income in man hours per month      (man hours)
      xnfit      total non farm income in man days per year
      GOALOBJ    deviations from goal objective

```

positive variables xcrop,xfcrop, lswitch,sales,msales,cons,flab,tlab,plab,pdev,ndev,surplus,
 SHORTFALL(goal),
 EXCESS(goals), GOALLEVEL(GOALS),ccost, labcost, vetcost,xtrnc(tr),
 xinfor(tm),xnfinc(tm),lsurplus(tm), savings(tm);
 integer variables xlive(d,r), xlive ;

equations landb(s,tm) land balance

lbal livestock balance

ulimit limit on urad crop

sclimit limit on sugarcane crop

rliv livestock ration requirements definition

fsberseem sale limit of berseem

fsjowar sale of jowar crop

fsmaize sale of maize crop

mbalc(c) material balance: crops

mbald(m) dairy balance: dairy

cprod(c) crop production definition

dprod(m) milk production definition

cond on farm consumption definition

labc(tm) labor supply-demand relation

ddev(ty) crop price deviation definition

income farm income definition

arev accounting: revenue definition

acrop accounting: cropping cost definition

alab accounting: labor cost definition

awcc accounting: working capital requirements

avet accounting: veterinary costs (Rs.)

dfcost other costs in dairying

wcreq(tm) meeting working capital requirements monthly (Rs)

flabb(tm) family labour available per month

nfinc(tm) maximum non farm labour inmandays

tnfi total non farm labour in mandays per year

pcrop paddy-straw relation

wcrop wheat-straw relation

scrop sugarcane-tops relation

lclink(f) fcrop-livestock linkage

creditc cost of credit (Rs)

OBJT OBJECTIVE FUNCTION

PROFITGL MIN PROFIT GOAL

RISKGL MIN RISK GOAL

LEISUREGL MIN LEISURE GOAL

FINANCEGL MIN FINANCE GOAL

TARSGS(GOALS) GOAL TARGETS

MAXSHORT(GOALS) SHORTFALL LIMITS

landb(s,tm).. sum(p\$ps(p,s), a(p)*xcrop(p,s)*landreq(p,tm))\$sc(s) ; +sum(q\$qs(q,s),
 b(q)*xfcrop(q,s)*flandreq(q,tm))\$sc(s) != landc(s);

pcrop.. sum(s,xcrop("crop-02",s))=e= sum(s,xfcrop("crop-17",s)) ;

wcrop.. sum(s,xcrop("crop-15",s))=e= sum(s,xfcrop("crop-15",s));

scrop.. sum(s,xcrop("crop-05",s))=e= sum(s,xfcrop("crop-18",s));

fsberseem.. fsales("berseem") != 140;

fsjowar.. fsales("jowar") != 120;

fsmaize.. fsales("maize") != 90;

ulimit.. sum(s,xcrop("crop-12",s)) != 0.07;

sclimit.. sum(s,xcrop("crop-05",s)) != 3;

lclink(f).. sum(s,sum(d,sum(r,xliver(d,r)*lio(d,s,f)))) != sum(q,sum(s,xfcrop(q,s)*fyield(q,f,s)))-
 fsales(f);

lbal.. xlive =e= sum(d,sum(r, xliver(d,r)));

rliv.. rationr =e= sum((d,r), aration(d,r)*xliver(d,r));

```

mbalc(c)..      sum((s,p), yield(p,c,s)*xcrop(p,s)) =g= sales(c) + sum(dr, cbndl(c,dr)*cons(dr));
sum(s,sum(d,sum(r,xliver(d,r)*lio(d,s,f)))));
mbald(m)..      sum((d,r), yieldd(d,m,r)*xliver(d,r)) =g= msales(m) + sum(dr, dbndl(m,dr)*cons(dr));
cprod(c)..      xprod(c) =e= sum((p,s), yield(p,c,s)*xcrop(p,s));
dprod(m)..      mprod(m) =e= sum((d,r), yieldd(d,m,r)*xliver(d,r));
labc(tm)..      sum((p,s)$ps(p,s), labor(p,tm)*xcrop(p,s)) +sum((q,s)$qs(q,s),
flabor(q,tm)*xfcrop(q,s))+ sum((d,r), llab(d,tm,r)*xliver(d,r)) =l= flab(tm) + tlabor(tm) ;
flabb(tm)..      flab(tm) + lsurplus(tm) =e= famlab;
cond..          sum(dr, cons(dr)) =e= 1;
ddev(ty)..      sum(c, prdev(c,ty)*sales(c)) =e= pdev(ty) - ndev(ty);
arev..          revenue =e= sum(m,prices(m) * msales(m))+ sum(c,
price(c)*sales(c))+sum(f,fsales(f)*fprice(f));

acrop..          cropcost =e= sum((p,s)$ps(p,s), pcost(p)*xcrop(p,s))+ sum((q,s)$qs(q,s),
fcost(q)*xfcrop(q,s));

alab..          labcost =e= (fwage*sum(tm, flab(tm)) + twage*sum(tm, tlabor(tm)))/dpm ;
awcc..          cropcost + rationr + vetcost + twage/dpm*sum(tm, tlabor(tm)) =l= wccbar;
nfinc(tm)..      xnfinc(tm) =l= nfjob*nfjoba(tm);
tnfi..          xnfic =e= sum(tm,xnfinc(tm));
avet..          vetcost =e= sum(d,sum(r,vcost(d,r)*xliver(d,r)));
dfcost..         fxcost =e= sum(d, sum(r,ocost(d,r)*xliver(d,r)));
wcreq(tm)..      -sum((p,s),wc(p,tm)*xcrop(p,s))-sum((q,s),wf(q,tm)*xfcrop(q,s)) - sum((d,r),wcd(d,tm) *
xliver(d,r)) + sum(c,wccc(c,tm) * price(c) * xprod(c))+ sum(f,wccf(f,tm) * fprice(f) *
fsales(f)) +
sum(m, wccd(m,tm) * prices(m) * mprod(m)) + sum(tr,ctrf(tr,tm) * xtrnc(tr)) + xinfcr(tm)
+ sum(nfi, xnfinc(tm) * pricee(nfi)) - hc(tm)-savings(tm) =e= 0;
creditc.. ccost =e= sum(tm, (creditinf(tm)* xinfcr(tm)));
income..         yfarm =e= revenue + vsc*sum(dr, cons(dr)) - labcost - rationr - vetcost - fxcost -
cropcost - ccost;
PROFITGL.. yfarm =E= GOALLEVEL("MPROFIT");
RISKGL..         yfarm + phi*sum(ty, pdev(ty) + ndev(ty))/card(ty) =E= goallevel("RISK");
LEISUREGL..      sum(tm,(lsurplus(tm))) =E= GOALLEVEL("LEISURE");
FINANCEGL..      sum(tm, xinfcr(tm)) =E= GOALLEVEL("FINANCE");
TARGSGOALS)..    GOALLEVEL(GOALS)+SHORTFALL(GOALS)- SURPLUS(GOALS) =E=
TARGET(GOALS);
MAXSHORT(GOALS).. SHORTFALL(GOALS)=L= DEV(GOALS);
OBJT..           GOALOBJ =E= SUM(GOALS, WEIGHTS(GOALS)*SHORTFALL(GOALS));

model agreste farm level model / all /;
flab.up(tm) = famlab;
xinfcr.up(tm) = infcr;
PARAMETER GOALDATA(GOAL,*,*)
LOOP(GOAL,
WEIGHTS(GOAL)= 1.
SOLVE agreste USING MIP MINIMIZING GOALOBJ;
WEIGHTS(GOAL)=0.00001;
);

```

**OLS AND MLE ESTIMATES OF STOCHASTIC TRANSLOG FRONTIER MILK
PRODUCTION FUNCTION OF FARM HOUSEHOLDS IN HARYANA (2000-01)**

Variables	OLS Estimate	Standard Errors	MLE Estimates	Standard errors
Intercept	-13.662	15.063	-13.554**	0.990
Greenfodder index	2.303	4.118	1.183	1.096
Dryfodder index	-0.243	3.977	1.353	0.941
Concentrate index	0.617	3.154	3.481**	1.020
Hired labour	-0.242	2.515	-0.160	0.982
Familylabour	6.214**	1.811	4.153**	0.848
Depreciation	-1.252	1.921	0.706	0.978
Veterinary expenses	-0.889**	2.494	-0.776**	0.884
Miscellaneous costs	0.438*	1.964	0.522**	0.766
Gfindex * gfindex	-0.117	0.455	0.108	0.441
Dfindex * dfindex	0.166	0.422	0.111	0.237
Concindex * concindex	-0.076	0.219	-0.084	0.256
Hlabour * hlabour	-0.040	0.189	-0.103	0.477
Flabour * flabour	-0.092*	0.108	-0.126	0.080
Deprecn * deprecn	-0.046	0.131	-0.034	0.104
Veterinary * veterinary	-0.123	0.212	-0.019	0.193
Misc. * misc.	0.032	0.161	0.024	0.17
Gf index * df index	-0.027	0.559	-0.267	0.390
Gf index * conc. Index	0.167	0.560	-0.189	0.660
Gf index * hired labour	0.285	0.514	0.319*	0.300
Gfindex * familylabour	-0.020	0.244	0.326*	0.298
Gfindex * depreciation	-0.057	0.279	-0.194	0.284
Gfindex * veterinary expenses	-0.393**	0.336	-0.454*	0.430
Gfindex * misc. Expenses	0.348*	0.316	0.329	0.441
Df index * conc. Index	-0.149	0.504	0.040	0.399
Df index * hired labour	0.041	0.174	-0.025	0.109
Dfindex * familylabour	-0.220*	0.243	-0.232**	0.184
Dfindex * depreciation	0.193	0.364	0.004	0.245
Dfindex * veterinary expenses	0.648**	0.389	0.743**	0.331
Dfindex * misc. Expenses	-0.679**	0.364	-0.507**	0.352
Conc index * hired labour	-0.197*	0.230	-0.204*	0.242
Conindex * familylabour	-0.153	0.234	-0.362**	0.238
Concindex * depreciation	0.131	0.272	0.179	0.283
Concindex * vety expenses	0.293	0.371	0.459**	0.345
Concindex * misc. Expenses	-0.165	0.329	-0.226	0.376
Hlabour * familylabour	-0.077*	0.083	-0.089**	0.075
Hlabour * depreciation	0.039	0.179	0.127	0.466
Hlabour * veterinary expenses	0.042	0.079	0.009	0.085
Hlabour * misc. Expenses	-0.005	0.076	0.020	0.072
Flabour * depreciation	-0.128	0.194	-0.080	0.178
Flabour * veterinary expenses	0.139	0.219	0.150*	0.160
Flabour * misc. Expenses	0.018	0.163	0.067	0.155
Deprecn * veterinary expenses	0.146	0.310	0.108	0.239
Deprecn * misc. Expenses	0.019	0.259	0.047	0.193
Veterinary * misc. Expenses	-0.039	0.286	-0.168	0.311
Variance parameter				
$\sigma^2 = s^2v + s^2u$	0.050		0.113**	0.010
$\gamma = s^2u / s^2s$			0.999**	0.010
Lr test of the one-sided error			22.992	0.006
Log likelihood function	39.260		50.756	

ANNEXURE-XII

**FIRST ORDER DERIVATIVES OF VARIABLES OF TRANSLOG FRONTIER
PRODUCTION FUNCTION OF MILK PRODUCTION**

Variables	SMU	BUFFALO
Green fodder index	1.27	3.86
Dry fodder index	1.33	1.75
Concentrate index	3.01**	2.69
Hired labour	-0.21*	-0.73
Family labour	3.68**	0.90
Depreciation	0.83	0.33
Veterinary expenses	-0.37*	-0.27
Miscellaneous costs	0.33**	0.14

* Significant at 5 percent level; ** Significant at 1 percent level

ANNEXURE-XIII

LIST OF SAMPLE FARM HOUSEHOLDS WITH THEIR EFFICIENCIES OF MILK PRODUCTION USING TRANSLOG FRONTIER MILK PRODUCTION FUNCTION

Sl. No.	Farm.no.	Village	B	CB	LC	Land*	T.E.	E.E.
Irrigated landless dairy farming system (ILL-2)								
1	31	Bendi	2	0	0	0	97	93
2	21	Bendi	2	0	0	0	97	93
3	22	Bendi	1	1	1	0	97	95
4	23	Antawa	1	0	0	0	96	79
5	17	Bendi	1	0	1	0	96	91
6	1	Antawa	1	0	0	0	96	85
7	5	Antawa	1	0	0	0	96	77
8	30	Bendi	2	0	0	0	96	85
9	6	Antawa	2	0	0	0	95	84
10	28	Antawa	1	0	0	0	95	77
11	13	Bendi	1	0	0	0	95	77
12	27	Antawa	1	0	0	0	95	75
13	19	Bendi	1	0	1	0	95	89
14	14	Bendi	1	0	0	0	95	77
15	35	Antawa	1	0	1	0	94	89
16	29	Bendi	1	0	0	0	94	79
17	24	Antawa	2	0	0	0	94	92
18	10	Antawa	1	1	0	0	93	93
19	9	Antawa	1	1	2	0	93	90
20	20	Bendi	2	0	0	0	93	91
21	2	Antawa	2	0	0	0	93	78
22	7	Antawa	1	0	0	0	93	78
23	25	Antawa	1	0	0	0	93	76
24	18	Bendi	1	0	0	0	92	76
25	15	Bendi	2	0	1	0	92	93
26	4	Antawa	1	0	0	0	91	74
27	3	Antawa	2	0	0	0	91	78
28	32	Bendi	1	0	0	0	90	72
29	12	Antawa	1	1	0	0	89	77
30	26	Antawa	2	0	0	0	88	90
31	34	Bendi	1	1	0	0	88	79
32	16	Bendi	2	0	0	0	86	90
33	11	Antawa	1	1	0	0	84	79
34	8	Antawa	1	0	2	0	83	79
35	33	Bendi	1	1	0	0	83	78

Contd....

Contd....(Annexure-XIII)

Sl. No.	Farm.no.	Village	B	CB	LC	Land*	T.E.	E.E.
Irrigated marginal dairy farming system (IM-2)								
36	39	Bendi	1	0	0	0.8	94	92
37	36	Bendi	1	0	0	0.6	92	87
38	38	Antawa	1	0	0	0.5	92	90
39	44	Antawa	2	0	0	2.8	90	84
40	37	Antawa	3	0	0	0.8	89	89
41	41	Bendi	2	0	2	0.8	86	85
42	43	Bendi	3	1	0	0.9	82	87
43	40	Bendi	2	0	0	0.5	79	84
44	42	Bendi	2	0	0	0.2	77	76
Irrigated small dairy farming system (IS-3)								
45	52	Antawa	1	0	1	1.6	97	92
46	53	Antawa	1	0	1	1.2	95	92
47	54	Antawa	2	2	0	2	95	95
48	46	Bendi	5	1	0	3.2	95	93
49	51	Antawa	2	1	0	2	95	90
50	49	Antawa	1	0	0	1.6	93	95
51	48	Antawa	2	0	0	2.8	93	96
52	50	Antawa	2	0	0	3.4	93	94
53	45	Antawa	3	1	1	4	91	80
54	55	Bendi	3	0	0	2.8	91	93
55	47	Bendi	4	0	1	1.6	75	89
Irrigated large dairy farming system (IL-4)								
56	57	Antawa	2	2	0	8	92	90
57	58	Antawa	4	1	0	11.6	90	86
58	59	Bendi	4	1	0	4.4	89	92
59	56	Bendi	3	0	1	5	86	80
60	60	Bendi	4	0	0	8	75	93
Rainfed landless dairy farming system (RLL-2)								
61	82	Alipur	2	0	0	0	96	92
62	72	Berka	2	0	0	0	95	93
63	63	Dokhaharia	2	0	0	0	94	91
64	77	Berka	2	0	0	0	94	92
65	79	Alipur	2	0	0	0	94	89
66	81	Alipur	1	0	0	0	93	69
67	68	Mehra	2	0	0	0	93	91

Contd....

Contd....(Annexure-XIII)

Sl. No.	Farm.no.	Village	B	CB	LC	Land*	T.E.	E.E.
68	70	Mehra	3	0	0	0	93	95
69	66	Mehra	2	0	0	0	92	87
70	67	Mehra	2	0	1	0	92	93
71	80	Alipur	1	0	0	0	92	65
72	71	Berka	1	1	0	0	91	88
73	61	Mehra	3	0	0	0	91	95
74	62	Dohkaharia	2	0	0	0	91	90
75	65	Mehra	1	0	0	0	91	67
76	75	Berka	1	0	0	0	90	65
77	73	Berka	1	0	0	0	90	74
78	74	Berka	1	0	0	0	90	73
79	83	Alipur	1	0	0	0	88	71
80	76	Dohkaharia	1	0	0	0	87	77
81	64	Dokhaharia	1	0	1	0	86	82
82	78	Alipur	1	0	0	0	83	75
83	69	Mehra	2	0	0	0	73	79
Rainfed marginal dairy farming system (RM-2)								
84	113	Alipur	2	0	0	0.6	96	87
85	110	Alipur	1	0	0	0.6	96	79
86	111	Alipur	2	0	0	0.2	95	87
87	94	Mehra	2	0	0	0.8	95	89
88	107	Berka	3	0	2	0.6	94	91
89	95	Mehra	2	0	0	0.8	94	83
90	93	Dokhaharia	2	0	0	0.8	94	85
91	120	Berka	2	0	0	0.4	93	84
92	88	Dohkaharia	2	0	0	0.4	93	83
93	92	Dokhaharia	2	0	0	0.4	93	63
94	101	Mehra	2	0	0	0.8	93	85
95	84	Dohkaharia	2	0	1	0.4	93	91
96	90	Dokhaharia	2	0	0	0.8	93	89
97	98	Mehra	2	0	0	1	93	90
98	86	Dohkaharia	2	0	0	0.5	92	73
99	99	Mehra	3	0	0	1	92	91
100	119	Berka	4	0	0	0.6	92	93
101	115	Alipur	1	0	0	0.6	91	65
102	100	Mehra	1	0	0	0.8	91	64
103	114	Alipur	1	0	1	0.6	90	81
104	117	Alipur	2	0	0	0.8	90	84
105	91	Dohkaharia	1	0	0	0.8	90	75
106	105	Berka	1	0	0	0.2	89	31

Contd....

Contd....(Annexure-XIII)

Sl. No.	Farm.no.	Village	B	CB	LC	Land*	T.E.	E.E.
107	85	Dohkaharia	1	0	0	0.5	89	44
108	109	Alipur	3	0	0	0.4	89	91
109	89	Dokhaharia	1	0	0	0.4	89	35
110	103	Mehra	2	0	0	0.24	89	81
111	108	Berka	3	0	1	1	89	81
112	102	Mehra	2	0	0	0.8	89	83
113	118	Alipur	1	0	0	0.2	88	31
114	96	Mehra	1	0	0	0.8	88	65
115	116	Alipur	1	0	0	0.6	87	70
116	87	Dohkaharia	1	0	0	0.6	87	66
117	106	Berka	1	0	0	0.4	86	70
118	112	Alipur	2	2	0	0.2	86	83
119	97	Mehra	1	0	0	0.8	82	62
120	104	Berka	1	0	0	0.4	78	28
Rainfed small dairy farming system (RS-3)								
121	121	Dohkaharia	1	0	0	2	97	70
122	156	Berka	2	0	0	1.8	97	87
123	152	Alipur	1	0	0	1.2	97	60
124	164	Mehra	1	0	0	2.8	96	68
125	166	Mehra	2	0	0	2	96	86
126	139	Berka	3	0	0	1.2	96	88
127	129	Dokhaharia	2	0	0	3.2	95	85
128	125	Dokhaharia	4	0	0	2	95	89
129	157	Berka	3	0	0	1.6	95	92
130	138	Berka	5	0	0	1.2	95	92
131	163	Mehra	2	0	0	2	95	81
132	135	Mehra	2	0	0	2	94	86
133	149	Alipur	1	0	0	1.2	94	67
134	165	Mehra	1	0	0	2	94	62
135	131	Mehra	2	0	0	1.6	94	88
136	126	Dokhaharia	1	0	0	2.4	94	63
137	158	Berka	3	0	0	1.6	94	91
138	132	Mehra	1	1	0	2.4	94	90
139	160	Berka	3	0	0	2	94	91
140	124	Dokhaharia	4	0	2	1.4	94	83
141	134	Mehra	2	0	0	3.6	94	89
142	159	Berka	3	0	0	2	94	90
143	127	Dokhaharia	2	0	0	1.2	93	76
144	144	Alipur	2	0	1	2.8	93	86
145	171	Mehra	3	0	1	1.6	93	82

Contd....

Contd....(Annexure-XIII)

Sl. No.	Farm.no.	Village	B	CB	LC	Land*	T.E.	E.E.
146	155	Alipur	3	0	0	1.6	93	91
147	133	Mehra	1	0	0	2.8	93	70
148	130	Dohkaharia	3	0	0	3.6	93	86
149	123	Dokhaharia	2	0	0	2	92	64
150	136	Berka	2	0	1	1.2	92	68
151	128	Dohkaharia	3	0	1	2.4	92	85
152	146	Alipur	4	0	0	2.8	92	89
153	170	Mehra	2	0	1	2	92	78
154	167	Mehra	2	0	0	2.4	91	70
155	169	Berka	3	1	0	1.8	91	92
156	153	Alipur	2	0	0	2	91	88
157	150	Alipur	2	0	0	1.4	91	74
158	143	Berka	2	0	0	4	91	80
159	168	Mehra	1	0	0	2.4	90	65
160	122	Dohkaharia	3	0	0	2.8	90	90
161	137	Berka	1	0	1	1.6	90	71
162	162	Mehra	1	0	0	2.8	90	67
163	147	Alipur	3	0	0	2.8	89	85
164	148	Alipur	1	0	1	0.6	89	59
165	141	Berka	2	0	0	2.8	88	79
166	151	Alipur	2	0	0	1.2	85	88
167	145	Alipur	4	0	0	3	84	89
168	154	Alipur	1	0	0	1.2	83	50
169	161	Mehra	3	0	0	2	81	90
170	142	Berka	4	0	0	4	79	95
171	140	Berka	4	0	0	2	78	88
Irrigated large dairy farming system (RL-3)								
172	178	Dokhaharia	2	0	0	6.4	98	95
173	176	Dhokaharia	4	0	0	4.2	96	93
174	180	Berka	4	1	0	6	94	93
175	175	Berka	5	0	0	6.8	93	92
176	172	Dohkaharia	2	0	1	7.2	91	85
177	177	Mehra	4	0	0	12	90	96
178	173	Dohkaharia	2	0	0	7.2	90	97
179	174	Mehra	3	0	0	6.4	89	93
180	179	Alipur	5	0	0	8	78	92

B: Buffalo; CB: Crossbred; LC: Local cow; TE: Technical efficiency; EE: Economic efficiency

* Land in hectares

ANNEXURE-XIV

FREQUENCY OF EFFICIENCY ESTIMATES USING TRANSLOG FRONTIER MILK PRODUCTION FUNCTION IN FARM HOUSEHOLDS OF HARYANA (2000-01)

Percentage range	Technical efficiency		Economic Efficiency	
	SMU	Buffalo	SMU	Buffalo
< 20	0	0	23	40
20 - 35	1	0	12	14
35 - 50	7	2	28	16
50 - 65	28	12	25	37
65 - 80	60	39	64	46
80 - 95	59	125	28	27
95 - 100	25	2	0	0

ANNEXURE-XV

MOST AND LEAST TECHNICAL EFFICIENT FARMS OF THE DIFFERENT DAIRY FARMING SYSTEMS IN THE STUDY AREA USING TRANSLOG PRODUCTION FRONTIER FUNCTION

DFS	Most efficient farm				Least efficient farm			
	Farm	T.E.	E.E.	Yield litres / lactation	Farm	T.E.	E.E.	Yield litres / lactation
Standard milch unit								
ILL-2	17	0.99	0.71	1279	33	0.56	0.41	713
IM-2	37	0.71	0.75	810	42	0.36	0.38	566
IS-3	52	0.99	0.60	1745	47	0.41	0.76	423
IL-4	57	0.92	0.79	1392	60	0.52	0.65	606
RLL-2	83	0.99	0.35	732	69	0.31	0.23	446
RM-2	110	0.99	0.37	1334	104	0.54	0.13	607
RS-3	125	0.99	0.77	1320	154	0.38	0.18	971
RL-3	180	0.96	0.81	1266	173	0.51	0.88	1035
Buffalo enterprise								
ILL-2	22	0.95	0.90	1595	16	0.63	0.77	675
IM-2	39	0.87	0.47	1220	40	0.54	0.47	565
IS-3	54	0.96	0.84	1715	47	0.42	0.82	366
IL-4	58	0.89	0.01	1366	57	0.79	0.08	1643
RLL-2	82	0.93	0.67	1160	69	0.46	0.05	448
RM-2	110	0.92	0.26	1340	109	0.64	0.76	733
RS-3	152	0.95	0.05	1950	142	0.52	0.64	551
RL-3	180	0.90	0.78	1215	174	0.69	0.62	975

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

ANNEXURE-XVI

MOST AND LEAST ECONOMIC EFFICIENT FARMS OF THE DIFFERENT DAIRY FARMING SYSTEMS IN THE STUDY AREA USING TRANSLOG FRONTIER COST FUNCTION

DFS	Most efficient farm				Least efficient farm			
	Farm	E.E.	T.E.	Costs Rs. / litre	Farm	E.E.	T.E.	Costs Rs. / litre
Standard milch unit								
ILL-2	22	0.86	0.99	7.56	32	0.32	0.68	23.27
IM-2	39	0.77	0.69	7.66	44	0.16	0.60	14.41
IS-3	54	0.90	0.94	5.94	52	0.60	0.99	6.51
IL-4	59	0.85	0.82	9.24	56	0.61	0.75	14.13
RLL-2	70	0.88	0.76	9.29	81	0.09	0.95	22.16
RM-2	119	0.85	0.67	9.65	118	0.16	0.80	22.99
RS-3	169	0.81	0.69	8.98	154	0.08	0.38	26.46
RL-3	177	0.92	0.81	5.38	172	0.69	0.96	11.38
Buffalo enterprise								
ILL-2	22	0.90	0.95	5.08	32	0.04	0.84	22.88
IM-2	38	0.78	0.80	14.13	42	0.12	0.54	24.84
IS-3	54	0.84	0.96	4.44	51	0.35	0.89	11.85
IL-4	59	0.59	0.85	14.44	58	0.01	0.89	17.16
RLL-2	61	0.88	0.69	13.50	75	0.04	0.85	26.53
RM-2	107	0.93	0.83	5.80	118	0.03	0.85	26.79
RS-3	138	0.88	0.87	6.96	154	0.09	0.60	25.57
RL-3	178	0.85	0.90	7.87	174	0.62	0.69	15.90

Dairy Farming System codes: ILL-2 = irrigated landless; IM-2 = Irrigated marginal; IS-3 = Irrigated small; IL-4 = Irrigated large; RLL-2 = Rainfed landless; RM-2 = Rainfed marginal; RS-3 = Rainfed small; RL-3 = Rainfed large; All systems are buffalo based dairy farming systems. Legend: ILL2: 2 represent the mean number of milch animals representing the systems.

ANNEXURE-XVII**CROP YIELD OF MAJOR CROPS ACROSS DAIRY FARMING
SYSTEMS IN THE STUDY AREA**

(Quintals per ha)

	IM-2	IS-3	IL-4	RM-2	RS-3	RL-3
Berseem	700	750	720	650	715	700
Jowar	550	575	570	410	583	520
Maize	0	295	303	200	250	310
Urad	17	--	--	13	14	13
Gram	--	--	--	20	23	20
Cotton	--	--	--	--	7	8
Wheatstraw	60	83	75	60	60	63
Bazrastraw	--	--	--	50	74	70
Bazra	--	--	--	21	34	26
Wheat	52	62	53	42	52	42
Mustard	--	--	--	17	18	16
Paddy	71	85	83	--	--	--
Paddy straw	88	112	108	--	--	--
Sugarcane	0	875	878	--	--	--
Sugarcane tops	--	175	178	--	--	--

GLOSSARY OF CONCEPTS

Adult milch animal: The milch animal of 2½ years and more (in case of crossbred cow and 3 years and more (in local cattle and buffaloes) are termed as adult milch animals.

Age at first calving: The age at which animal has calved for the first time.

Allocative efficiency: It reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices.

Cropping intensity: It is defined as the percentage of net cultivated area to the gross cropped area. Higher the intensity, larger the intensity of land use.

Crossbred cow: The cow which is produced by the mating between animals belonging to different breeds. In Indian context, it is mating of low genetic potential native breeds with high milk potential temperate exotic breeds. The practice of crossbreeding is generally practiced to increase productivity of milk and enhance ability to adapt to tropical climate.

Dairy farming system: A subcomponent of farming system incorporating the linkages between the farm, household and dairy enterprise.

Depreciation: Depreciation refers to the gradual loss in value of an asset due to wear and tear and also technological obsolescence.

Deterministic Frontier function: It refers to a bounding function, representing the maximum output attainable from a given bundle of resources. No account is taken of possible influence of measurement errors and other noise upon the frontier.

Dry period: It is the period between the last milking day of the animal in the current lactation and the beginning of the next parturition (calving).

Ecological sustainability: It refers to compliance with the carrying capacity limit of the natural system, imposing limits to growth and underlining the negative externalities on environment, in a production environment.

Economic efficiency: It reflects the ability of a firm to be technically and allocatively efficient

Economic sustainability: It implies maintaining or improving production without reducing the stock of natural and produced capital.

Equity: The equitable (uniform) distribution of resources among the different state of people, is generally referred to as equity.

Evaluation: A systematic procedure for analyzing the technical and financial information of a project / context with relevant data about its economic environment together into one or few criteria on the basis of which the project / context is recommended for selection / modification / rejection.

Fixed costs: Costs that remain unchanged irrespective of scale of production in the short run. They include costs like depreciation, interest on capital, insurance premiums, wage paid to permanent labour, etc.

Grassland: A land under grass, but not under cultivation.

Intercalving period: It is the period between two subsequent calvings. In other words, it is a sum total of lactation length and dry period.

Lactation length: Production of milk by mammary glands of mammals in the post-calving period (parturition (calving) to final "drying off" or cessation of milk).

Lactation: Production of milk by mammary glands of mammals in the post calving period (parturition to final "drying off" or cessation of milk).

Linear programming: Linear programming is a computational method to determine the best plan or course of action, among many which are possible, when there are many alternatives for the plan, a specific or numerical objective exist for it, and the means or resources available for attaining it are limited.

Monitoring: Refers to the short term requirement to ensure the various elements of performance appraisal cycle takes place in the way intended, and according to time scale developed in setting objectives and developing a plan for the appraisal.

Order of lactation: It refers to the number of completed or running lactation (in milk) after first calving.

Organic farming: System of farming that avoids use of artificial fertilizers, pesticides, etc. It concentrates on such methods on crop rotation and use of manures (FYM), lay farming, etc.

Production function: It specifies a technical relationship between the regress (dependent variable) and regressors (independent variables). The ordinary least squares (OLS) methods to estimate the production function, fits a line of best fit through sample data.

Productivity: It is defined as the output resulting from a unit of particular input, in a production environment.

Stage of lactation: It is defined as the total number of days/months, the animal has been in milk after parturition (calving).

Stochastic frontier function: A frontier function whose output values are bounded above by the stochastic variable ($\exp(x_i\beta + v_i)$) making it vary about the deterministic frontier function ($\exp(x_i\beta)$).

Sustainability: The concept is derived from the latin word 'sustinere' which means 'to hold'. In simple words, it is the capacity of a production system to 'attain' and 'retain' higher yields.

Sustainable development: It is a development strategy that meets the need of the present generation without compromising the ability of future generations to meet their own demands.

Technical efficiency: It reflects the ability of a firm to obtain maximal output from a given set of inputs. The ratio of the observed output of the i^{th} firm to the potential output defined by the frontier function, for the given input vector, is used to define the technical efficiency of the i^{th} firm.

Technological change: Neutral and non-neutral changes in output per unit input(s) brought about due to change in technique, method or intensity of input use.

Variable costs: Variable costs are the costs, which vary with level of output. In case of milk production, it includes expenses on feed and fodder; human labour; veterinary and miscellaneous expenses. In the long run all costs are variable costs.

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